Defining the hidden burden of disease in rural areas of Bangladesh, Cambodia and Thailand: A cross-sectional household health survey



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Abstract

Background

Understanding the burden of disease is critical for guiding healthcare priorities, yet data gaps remain for many conditions, particularly in rural populations of low- and middle-income countries. This thesis aimed to provide population-based estimates of the disease burden and healthcare utilisation in rural Bangladesh, Cambodia, and Thailand, as part of the Rural Febrile Illness (RFI) project under the South and Southeast Asian Community-based Trials Network (SEACTN).

Methods

A site-representative two-stage cluster sampling design was employed to recruit all members from randomly selected households in villages located within the SEACTN operational area. Data collection included questionnaire-based interviews of household heads and members, physical examinations, and laboratory tests to assess disease prevalence, risk factors, and healthcare utilisation. All results were reported by site and for all sites, with two exceptions. In Chapter 5, enteric fever serology was conducted only among children and young adults in Cambodia with a specific funding scheme. In Chapter 7, laboratory results for non-communicable diseases (NCDs) in Bangladesh were not available at the time of thesis writing. Therefore, NCD-related findings were reported only for the Cambodian and Thai sites.

Results

There was a high burden of infectious diseases and NCDs across study sites, with notable regional variations. In Bangladesh, 17% of individuals reported fever in the past 30 days, 6% in Cambodia and 1% in Thailand. Self-medication for fever was common in Bangladesh (39%), while in Cambodia, most individuals reported accessing private healthcare providers (67%). Seroprevalence varied by pathogen. While *P. vivax* were low in all countries (0.3%-3%), Bangladesh had a higher seroprevalence of *P. falciparum* (24%) compared to the other two sites (6%-11%). The seroprevalence of non-malaria fever pathogens ranged from 2% for *O. tsutsugamushi* to 36% for *Rickettsia spp.* in Bangladesh, from 24% for *Rickettsia spp.* to 75% for dengue virus (DENV) in Cambodia, and from 6% for chikungunya virus (CHIKV) to 77% for Japanese encephalitis virus (JEV) in Thailand. Most pathogens showed increasing seroprevalence with age, except JEV in Thailand and

Leptospira, which peaked in younger children. Geographic variations in arboviral and bacterial exposure risks were also observed. The seroincidence of typhoid fever in Cambodia was high (188/ 1,000 person-years), aligning with poor water, sanitation, and hygiene (WASH) infrastructure.

Hepatitis B virus (HBV) prevalence was 3% in Bangladesh, 4% in Cambodia and 6% in Thailand, while hepatitis C seroprevalence among adults was 5% in Cambodia and 1% in both Bangladesh and Thailand, with viraemic prevalence at 0.9% in Cambodia and 0.2% in both Bangladesh and Thailand. The odds of having hepatitis B and C increased with age. Gaps in HBV vaccination coverage were identified, with the coverage rates lower than national estimates across sites.

NCDs were highly prevalent among adults. In Cambodia, 20% of adults had hypertension, and 6% had diabetes, while in Thailand, the prevalence was 44% and 13%, respectively. Over 40% of adults in both sites had raised total cholesterol. However, major gaps remained in diagnosis and disease management. Hypercholesterolemia showed the poorest care cascade, with less than 20% of affected individuals in Cambodia and 62% in Thailand having ever had their cholesterol measured, and none had achieved cholesterol control.

Cost of care was the most frequently reported health-related concern in Bangladesh (46%) and Cambodia (82%), contrasting with Thailand, where universal health coverage alleviated cost concerns and 40% of adults reported no concerns. In Bangladesh, the next most frequently reported concerns were health risks related to household amenities (e.g. toilet, cooking stove, 42%), and exposure to the natural environment at work (36%). In Cambodia, concerns about the efficiency of health services (67%) and their safety (50%) followed cost-related worries.

Conclusions

By providing prevalence data on a wide range of infectious diseases and NCDs, this study contributes to a better understanding of the overall burden of disease in these rural areas. These findings highlight the need to enhance diagnostic capacity for non-malaria febrile illnesses, ensure vaccination coverage, and strengthen NCD screening and management. In addition to healthcare improvements, efforts should be made to improve WASH infrastructure and reduce financial barriers. The findings support the evidence-based decision-making process for interventions that address both acute and chronic health challenges in these rural communities.

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Statement of contributions

The research and writing presented in this thesis are primarily my own. I designed the study and wrote the study protocol. I contributed to the development of standard operational procedures (SOPs), including authoring those directly related to survey procedures, such as Questionnaire interview and Field procedures SOPs. I coordinated and conducted field team training sessions, oversaw the entire data collection process, and managed the dataset. I wrote the statistical analysis plan, performed data cleaning and statistical analysis, and led the literature review. I drafted, revised, and finalised the thesis writing.

Throughout all stages of this work, my supervisors, Thomas J Peto, Sue J Lee, Richard J Maude, and Yoel Lubell provided methodological and scientific guidance.

Additional contributors for specific procedures and chapters are listed below:

- **Filed data collection and blood sample collection**

  All the fieldwork was conducted by the field teams led by the field coordinators and supervisors: Aninda Sen, Mahbubur Rahman, Didar Uddin in Bangladesh, Rupam Tripura, Phal Chanpheakdey, and Sovann Kem in Cambodia, and Carlo Perrone, Nattida Toonin and Nipaphan Kanthawang in Thailand.

- **Laboratory analysis**

  A commercial laboratory conducted laboratory testing for Chapter 6 and Chapter 7.

- **Chapter 1**

  For the scoping review, Hannah Kozlowski, Rusheng Chew, Nan Shwe Nwe Htun, Shaun K Morris, Carolyn Akladious, Abdur Razzaque Sarker, and Yoel Lubell have contributed to paper screening. Hannah Kozlowski extracted data from included publications. All the listed contributors and Thomas J Peto provided critical reviews of the manuscript.

- **Chapter 4**

  Jantana Wongsantichon led the development of the multiplex bead-based assay and the sample analysis.

- **Chapter 5**

  Natnaree Saiprom led the laboratory analysis. Kristen Aiemjoy provided guidance on the laboratory quality control, the data analysis, and provided critical reviews to the chapter.

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List of Abbreviations

AMR . . . . . Antimicrobial resistance

aOR . . . . . Adjusted odds ratios

CHIKV . . . . Chikungunya virus

CI . . . . . Confidence intervals

COPD . . . . . Chronic obstructive pulmonary disease

cOR . . . . . Crude odds ratios

CVD . . . . . Cardiovascular diseases

DALY . . . . . Disability-adjusted life years

DBS . . . . . Dried blood spots

DENV . . . . . Dengue virus

DHS . . . . . Demographic and Health survey

eCRF . . . . . Electronic case report forms

EPI . . . . . Expanded program on immunization

EPV . . . . . Events per variable

HBV . . . . . Hepatitis B virus

HCV . . . . . Hepatitis C virus

HlyE . . . . . Haemolysin E

ICPC-3 . . . . International Classification of Primary Care 3rd Edition

IQR . . . . . Interquartile range

JEV . . . . . Japanese encephalitis virus

MeSH . . . . . Medical Subject Headings

MFI-bg . . . . Median fluorescence intensity with background subtracted

MUAC . . . . Mid-upper arm circumference

NCDs . . . . . Non-communicable diseases

NTD . . . . . Neglected tropical disease

ODK . . . . . Open Data Kit

PCU . . . . . Primary healthcare unit

PPS . . . . . Probability-proportional-to-size

PSU . . . . . Primary sampling units

qPCR . . . . . Quantitative polymerase chain reaction

RPCE . . . . . Revised Pooled Cohort Equation

SAECTN . . . The South and Southeast Asian Community-based Trials Network

SAP . . . . . Statistical analysis plan

SOP . . . . . Standard operational procedures

STEP . . . . . World Health Organisation's STEPwise approach to non-communicable disease risk factor surveillance

TC . . . . . Total cholesterol

TCV . . . . . Typhoid conjugate vaccines

UHC . . . . . Universal healthcare coverage.

VIF . . . . . Variance inflation factor

WASH . . . . . Water, sanitation and hygiene

WHO PEN . . World Health Organisation's Package of Essential Non-Communicable Disease Interventions

WHO . . . . . World Health Organisation

ZIKAV . . . . Zika virus

1

Background and literature review

Chapter outline

This chapter provides background and the literature review that shape the scope of the thesis. It begins with an introduction of the South and Southeast Asian Community Based Trials Network and the Rural Febrile Illness project, the framework within which this study was conducted. Following this, it presents an overview of disease burden in the study countries- Bangladesh, Cambodia, and Thailand, based on the findings from the Global Burden of Disease Study. This chapter then introduces the current health data collection mechanisms, highlighting the strengths and the gaps that necessitate a community-based cross-sectional survey. To inform study design, a scoping review was conducted to evaluate the spectrum of health conditions studied in recent community-based studies conducted in the study countries. This review identified the current focus and gaps of research. Building on the findings from the scoping review, the chapter outlines how the scope of this thesis was defined, detailing the selection of health conditions and corresponding evaluation methods. The chapter then sets out the study's aims and objectives. It concludes with the thesis structure outlining the contents by chapter.

1.1 The South and Southeast Asian Community-Based Trials Network

The South and Southeast Asian Community-based Trials Network (SEACTN) was established in response to the shifting landscape of febrile illness in the region. While malaria incidence has been declining, febrile illnesses continue to pose a significant burden of morbidity and mortality in rural communities (Wangrangsimakul et al., 2018; World Health Organization, 2017b). Village health workers and village malaria workers are the first point of contact for individuals having fever, yet they often lack the necessary training, diagnostic tools, and treatment resources beyond malaria care (World Health Organization, 2013). This results in missed diagnoses and inappropriate antibiotics usage (Lubell et al., 2019).

Therefore, SEACTN aims to establish a network of community-based healthcare providers and facilities capable of implementing interventions to triage, diagnose, and treat patients with febrile illness and other causes of ill health within these communities in the future (Chandna et al., 2022). While this is the ultimate goal of the network, the current phase of the project focuses on mapping the epidemiological background of the coverage areas to guide and plan for future interventions.

1.1.1 The Rural Febrile Illness project (RFI)

The Rural Febrile Illness Project (RFI) was the first series of projects under SEACTN, dedicated to establishing the epidemiological baseline of febrile illness in remote and underserved regions. The primary objective of the RFI project was to determine the incidence, causes, and outcomes of febrile illness in rural communities located within the project areas, while assessing broader healthcare access and disease burden in the region.

To achieve a comprehensive understanding of the health dynamics and healthcare gaps, RFI encompassed multiple interrelated components:

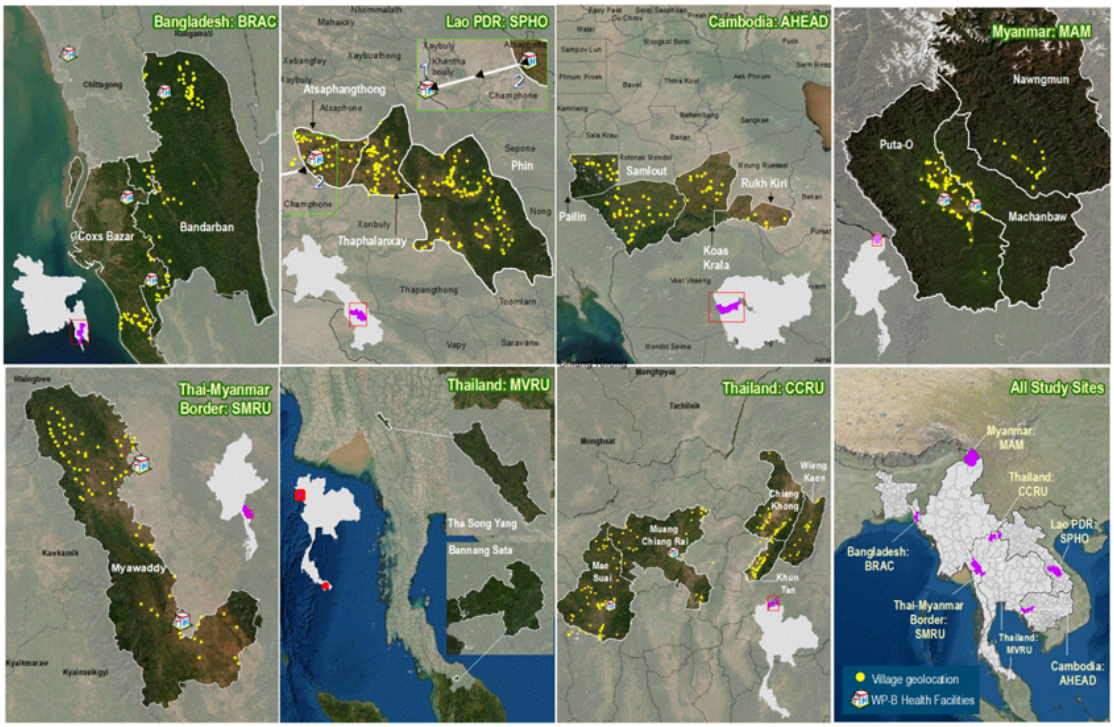


Figure 1.1: SEACTN study areas with selected villages and health facilities.
Collaborating partners: AHEAD, Action for Health Development; CCRU, Chiang Rai Clinical Research Unit; MAM, Medical Action Myanmar; MVRU, Mahidol Vivax Research Unit; SMRU, Shoklo Malaria Research Unit; SPHO, Savannakhet Provincial Health Office.
Source: Chandna A, Chew R, Shwe Nwe Htun N et al. Defining the burden of febrile illness in rural South and Southeast Asia: an open letter to announce the launch of the Rural Febrile Illness project [version 2]. Wellcome Open Res 2022, 6:64 (doi: 10.12688/wellcomeopenres.16393.2)

- Fever aetiology studies: Investigating common pathogens causing febrile illness in the region, and evaluating potential point-of-care tests to improve their diagnosis.

- Verbal autopsy study: Investigating common causes of mortality and the circumstances surrounding death.

- Village and health facility mapping study: Creating detailed geographic profiles of the study villages, estimating travel time to health facilities, and identifying health service coverage gaps.

- Cross-sectional household health survey (The focus of this thesis): Assessing

disease prevalence, associated factors, and healthcare utilisation patterns among rural populations.

Each study offers insights into different aspects of disease burden independently, and their findings are complementary, collectively contributing to a thorough understanding of healthcare needs. This integrated approach facilitates evidence-based decision-making, ensuring that future interventions are effectively targeted to address the most pressing health challenges in these rural communities.

RFI was conducted in seven study sites in Bangladesh, Cambodia, Lao PDR, Myanmar and Thailand (3 sites). These study sites and their respective implementation partners are displayed in Figure 1.1. The implementation of each RFI component varied across study sites based on local research capacity, logistical feasibility and specific health priorities. This thesis focuses on the cross-sectional household health survey, which was implemented in Bangladesh, Cambodia, and Chiang Rai province, Thailand (Table 1.1).

1.2 An overview of the disease burden and data collection mechanisms

1.2.1 Current knowledge of the disease burden

Our study countries, Bangladesh, Cambodia, and Thailand, are located in South and Southeast Asia, and differ in terms of economic development, healthcare infrastructure and demographic transition. Despite these differences, they share many health challenges shaped by common regional factors such as rapid urbanisation, environmental changes, and evolving disease patterns (Chongsuvivatwong et al., 2011).

Based on the Global Burden of Disease study (GBD), the most comprehensive and widely recognised effort to quantify global, regional, and national health trends (C. J. L. Murray, 2022), the region has undergone a substantial epidemiological transition over the past few decades (Figure 1.2). Historically, these countries

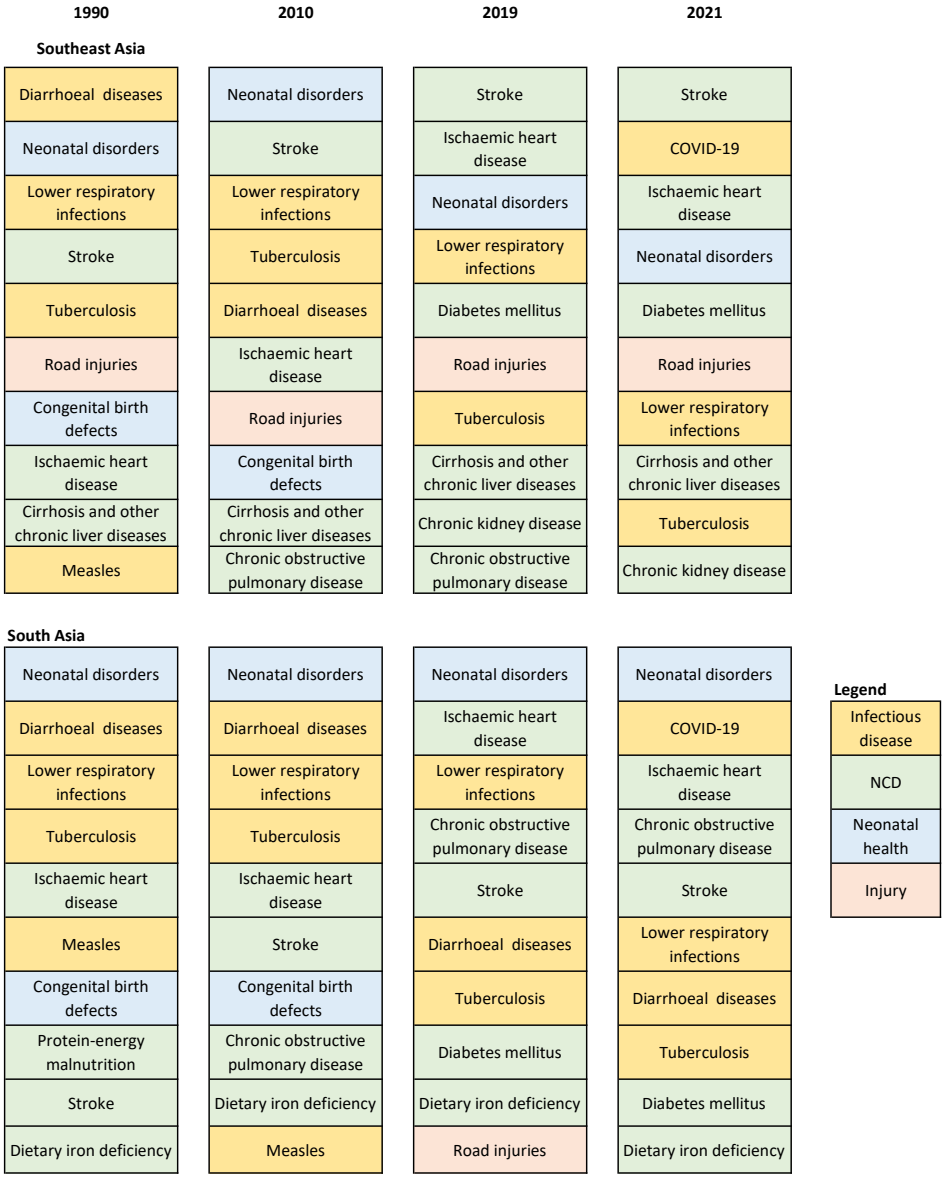


Figure 1.2: Top ten leading causes of disability-adjusted life years (DALY/ 100,000 population) from the highest to the lowest in Southeast Asia and South Asia from 1990 to 2021.
Source: Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2021 (GBD 2021) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2022. Available from https://vizhub.healthdata.org/gbd-results/.

faced a high burden of infectious disease (e.g. diarrhoeal diseases, tuberculosis) and maternal and neonatal health issues (Figure 1.2) (Global Burden of Disease Collaborative Network, 2022). As continued efforts have targeted these traditional high-burden issues, a concomitant increase in life expectancy has been observed in the region, increasing from 63 to 71 years between 2000 and 2019 (Bygbjerg, 2012; World Health Organization, 2019). However, the burden of several diseases persists, and there is a transition towards rising burden of non-communicable diseases (Chongsuvivatwong et al., 2011; Coker et al., 2011; Dans et al., 2011; Naghavi et al., 2024). The COVID-19 pandemic further underscored the persistent vulnerability of healthcare systems in managing infectious disease outbreaks (Bollyky et al., 2022).

This shift reflects a long-term trend. In the 1990s infectious diseases such as tuberculosis and measles and neonatal disorders were the predominant contributors to disability-adjusted life years (DALY) loss (Figure 1.2). Improved sanitation, vaccination programs, and maternal healthcare have reduced childhood mortality from infectious diseases. However, neonatal disorders, diarrhoeal disease, and lower respiratory tract infection remain key health concerns in 2021, which may reflect disparities in healthcare access.

The current disease burden is characterised by the continued dominance of cardiovascular diseases, with ischemic heart disease and stroke ranking among the leading causes of mortality in the region, reflecting an aging population and the increasing prevalence of metabolic risk factors (Figure 1.2) (Mensah et al., 2019). Diabetes and chronic kidney disease are rising towards the top of the disease burden, potentially affected by lifestyle changes associated with economic growth (Tamaoki et al., 2022). Chronic respiratory conditions, including chronic obstructive pulmonary disease (COPD), have emerged as major contributors to disease burden. The high prevalence of tobacco use and exposure to air pollution has exacerbated respiratory conditions (Mannino & Buist, 2007). Meanwhile, liver cirrhosis, linked to chronic hepatitis B and C infections, remains a major health issue, particularly in areas where viral hepatitis is endemic (The CDA Foundation, 2024b, 2024a, 2024c, 2024d, 2024f, 2024e). Road injuries persist

as a high burden concern, with increased motorisation and inadequate road safety measures contributing to high mortality and disability rates from traffic accidents.

In the context of a dual burden of persistent infectious diseases and maternal neonatal health issues coexisting with a rapidly growing NCD epidemic, the healthcare system's capacity and accessibility are an increasing concern. While Thailand, as an upper-middle-income country, has a more established healthcare system with universal health coverage (Table 1.1), Bangladesh and Cambodia face bigger barriers to healthcare access (World Health Organization, 2024c; World Health Organization (WHO), 2024a, 2024b). To address current disease burden, healthcare systems need to be strengthened to reduce the disparities in access to services for infectious diseases and maternal-neonatal conditions, while simultaneously expanding services to support chronic disease prevention, lifestyle interventions, and long-term disease management.

Table 1.1: Study sites overview on life expectacy, economy and health systems

Countries	Bangladesh	Cambodia	Thailand
Study site	Coxs Bazaar and Bandarban district	Battambang and Palin province	Chiang Rai province
Life expectancy	Male: 71.6, Female: 74.6	Male: 66.4, Female: 71.5	Male: 71.8,Female: 79.0
Rural population	72.6%	74.9%	50.1%
GDP per capita (US$)	1698	1270	7274
Current health expenditure (% GDP)	2.4%	7.5%	5.2%
Birth registration coverage	56.0%	92.0%	99.8%
Death registration coverage	<75.0%	No data	85.0%

Note:
Source: Health data overview for Bangladesh, Cambodia and Thailand, World Health Organisation. Retrieved June 1, 2023, from https://data.who.int/countries.
Various data sources were used for different indicators, with reference years ranging from 2021 to 2023. For detailed source information, please refer to the original WHO website.

1.2.2 The data collection mechanisms: Strengths and gaps

This overview of disease burden is largely based on the GBD Study, which provides regularly updated population-level estimates, serving as an essential resource for understanding population-level health trends. However, the accuracy of these

estimates depends on the availability and quality of primary data sources, which remain scarce in many low- and middle-income countries (LMIC), including South and Southeast Asia (C. J. L. Murray, 2022). The limited data availability constrains the ability to fully understand current disease epidemiology, making it difficult for policy makers to develop targeted interventions.

In Bangladesh, Cambodia and Thailand, disease surveillance systems focus on the traditional high burden conditions, such as tuberculosis, malaria, and maternal neonatal health, through monitoring and evaluation systems embedded in each vertical program targeting specific health conditions (World Health Organization. Regional Office for South-East Asia, 2019b; World Health Organization. Regional Office for South-East Asia, 2019a; World Health Organization. Regional Office for the Western Pacific, 2018). Additionally, internationally supported national population-based surveys, such as the Demographic and Health Survey (DHS) and Multiple Indicator survey (MICS), provide updates on maternal, neonatal, and child health, while national tuberculosis surveys provide updates on prevalence of tuberculosis and drug-resistance patterns (Kamal et al., 2015; National Institute of Statistics (NIH) Cambodia et al., 2023; National Statistical Office of Thailand, 2020a; Population Research et al., 2020; Yamada et al., 2007). With the rising burden of non-communicable disease (NCD), many countries also adopted the WHO's STEPwise approach to NCD risk factor surveillance (STEP), which systematically collects data on hypertension, diabetes, and related conditions (World Health Organization, 2017c). Despite these efforts, significant gaps remain in disease burden estimation, particularly for conditions that do not fall within traditional vertical program priorities. The available data are often fragmented, with limited integration across disease categories. Surveillance and registration systems, such as health information systems, disease-specific registration systems, and death registration systems, exist in theory but frequently lack coverage or quality assurance (World Health Organization, 2014b, 2021). For instance, in Cambodia, death registration data remain mostly unavailable or unreliable, while in Bangladesh only 56% of births are officially registered (Table 1.1).

Another major limitation of existing data collection mechanisms is the disparities in healthcare resources between urban and rural areas. While the rural population constitute 50%- 75% of the population in these countries, their health status is relatively understudied compared to the countrywide estimates (Vos et al., 2020; World Health Organization. Regional Office for South-East Asia, 2019b; World Health Organization. Regional Office for South-East Asia, 2019a; World Health Organization. Regional Office for the Western Pacific, 2018). Due to health access constraints in rural areas, health facility-based studies may offer skewed estimates of disease prevalence towards the urban population, highlighting the need for rural-specific epidemiological data (Chongsuvivatwong et al., 2011).

Given these constraints, while achieving better surveillance coverage through improved health system can take long time, community-based research can be useful in bridging this information gap. This type of study can provide up-to-date information and subnational estimates of disease burden and contribute essential primary data to improve global modelling studies. Furthermore, community-based studies could identify regional differences, helping policy makers to optimise resource allocation based on regional variances (Voigt & King, 2017).

Cross-sectional surveys, in particular, are a powerful research method to provide population-level disease surveillance. They can capture a wide range of health-related factors within a short timeframe and at a relatively lower cost than other research methods for obtaining population-based data. In resource-limited settings where routine data collection remains inadequate, cross-sectional surveys offer a practical means of gathering health information to improve the understanding of disease burden in the population.

1.3 Defining the thesis scope: a scoping review on recent community-based cross-sectional surveys

To ensure that this community-based cross-sectional survey effectively addresses key knowledge gaps to improve the understanding of disease burden, a scoping review was conducted to map recent similar studies conducted in South and Southeast Asia. The knowledge on the spectrum of health conditions and their evaluation methods from existing surveys informed our survey design. The scoping review has been published previously and the full-text is included in the Appendix A (Zhang, Kozlowski, et al., 2024). Here we have summarised it.

There were three main objectives:

1. To map out where and when community-based cross-sectional surveys have recently been conducted within the region.
2. To identify the health conditions studied and their evaluation methods used, including variations across geographies and populations
3. To identify knowledge gaps that may serve as areas of focus in future surveys

Conducted at the study's inception, the scoping review sought to build a regional evidence base and apply the evidence to plan for the future cross-sectional survey that had the potential for the inclusion of all SEACTN study sites. It therefore covered all five SEACTN countries. As the project evolved, only the sites in Bangladesh, Cambodia and Thailand were able to implement the survey, thus the subsequent chapters focus on these three countries.

1.3.1 Methods

This scoping review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis Extension for Scoping Review (PRISMA-ScR) and the Joanna Briggs (JBI) Manual for Evidence Synthesis (Aromataris

E & Munn Z, 2020; Tricco et al., 2016). The study protocol is registered with the Open Science Framework (OSF registration DOI: https://doi.org/10.17605/OSF.IO/9GBNK).

Literature search strategy

A systematic search was conducted in seven databases: Medline, Embase, Global Health, CINAHL, Scopus, Web of Science Core Collection, and Global Index Medicus. Additionally, we searched Google Scholar for grey literature. We employed a broad search that consisted of Medical Subject Headings (MeSH) and free-text terms, and excluded publications published before 2010. The full search terms are included in Appendix A1.

Study selection and full-text review

The screening process followed JBI recommendations, and the details are in Appendix A2. Only publications that meet the predefined inclusion criteria were included:

- Studies conducted in Bangladesh, Cambodia, Laos, Myanmar, and Thailand;
- Published between January 1, 2010, and January 27, 2022;
- Cross-sectional health surveys with participants recruited from the community, irrespective of symptoms or disease status;
- Number of participants with a condition and the total number of participants assessed was reported.

Data extraction and analysis

Data from publications deemed eligible for the review were extracted into an Excel sheet with predefined variables, including bibliographic metrics, study methods, and health conditions reported as prevalence, along with the age and sex of the study population. The data extraction sheet and the supplementary data are

available online (https://static-content.springer.com/esm/art%3A10.1186%2Fs12889-024-19347-3/MediaObjects/12889_2024_19347_MOESM2_ESM.pdf).

If there was more than one paper from the same survey, the original survey from which the data was primarily collected for each publication was identified, and all publications were grouped by 'survey' (e.g. multiple publications used data collected from a particular DHS survey in Bangladesh). The process used to identify the original data source of a publication is detailed in Appendix A2.

For each study that was included in the review, the urban-rural coverage was recorded as it was described in the publications, as urban, rural, both urban and rural, or nationally representative. If a study did not describe the coverage, it was recorded as 'unspecified'.

The age distribution of the study population for each condition was organised into a context-appropriate classification. The age groups were categorised as: 'Lifespan', 'Childhood', and 'Adulthood' (Table 1.2). 'Childhood' and 'Adulthood' categories were further divided into subcategories with specific age bands. The exact match of inclusion of age group of a survey and the corresponding age group applied in this review is detailed in Appendix A3. Due to variations of inclusion criteria across studies, some age groups overlapped, for example, 'Reproductive age' was defined as 15-49 years and 'Reproductive age and older adulthood' was defined as 15-64 years.

Health conditions, symptoms, laboratory or point-of-care test results, and physical examination results were recorded as reported in the publications (Table 1.2). They were then placed into mutually exclusive categories, based primarily on the International Classification of Primary Care 3rd Edition (ICPC-3), including non-communicable conditions, infectious conditions, symptoms, disability and functional limitation (disability), self-perceived health status, and general health condition inquires (general health) (Edemekong et al., 2022; Janssen et al., 2019; Jeroen K Van Ginneken & George Groenewold, 2012; Leonardi et al., 2006; Revicki et al., 2014; The World Organization of National Colleges & Academies and Academic Associations of General Practitioners/Family Physicians (WONCA), 2021; World

Health Organization, 2018b). Further details of the categorisation are described in Appendix A3.

Table 1.2: Categorisations of age groups and health conditions

Categories	Subcategories and Definitions
Age groups (years)	
Lifespan	When a condition was studied among participants recruited without specific age criteria or across both the "Childhood" and "Adulthood" groups
Childhood (<=19)	Child (<=19) Preschool child (<=5) School-age child (5-19)
Adulthood (>=15)	Adulthood (>=15) Reproductive age (15-49) Reproductive age and older adulthood (15-64) Older adulthood and retirement age (>=50)
Health condition categories	
Non-communicable conditions	Non-communicable conditions reflecting the same underlying pathophysiology but representing different degrees of severity were grouped together(e.g. elevated blood glucose level, prediabetes, and diabetes were grouped as one type of health condition and referred to as diabetes).
Infectious conditions	Infectious conditions were categorized based on a. Direct microbiologic identification of a pathogen (e.g., through culture or molecular tests) or b. Indirect measures (e.g., serologic tests). c. Infective syndromes without a reported microbiologic cause, such as acute respiratory infection (ARI), were also categorized as infectious conditions. Based on the microbiologic results or lack thereof the subcategories applied: Bacterial, viral, parasitic, non-specified
Symptoms and abnormal findings (Symptoms)	Conditions that could not be determined as infectious or non-infectious causes (e.g., fever, diarrhoea).

Table 1.2: Categorisations of age groups and health conditions *(continued)*

Categories	Subcategories and Definitions
Disability and functional limitation (Disability)	Disability was defined either directly by the study that referred to a condition as disability, or categorised by the review authors when a condition fit the WHO definition of disability. Based on the aspects of disability, the conditions were grouped into: a. Body structure: impairments of anatomical parts of the body such as organs, limbs and their components b. Body function: impairments of physiological functions of body systems (including psychological functions) c. Activity and participation (Activity): difficulties and problems of execution of a task or action, and/ or involvement in a life situation. d. Activity of daily living: Fundamental skills, related with body function and activity, required to independently care for oneself.
Self-perceived health status	Self-perceived health status encompassed the questionnaire-based assessments of: a. Self-rated health: a single question assessing an individual's own opinion on their health or b. Health-related quality of life: the impact of health status on quality of life.
General health condition inquiries (General health)	It describes the data collected from the questions asked to the survey participants, soliciting self-reported presence or history without limiting the answers to specific diseases or symptoms. E.g. Have you been ill in the past 30 days? Could you tell me all the symptoms or diagnosis you had?

Comparison to Global Burden of Disease estimates

To understand how well the highest-burden causes of death and disability ('causes') identified by the GBD study were studied by prevalence surveys, we:

- Identified high-burden conditions: Extracted the conditions that ranked as the top 20 'causes' with the highest disability-adjusted-life-years (DALY) rate (/100,000 population) of each country.
- Quantified survey representation: Counted the number of surveys included in this review, reporting each 'cause', by country.

The inclusion criteria of the datapoints used by GBD include a wider range of data sources (e.g.vital registration system, reports) (Health Metrics & Evaluation,

2019).To further understand how well these 'causes' were studied or described using alternative data sources beyond the community-based cross-sectional survey, we:

- Reviewed GBD metadata: Extracted the metadata from the GBD for the top 20 'causes' with the highest DALY rate of each country (Institute for Health Metrics and Evaluation, 2019).

- Quantified datapoints beyond cross-sectional surveys: Counted the number of datapoints where data collection was completed from 2010 onwards from the metadata of each country. By analysing the number of data sources from each country, we could identify the 'causes' with extensive data availability as well as those with limited primary data.

Statistical analysis

The unit of analysis was the 'survey', which represented the original data source in the case of multiple publications. Each survey was characterised by the country in which the survey was conducted, urban versus rural coverage. Each health condition was further described by the target population's age group. All analyses were carried out using R software version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria), and graphical presentations were done using the ggplot2 library in R.

1.3.2 Results

The screening process and publication inclusion are shown in the PRISMA flowchart for the review in Figure 1.3. The search strategy located an initial 9602 articles, from which 542 publications were finally included, reporting results from 337 surveys.

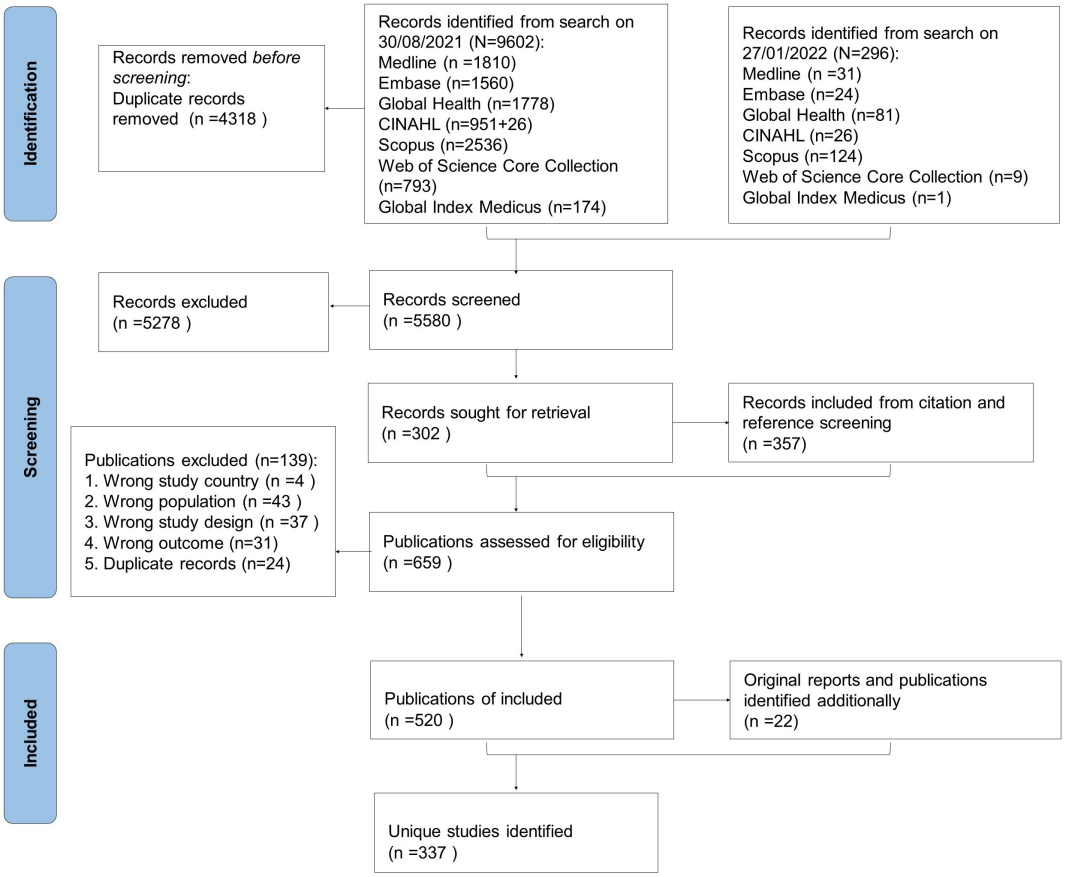


Figure 1.3: PRISMA flowchart showing selection of studies.

Definitions and categorisation

Most surveys were conducted in a single country, with the highest number in Bangladesh (36.5%, n=123), followed by Thailand (29.1%, n=98), Laos (12.2%, n=41), Cambodia (11.0%, n=37), and Myanmar (9.8%, n=33) (Appendix A4). Additionally, five surveys were conducted in multiple countries. The majority of surveys had some rural coverage, including surveys conducted only in rural areas (38.8%, n=78), nationally representative surveys (23.1%), and surveys conducted in both rural and urban areas (14.8%, n=50). Fewer surveys (10.1%, n=34) had urban only coverage, and 13.4% (n=45) surveys did not specify the coverage. Across countries, the majority of surveys (32.5% -54.1%) had rural only coverage; 17.1%-30.3% surveys were nationally representative; and less than 10% of surveys had urban only coverage, except for Bangladesh (n=24, 19.4%) (Appendix A4).

While 70.0% (n=236) of surveys reported on conditions from a single health condition category, 18.1% (n=61) reported across two categories, and 11.9% (n=40) reported across three to five categories. Overall, non-communicable conditions were reported by 205 surveys, followed by infectious conditions (n=124), disability (n=49), symptoms (n=45), general health (n=35), and self-perceived health (n=34). The majority of surveys studying non-communicable conditions (n=119, 58.0%) or infectious conditions (n=90, 72.6%), studied conditions from a single health conditions category. In contrast, most surveys studying symptoms (n=40, 88.9%), disability (n=42, 85.7%), self-perceived health (n=27, 79.4%) and general health (n=27, 77.1%), also studied conditions of other categories.

The most studied conditions, regardless of condition categories, were: undernutrition (n=77), obesity (n=75), hypertension (n=60), diabetes (n=56), and intestinal parasites (n=38).

Non-communicable conditions

Non-communicable conditions were most frequently surveyed in Bangladesh (n=94), Thailand (n=54), Cambodia (n=20), and Myanmar (n=17), and across surveys with different urban-rural coverage (rural: n=69, nationally representative: n=61, rural and urban: n=30, and urban: n=22) (Appendix A5). Non-communicable conditions were most commonly surveyed in 'adults' (n=76) and 'preschool child' (n=43) age categories (Figure 1.4). The most studied non-communicable conditions are described in Table 1.3.

Infectious conditions

Infectious conditions were categorised into parasites (n=83), viruses (n=23), bacteria (n=14), and unspecified pathogens (n=17). Infectious conditions were commonly surveyed in Laos (n=28) and Cambodia (n=20). They were also studied in approximately half of the surveys conducted in Thailand (n=41) and Myanmar (n=13), and surveys with rural only coverage (n=62), and unspecified coverage (n=21)(Appendix A5). They were mostly studied among participants across the

'lifespan' (n=49), 'adult' (n=24) and 'preschool child' (n=20) categories (Figure 1.4).

Symptoms

Symptoms were studied by a relatively larger number of surveys from Laos (n=10) and Myanmar (n=7), and surveys with nationally representative samples (n=20), compared with surveys conducted in other countries and with urban-rural coverages (Appendix A5). Notably, only a small number of surveys conducted in Thailand reported symptoms (n=2). Symptoms were mainly surveyed among 'preschool children' (n=26) (Figure 1.4).

Disability, self-perceived health status, and general health

While disability, self-perceived status and general health, were studied by fewer surveys across countries and geographic coverage compared with other condition categories, relatively more surveys that studied these categories were identified from Myanmar (disability: n=7, self-perceived health status: n=7, general health: n=6). Disability specifically, was studied by relatively more surveys conducted in Thailand (n=20), with nationally representative samples (n=22), or rural and urban coverage (n=10) (Appendix A5).

Participants in the 'older adult and retirement age' group were the most common study population for general health (n=13), disability (n=27), and self-perceived health (n=16) (Figure 1.4). In addition, 'adult' was also the most common target group for surveys of general health (n=12) and self-perceived health (n=11).

Table 1.3: The top 5 most studied conditions of each health condition category, by age groups

Overall across age groups	Lifespan	Childhood	Adulthood	Missing
Non-communicable conditions				
Undernutrition (n=77)	Injury- animal cause (n=3)	Undernutrition (n=45)	Hypertension (n=56)	Obesity (n=3)

Table 1.3: The top 5 most studied conditions of each health condition category, by age groups *(continued)*

Overall across age groups	Lifespan	Childhood	Adulthood	Missing
Obesity (n=75)	Injury-electrocution cause (n=2)	Obesity (n=16)	Obesity (n=56)	Undernutrition (n=3)
Hypertension (n=60)	Epilepsy/seizure (n=2)	Anemia (n=11)	Diabetes (n=54)	Hypertension (n=3)
Diabetes (n=56)	Injury-non-specific cause (n=2)	Micronutrition deficiency (n=4)	Undernutrition (n=39)	Depression (n=3)
Anemia (n=30)	Anemia (n=1)	Hemoglobinopathy (n=3)	Hyperlipidemia (n=22)	Anxiety (n=3)
	Injury- eye (n=1)	Aggressive behavior (n=3)		
	Depression (n=1)			
	Micronutrition deficiency (n=1)			
	Obesity (n=1)			
	Periodontal conditions (n=1)			
	Psoriasis (n=1)			
	Suicidality (n=1)			
	Teeth related oral health condition (n=1)			
Infectious conditions				
Intestinal parasites (n=38)	Malaria(n=20)	Acute respiratory infection (n=12)	Intestinal parasites (n=8)	Intestinal parasites (n=5)
Malaria (n=32)	Intestinal parasites (n=18)	Intestinal parasites (n=7)	Tuberculosis (n=7)	Hepatitis B virus (n=2)
Acute respiratory infection (n=13)	Soil-transmitted-helminth (n=2)	Malaria(n=6)	Hepatitis C virus (n=7)	Hepatitis C virus (n=1)
Tuberculosis (n=11)	Hookworm (n=2)	Tuberculosis (n=3)	Malaria(n=5)	Malaria (n=1)
Hepatitis B virus (n=11)	Tapeworm (Taeniasis, Cysticercosis) (n=2)	Hepatitis B virus (n=2)	Hepatitis B virus (n=5)	Dengue (n=1)
	Dengue (n=2)	Pneumonia (n=2)		Acute respiratory infection (n=1)
	Japanese encephalitis (n=2)			Trematodes (O. viverrini, H. taichui) (n=1)
	Hepatitis B virus (n=2)			Trematodes (O. viverrini) (n=1)
Symptoms				
Diarrhea (n=25)	Fever (n=2)	Diarrhea (n=24)	Cough (n=2)	-
Fever (n=19)	Diarrhea (n=1)	Fever (n=16)	Impaired lung function (n=2)	

Table 1.3: The top 5 most studied conditions of each health condition category, by age groups *(continued)*

Overall across age groups	Lifespan	Childhood	Adulthood	Missing
Cough (n=7)		Cough (n=5)	Proteinuria (n=2)	
Proteinuria (n=2)		Shortness of breath (n=1)	Wheezing (n=2)	
Shortness of breath (n=2)		Multiple symptoms of digestive system (n=1)	Constipation (n=1)	
Impaired lung function (n=2)		Palpable spleen (n=1)	Dizziness (n=1)	
Wheezing (n=2)			Shortness of breath (n=1)	
			Fever (n=1)	
			Headache (n=1)	
			Presence of inflammation (n=1)	
			Raised serum creatinine (n=1)	
			Abnormal pulse rate (n=1)	
			Weakness (n=1)	
Disability				
Activity of daily living (n=16)	Function- &activity- related (n=2)	Activity- Oral health related (n=2)	Activity of daily living (n=15)	-
Function- &Activity-related (n=10)	Body-structure (n=1)	Function- & activity- related (n=2)	Function- Vision (n=7)	
Function-Vision (n=7)		Activity of daily living (n=1)	Function- &Activity-related (n=6)	
Non-specified (n=6)		Body structure- & function related (n=1)	Non-specified (n=6)	
Body structure- &function-related (n=5)			Body structure- &function- related (n=4)	
			Function-related (n=4)	
Self-perceived health status				
Quality of life (n=20)	-	Quality of life (n=2)	Quality of life (n=18)	-
Self-rated health (n=19)		Self-rated health (n=1)	Self-rated health (n=18)	

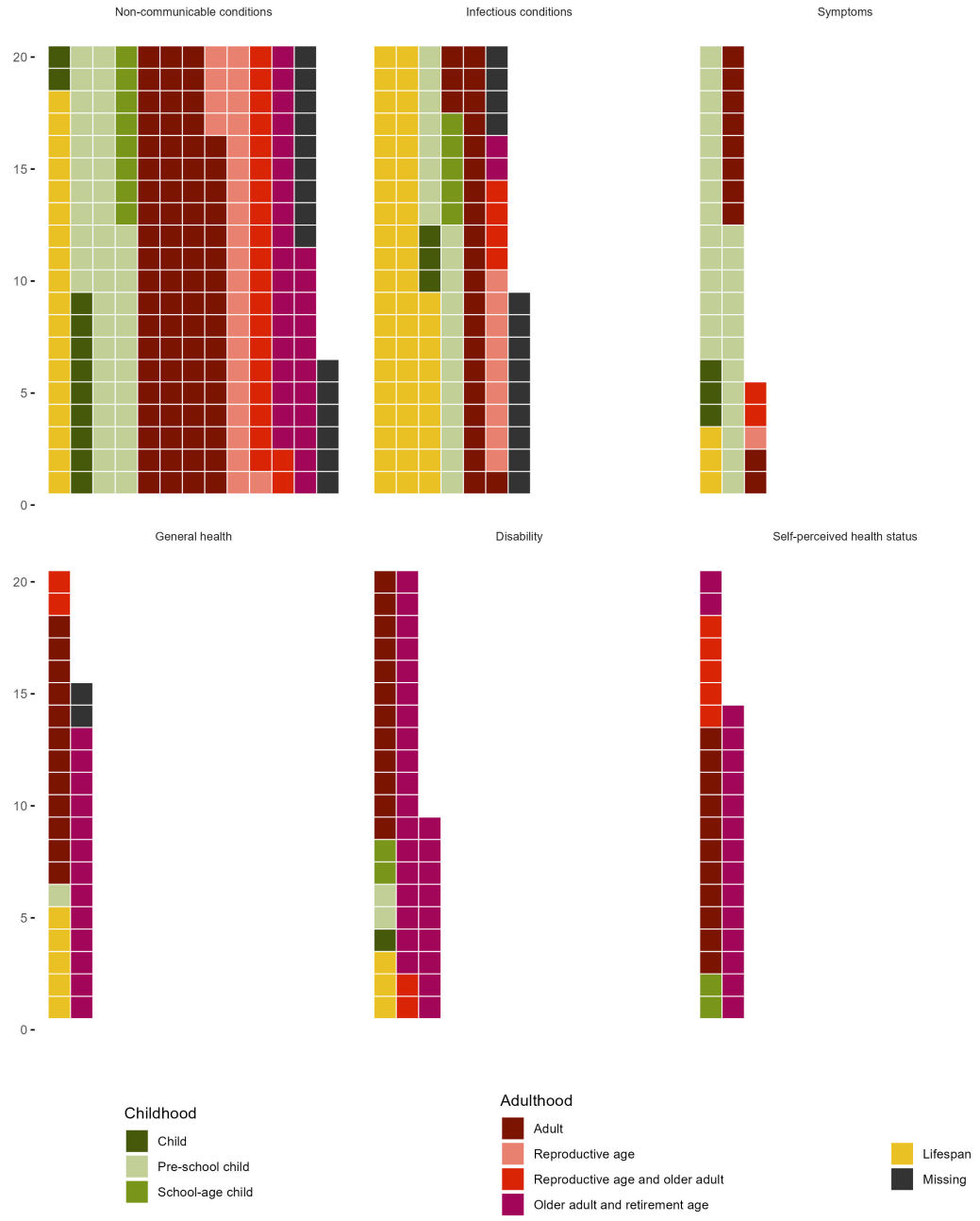


Figure 1.4: Waffle plot showing the distribution of health conditions by age categories. Figure showing (from the top left to bottom right) the number of surveys studied among participants of each age group, on Non-communicable conditions, Infectious conditions, Symptoms and abnormal findings (Symptoms), General health condition inquiries (General health), Disability and functional limitation (Disability), and Self-perceived health status. Each square represents one survey. However, there are more squares than the total number of surveys, because multiple age groups can be studied by a survey. The number of squares of each condition category are: non-communicable condition (n=236), infectious condition (n=129), Symptoms (n=45), General health (n=35), disability (n=49),to self-perceived health status (n=34).

Leading causes of disability and death

From the GBD study, the top 20 'causes' of disability and death with the highest DALY rate largely overlapped across study countries (Figure 1.5). In Bangladesh, 15 of the top 20 'causes' were reported by at least one survey included in this review. Six of the top 20 'causes' were reported by surveys in Cambodia, seven in Laos, six in Myanmar, and eight in Thailand. According to the metadata of GBD, 11 'causes' from Bangladesh had available datapoints, seven for Cambodia, six for Laos, five for Myanmar, and 15 for Thailand.

The surveys included in this review and the metadata from the GBD, regarding the coverage of common top burden 'causes' across the countries by available data sources, indicate that diabetes, respiratory infections, tuberculosis, and diarrhoeal disease have good study coverage. Each of these conditions has been studied by at least one survey, and identified with datapoints in GBD metadata, from all or most of the countries included in the scoping review. In contrast, headache disorders, hearing loss, and lower back pain were rarely studied by the surveys included in the review, and also had little or no data available from GBD metadata from the affected countries.

Discrepancies between survey study coverage and GBD metadata were also recognised. Other common 'causes' in the top 20, including ischemic heart disease, chronic liver diseases, tracheal/ bronchus/ lung cancer, congenital birth defects, neonatal disorders, and road injuries were studied only by a few or no surveys found in this scoping review. However, GBD metadata included more datapoints for these 'causes', especially in Thailand and Bangladesh. Whereas depressive disorder, despite having only 2 data points from GBD metadata available from Laos, was among the most commonly studied conditions in the surveys (n=24) and in all countries.



Figure 1.5: Available datapoints and surveys reporting the top 20 causes of disability and death according to disability-adjusted-life-years (DALY) rate (/100,000 population) from the Global Burden of Disease Study (GBD) 2019, by study country. (Legend continues on the next page.)

(Figure 1.5 legend continued.) The size of circle indicates number of available data sources, with blue indicating datapoints collected since 2010 and used in the GBD study, and red indicating surveys included in this review. The position of the circles on the x-axis represents the DALY rate, and the bars represent the 95% confidence intervals. The top 20 high-burden causes vary across countries. Common top-burden causes across all countries include: lower respiratory infections, diabetes mellitus, cirrhosis and other chronic liver diseases, ischemic heart disease, stroke, road injuries, chronic obstructive pulmonary disease, low back pain, headache disorders, age-related and other hearing loss; across four countries include: diarrhoeal diseases, tuberculosis, tracheal, bronchus, and lung cancer, congenital birth defects, chronic kidney disease, neonatal disorders, and depressive disorders. Other causes include: HIV/AIDS, falls, dietary iron deficiency, other musculoskeletal disorders, asthma, liver cancer, gynaecological diseases, self-harm, Alzheimer's disease and other dementias, typhoid and paratyphoid, interpersonal violence, anxiety disorders, other malignant neoplasms, and neck pain.

1.3.3 Discussion

This scoping review included 337 community-based and population-based cross-sectional surveys conducted in Bangladesh, Cambodia, Laos, Myanmar, and Thailand published between 2010-2022. This review highlighted firstly that the primary focus areas of these surveys are known high-burden causes of death and disability, aligning with the recent GBD estimates, with gaps on conditions that relate to ageing populations and other demographic changes in the region (Global Burden of Disease Collaborative Network., 2020). Secondly, this review highlighted that little has been studied outside of the known regional high-burden diseases according to the top 20 causes of disability and death (Global Burden of Disease Collaborative Network., 2020). The findings suggest that while continuous monitoring of well-studied high burden diseases is important for tracking the progress of current intervention strategies, the research focus of cross-sectional surveys could expand to address knowledge gaps.

According to GBD estimates, non-communicable conditions are the leading causes of morbidity and mortality across the five countries included in our scoping review (Vos et al., 2020). Non-communicable conditions were also studied in the

majority of surveys from each country. Risk factors attributable to cardiovascular disease (i.e. hypertension, underweight, and obesity) and diabetes were the most studied and are among the causes contributing to the most significant loss of DALYs. These surveys also extensively covered regional high-burden infectious diseases, including tuberculosis, acute respiratory infection, and diarrhoea. Data on these causes were also recorded from sources beyond the prevalence surveys we reviewed (e.g., censuses, vital statistics, and other health-related data), as indicated by the extensive datapoints used in the GBD study, which include a wider range of data sources (Health Metrics & Evaluation, 2019). While it is still important to continuously collect data on these conditions to monitor progress of disease control and intervention strategies, the scope of community-based surveys could expand to other disease and health conditions.

The scope of future cross-sectional surveys could fill gaps in knowledge by including some of the regional high-burden causes that are predicted to increase in prevalence due to the ageing population and socio-economic changes in the regions, but have not yet been widely studied (Haile et al., 2021; Li et al., 2023; The Lancet Rheumatology, 2023). This includes hearing loss, headache disorder, and lower back pain. Population groups with rising risks that were not previously considered high-risk for certain diseases could be included in future surveys. For example, with an evolving lifestyle and increasing prevalence of obesity among children, the prevalence of diabetes is rising in younger populations (Jaruratanasirikul et al., 2017). Children or adolescents could be the target population in surveys studying diabetes, whereas hitherto adults were the focus of the recent surveys. More attention could also be directed towards the elderly to understand their health problems. Notably, compared with other countries, there were many surveys from Thailand which studied the elderly population by evaluating their activity of daily living. This is likely attributable to Thailand's more rapidly growing aging population (World Bank, 2022). However, countries with younger population structures such as Cambodia and Laos could also benefit from the health data from the elderly to better anticipate their future healthcare needs (World Bank, 2022).

Including these conditions can fill gaps in current population-level disease estimates, and help health systems prepare for demographic change.

Although some important causes of DALYs were studied by only a limited number of surveys, due to their resource-demanding diagnostic criteria, which are not easily adaptable to cross sectional community -based surveys, many risk factors and early stage manifestations of these diseases can be effectively assessed. Such conditions include ischemic heart disease, liver cirrhosis, chronic kidney disease, and tracheal, bronchus and lung cancer. For instance, chronic viral hepatitis, a known risk factor for liver cirrhosis, has been surveyed with easy to use and well-validated point-of-care tests or other test procedures (Aye Aye Lwin et al., 2017; Lynch et al., 2021).

Additionally, the disease definitions used in surveys often differ from formal diagnostic criteria. The use of screening tools, which is easier to implement than diagnosis criteria, is common in surveys and may result in a higher number of surveys assessing a condition, even when clinically confirmed data sources are limited. Depression, for instance, is one of the most surveyed conditions, but limited datapoints were available from GBD metadata. It can be explained by the questionnaire-based screening tools often used in surveys versus the strict diagnosis criteria for depressive disorder applied in GBD (Cantor-Graae et al., 2014; Ekplakom, 2014). Despite these differences, surveys that assess risk factors of disease, early stage manifestation, or screening outcomes, could provide strong indications as to prevalence and trends of the diseases. They could also support the detection of diseases at an early stage, informing optimal strategies for prevention and control. Such public health approaches have been shown to be cost-effective (Yildirim et al., 2022).

There were some high burden causes that were reported by fewer surveys, but were covered by alternative data sources as indicated by the availability of GBD metadata, such as neonatal disorders and congenital birth defects. One explanation for this could be their low case numbers in the population. In this case, these types of causes can be more efficiently studied in health facility-based

studies, or using existing population data sources such as vital registration, or police reports (e.g. road traffic injury). For this reason, it could be argued that it is less critical for future community-based cross-sectional surveys to incorporate these conditions, although collecting data on knowledge, attitudes, and behaviour around such conditions could enrich the understanding and potentially improve the population-level estimations by addressing under-reporting and health service utilisation patterns (Boufous et al., 2010; Taubman Ben-Ari et al., 2016).

Conditions outside of the top high burden causes were less surveyed, such as neglected tropical diseases (NTD). Specifically those related to non-malarial febrile illnesses (e.g scrub typhus, melioidosis), still contribute significantly to morbidity and mortality in parts of the region (Hotez et al., 2015; Shrestha et al., 2020). However, other than intestinal parasites, NTDs have not been well studied in the surveys identified in this review. This may be due to the challenge of capturing an acute infection within a limited data collection period through cross-sectional surveys. Despite the challenges, seroprevalence studies have proven useful in rapidly generating data on disease transmission (e.g. for COVID-19, or dengue) (Aiemjoy et al., 2020; Kshatri et al., 2021; Salje et al., 2018). Current studies often rely on self-reported information for fever and related diseases (e.g., Acute respiratory infection), with the aetiology often absent. There is an opportunity to utilise seroprevalence surveys to detect the hidden burden of the causes of fever, and provide efficient and scalable approaches to generate population-based seroincidence data in resource-limited settings (Aiemjoy et al., 2022; Arnold et al., 2019). By incorporating self-reported disease and serology tests, the scope of surveys could be broadened to include other regionally important diseases and explore potentially unknown risk factors for high-burden diseases.

While expanding research focus could pose challenges in resource-limited settings, questionnaire-based evaluations, which collect data on a broad range of health problems within a limited time period could be an accessible and efficient means for surveys, compared to resource-intensive examinations and tests (Cleary, 1997). General health condition inquiries can offer direct prevalence data on a full

range of existing health problems; evaluations on self-perceived health and disability can provide a comprehensive picture of health, and though lacking specificity, can predict morbidity, mortality, and future healthcare needs (Benyamini & Idler, 1999; Guidet et al., 2020; Idler & Benyamini, 1997; Makovski et al., 2019). In addition, analysing the data with the results of a clinical diagnosis or objective measures (e.g. laboratory results) can aid in the identification of determinants (e.g. disease status, socio-economic status) of self-perceived health, thus informing public health planning for an improved self-perceived health status (Mutz & Lewis, 2022). However, the utilisation of general health condition inquiries, self-perceived health and disability measures remains relatively low. Most of the surveys targeting non-communicable conditions and infectious conditions did not incorporate these measures, and it was only commonly studied among the older adulthood and retirement age groups. There is an opportunity to consistently incorporate these measure in future research and apply them to a wider population.

Limitations

This review was limited by its nature of secondary data analysis. Significant heterogeneity of definitions of health conditions was applied across studies, and an exact match to a specific internal classification according to the guidelines was not always possible. Therefore, we have primarily followed the ICPC-3 for the categorisation of health conditions, while allowing for content appropriate differences due to variation of definitions used across studies. When matching the health conditions with the causes of the death and disability from GBD, similar principles applied.

Another limitation was the lack of sufficient study data to map geographically where surveys took place. We were not able to consistently distinguish between urban and rural study locations, as about 13% of the studies did not specify the urban-rural coverage of the study location. In addition, the names of the study area were sometimes ambiguous (e.g. the same name can refer to a city

and a district). Consequently, this restricted our ability to determine the sample representativeness of each survey.

A higher number of surveys covering certain health conditions does not necessarily indicate robust surveillance of those conditions. However, the findings of this scoping review achieved its aim of depicting the health spectrum studied in community-based cross-sectional surveys in Bangladesh, Thailand, Cambodia, Myanmar and Laos, and to identify knowledge gaps for future studies. As the next step, systematic reviews evaluating the sufficiency of surveillance for diseases studied by a high number of surveys could be conducted, including critical appraisal of study quality and more extensive data synthesis. Following the inclusion criteria, studies using health facilities or school-based recruitment were not included in the review. This omission partially explains the gaps in reported health conditions related to maternal and neonatal health, as well as among school-aged children. However, the inclusion criteria included only community-based studies, in which chiefly healthy participants were recruited, and avoided studies with potential selection bias such as facility-based surveys.

The inclusion criteria also restricted publications to quantitative studies that reported the prevalence of at least one health condition. Although community-based qualitative studies exist, their research methods and outcomes differ from those of quantitative studies. To maintain the focus of our review and to guide future prevalence surveys, we included only quantitative studies.

Implications

Cross-sectional surveys are an efficient method to obtain population-based data in Southeast Asia, where the epidemiology of many conditions is incomplete and the coverage of health reporting and surveillance systems is limited. While regionally high-burden diseases deserve continuous attention to monitor trends and progress, increased attention could be given to address population-based epidemiology gaps, particularly those associated with the aging populations and socioeconomic and environmental changes. This includes known high-burden diseases, hearing loss,

headache disorder, musculoskeletal pain, and other chronic conditions, including cancer, and potentially emerging risk factors or high-burden diseases that can be anticipated based on the evolving trend of epidemiology in the region. In addition, region-specific relevant diseases such as non-malaria febrile illness, have been understudied by prevalence surveys.

To balance the limitations of cross-sectional surveys, and address resource constraints, some study approaches and evaluation methods could be applied. Symptoms or early onset of diseases, indications of infection (i.e. serological responses) that are suitable to be studied in the field could be surveyed; questionnaire-based evaluation, including self-reported health conditions, self-perceived health and disability, that can provide improved disease estimates cost-effectively, could also be used in surveys. This expansion of study scope may inform new areas for disease prevention and control priorities at an early stage and prepare health system readiness to meet modern needs.

1.3.4 Conclusions from the scoping review

Rich prevalence data is available for many of the high burden diseases in the region, such as diabetes or tuberculosis. However, knowledge gaps were identified among conditions that have a high or emerging burden related to the dynamic epidemiology of the region. The findings of this review suggest that future surveys and other data collection methods could expand their scope to under-studied conditions to provide improved population-level prevalence estimates and to reflect the evolving regional epidemiology.

1.4 Implications for the scope of the thesis

While the scoping review synthesised evidence from five South- and Southeast-Asian countries and provided broader regional-based evidence, the thesis reports on three of these countries- Bangladesh, Cambodia and Thailand, which were the countries that implemented the survey. This scoping review, by mapping the

spectrum of health conditions studied in community-based cross-sectional surveys conducted in SEACTN study countries, provided insights into where research efforts could be directed. These findings shaped the scope of this DPhil thesis, ensuring that the study would not only monitor well-documented conditions but also address neglected areas of public health concern. Additionally, this review informed the selection of appropriate evaluation methods, balancing self-report disease histories, physical examinations, and laboratory tests to broaden the health condition coverage while maintaining feasibility in community settings in LIMCs.

1.4.1 Continuous monitoring of high-burden diseases with established surveillance

The review confirmed that existing cross-sectional surveys primarily focused on known high-burden diseases, particularly non-communicable diseases (NCDs) such as hypertension, diabetes, and obesity, as well as infectious diseases like diarrheal diseases, and malaria. Since these conditions remain major contributors to morbidity and mortality, this study incorporates them into its scope to continuously track their prevalence trends. Multiple evaluation methods are employed, including:

- Self-reported disease history:
  - To capture conditions that may not be detectable through physical examination or laboratory tests during survey data collection, such as previous diagnoses and well-controlled diseases. For example, an individual on cholesterol lowering medication for previously diagnosed hypercholesterolemia may have well controlled cholesterol levels at time of blood sample collection, but their conditions are still accounted for in prevalence estimates.
  - To capture recent acute conditions, such as diarrhoea and fever.
- Physical examinations (e.g., blood pressure measurements for hypertension, weight and height measures for body-mass index calculation).

- Laboratory tests for conditions that require biomarker tests:
  - NCDs: e.g., HbA1c for diabetes.
  - Malaria PCR, IgA and IgG response to *Salmonella enterica* serovars Typhi and Paratyphi.

1.4.2 Expanding the scope to understudied areas

While some conditions were frequently studied, the scoping review identified significant gaps in cross-sectional survey coverage for certain high-burden diseases or regionally important diseases that are less easily diagnosed in community settings. These include:

- Overlooked but high-burden conditions such as cancer, liver cirrhosis, and musculoskeletal pain, which are difficult to diagnose in field settings but can be assessed through self-reported history.
- Risk factors for these high-burden diseases: Hepatitis B and C are main contributors to cirrhosis and other chronic liver diseases in the region. Well validated and widely used laboratory tests could be employed for their evaluation.
- Pathogens causing fever.
  - The causes of febrile illness remain largely unexplored in community-based surveys. Based on their regional importance and the availability of multiplex serological assays, the IgG response of the pathogens- dengue virus, Japanese encephalitis virus, Zika virus, chikungunya virus, *Orientia tsutsugamushi, Rickettsia spp., and Leptospira spp.* were tested. Seroprevalence of these pathogens was estimated to capture past exposure to infection.

- Typhoid fever seroincidence was estimated. Unlike seroprevalence, seroincidence estimates recent infections using antibody kinetic models (Aiemjoy et al., 2024). It provides a more dynamic measure of disease transmission, making it a promising tool for disease surveillance and vaccine impact assessments. The approach demonstrates how seroprevalence data, when integrated with antibody kinetics, can generate other robust estimates of disease burden, a method that could be applied to other pathogens in future studies.

1.4.3 Broadening health condition coverage through self-perceived health and general health condition inquiries

The scoping review highlighted the limited attention given to self-perceived health and general health inquiries, despite their value in predicting long-term health outcomes and identifying individuals at higher risk of diseases of a wider range . To address this, the thesis expands the scope beyond disease-specific assessments to include:

- Self-perceived overall health status, and other domains of health. These are strong predictors of morbidity and mortality, and could demonstrate broader trends in functional health and disability that would not be detected in vertical, disease-specific surveys.

- General health enquiries. In addition to self-reported histories of specific conditions (e.g., asthma, cardiovascular disease), participants were also asked whether they had any other acute or chronic conditions, with the option to specify further.

  To facilitate data collection and improve accuracy, a dropdown list was incorporated, including commonly reported conditions, as well as underreported but high-burden diseases or symptoms, such as fever, persistent cough, depression, liver cancer, and musculoskeletal pain. This approach ensured

comprehensive data collection while allowing for flexibility in capturing a broad range of health conditions relevant to the study population.

By integrating these elements, the thesis takes a comprehensive approach to disease surveillance, bridging the gaps identified in the scoping review while ensuring alignment with regional health priorities.

1.5 Aim and objectives of the thesis

This thesis aims to contribute to the understanding of the epidemiology of selected rural populations in Southeast Asia, thereby facilitating the design of future interventions to improve health outcomes of these populations.

1.5.1 Primary objectives and outcomes

- To determine the prevalences of selected diseases and exposure to locally prevalent or important pathogens, including:
  - Immunoglobulin G (IgG) against selected common pathogens causing fever.
  - Hepatitis B and C: Hepatitis B virus (HBV) surface antigen; IgG against Hepatitis C virus (HCV) and presence of HCV
  - Selected non-communicable diseases and risk factors (e.g. raised blood cholesterol, hypertension, diabetes, cardiovascular diseases) according to self-reported disease history, and/or physical examinations, and/or laboratory tests.
  - Self-reported acute illness, including fever in the past 30 days
- To determine the point prevalence of a variety of indicators and domains of self-perceived health status.
- To determine the prevalences of major risk factors for common non-communicable diseases (e.g. smoking, alcohol consumption, overweight).

1.5.2 Secondary objectives and outcomes

- To describe household demographic and socioeconomic characteristics
  - Household wealth status and possession of household facilities (e.g. household roof material, main type of cooking fuel, source of drinking water)
  - Individual participants' education level, marital status, and work status
- To assess health seeking practices and health care utilisation in case of febrile or other illness
- To describe current health problems besides the outcome measures of the primary objectives according to self-reported disease history

1.6 Organisation and structure of the DPhil thesis

With the exception of chapters 1, 2, and 8, the chapters in this thesis are organised by the health conditions studied, corresponding to the thesis objectives.

- **Chapter 1**. Background and literature review: introduces the thesis background and how the study objectives were defined.
- **Chapter 2**. Methods: provides an overview of the methodology, including the study sites, population, design, procedures, and general statistical analysis. Specific procedures and statistical analysis are detailed in the respective chapters.
- **Chapter 3**. Participants' characteristics, self-perceived health status, and health-related concerns: discusses sample representativeness as the outcomes of recruitment. It also presents the population characteristics, including household and individual demographics, socioeconomic status, and the community concerns related to health, risks and healthcare provision.

- **Chapter 4**. Self-reported fever, health-seeking behaviour, and seroprevalence of febrile pathogens: discusses the prevalence of febrile illness, including self-reported recent fever and seroprevalence of pathogens causing fever. The health-seeking behaviour of the recent fever episode is also covered.

- **Chapter 5**. Estimating typhoid fever seroincidence in Cambodia: presents the estimation of typhoid seroincidence among study participants aged 5–24 years in Cambodia using an antibody kinetics model of typhoidal *Salmonalla*. Specifically, it applies serological markers—IgA and IgG responses to haemolysin E —to infer recent exposure and estimate seroincidence rates.

- **Chapter 6.** The prevalence of chronic hepatitis B and C: focuses on the prevalence of hepatitis B among all ages and hepatitis C among those aged 15 years and older.

- **Chapter 7**. The prevalence and care cascade of non-communicable diseases: describes the prevalence of non-communicable diseases and their risk factors, based on physcial examination, laboratory tests and self-reported disease histories. Evaluates care access along the continuum of care of NCDs among individuals diagnosed with NCDs in this study.

- **Chapter 8.** Discussion: synthesises the contents of all chapters into one discussion, reviewing the strengths and limitations of the study, highlighting its impact on policy and practice, and exploring further research directions.

2
Methods

Chapter outline

This chapter details the study design, sampling strategy, data collection procedures, and quality assurance measures of this household health survey. It describes the sampling frame and two-stage cluster sampling approach, which ensured sample representativeness and logistic feasibility. The preparation steps are outlined, including questionnaire development and validation, paper-based supporting documents for electronic data collection, and community engagement activities to facilitate study implementation. The pilot phase allowed for site-specific adaptations. The core components of the survey consisted of structured questionnaire interviews, physical examinations, and blood sample collection for assessing infectious and non-communicable diseases. The chapter also details data management and monitoring strategies, including real-time data validation, field supervision, and biweekly quality checks. An overview of the statistical analysis plan is provided. Ethical considerations were explained, particularly regarding informed consent and individual-level results feedback. This chapter provides an overview of the survey methods and further descriptions relevant to specific components are provided in subsequent chapters.

2.1 Study population and setting

Three SEACTN study sites in Bangladesh, Cambodia and Thailand, participated in this survey, while other SEACTN sites opted out of the study due to operational restrictions.

Villages covered by the SEACTN operational areas were selected by partner organisations to represent poor, remote, and rural communities with limited access to formal healthcare (Chandna et al., 2022). Initially, all villages within the SEACTN operational area were considered for inclusion in the sampling frame, however, 20 villages in Bangladesh were later excluded due to logistic challenges. The main reasons for the exclusion included the inaccessibility of the villages during monsoon seasons, extended transportation time for blood samples, exceeding the time limits required by Standard Operational Procedures (SOP), and limited capacity for sample processing and storage of samples as per SOP specifications. After these exclusions, the final sampling frame included 110 villages in Bangladesh, 82 in Cambodia, and 186 villages in Thailand (Figure 2.1). These selections ensured that the survey remained logistically feasible.

2.1.1 Inclusion criteria

Within each village, five or seven households were randomly selected (see Sampling methods). For each selected household, all usual remembers and visitors of the household were eligible to be enrolled, following eligibility criteria aligned with the Demographic and Health Survey (DHS) (ICF, 2020).

- A household was defined as one person or a group of persons who usually live and eat together.
- Usual members of the household included any people who live together, whether or not they are related.
- A visitor was someone who was not a usual member of the household but who stayed in the household the night before the day of the survey.

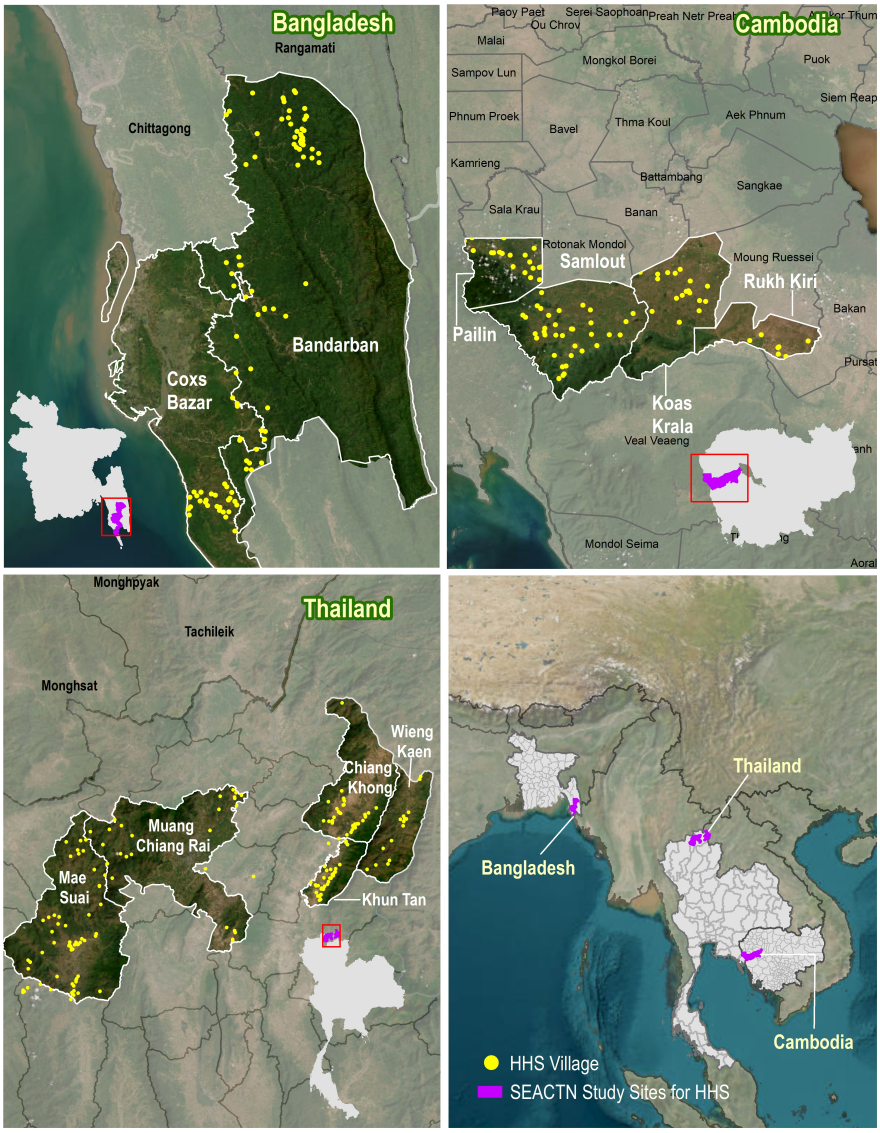


Figure 2.1: Map of the study sites and population of the cross-sectional household health survey conducted by the South and Southeast Asia Community-based Trials Network (SEACTN).
The Bangladesh site includes 110 villages (a total of 130 villages in the operational area) with an estimated population of 109,096 from Coxs Bazar and Bandarban districts; the Cambodia site includes 82 villages with an estimated population of 65,567 from Battambang and Pailin provinces; and the Thailand site includes 186 villages with an estimated population of 126,926 located in Chiang Rai province. HHS: The Household Health Survey; SEACTN: the South and Southeast Asia Community-based Trials Network.

2.1.2 Sample size and sampling methods

This study was designed to ensure a robust estimation of key health indicators of each study site.

Sample size calculation

The minimal sample size required was calculated based on the estimated prevalences of key indicators corresponding to primary study objectives, overall and within age groups (Table 2.1). All key indicators were listed in the Statistics Analysis Plan (SAP). The sample size was determined with a design effect of 1.5 and a range of 5-10% degrees of precision while considering a maximum cap of 1500 participants per study country. To account for a 10% non-response rate and assuming an average household size of 4.5 persons (Aekplakorn et al., 2018; National Institute of Statistics et al., 2015; Population Research et al., 2020; Washirasaksiri et al., 2021), the final sample size required was adjusted to 1667 participants per country.

The prevalence estimates, population proportions within each age group and average household size were derived from previously conducted national health surveys and published studies, preferably from the study country. If unavailable, data from countries with similar epidemiological contexts were used. Main data sources included the Demographic and Health Surveys (DHS) and the World Health Organization's (WHO) STEPwise approach to non-communicable diseases and risk factor surveillance (STEPS) (Ashraf et al., 2010; Aye Aye Lwin et al., 2017; Komada et al., 2015; Lynch et al., 2021; National Institute of Statistics et al., 2015; National Statistical Office of Thailand, 2020a; Population Research et al., 2020; Preventive & Social Medicine, 2018; World Health Organization (WHO), 2019). When prevalence estimates varied across study countries, the highest prevalence estimate was used to ensure that the largest required sample size was accounted for.

Sampling methods

Two-stage cluster sampling was used to obtain a representative sample from each study site. The first stage was village selection. From each site, 75 villages were selected using the probability-proportional-to-size sample method (PPS) to the village population size (Department of Economic and Social Affairs, United Nations, 2008; Milligan et al., 2004; World Health Organization, 2017c). The population size of all villages in the survey area was available from various sources obtained and verified by local partners- including the estimates from the local partner in Bangladesh, official operational health district estimates in Cambodia, and registration records from the health information system of local primary health units (PCU) in Thailand.

The second stage was household selection. Within each village, a simple random sample of five households (or seven for Thailand) was selected using computer-generated random sampling from the village household list. The household lists were obtained from various sources across sites. In Cambodia, the lists were initially acquired from village leaders following local approvals and community engagement meetings. In Thailand, the lists were obtained from the health information system of PCUs through existing collaborations and work relationships with the local partner. To ensure accuracy, these lists were extensively reviewed and revised by village leaders or village health workers, leveraging their local knowledge to confirm household inclusion and update any discrepancies. There was no existing household list in Bangladesh, so the local research team worked with the village health volunteer and the village malaria workers to prepare such lists. Given their close engagement with the community, these health workers systematically identified and listed households one by one, ensuring that the sampling frame was completed and accurate for the survey.

Adjustments for Household Selection in Thailand

Upon obtaining the household lists, the household size from the coverage area of Thailand proved to be much smaller than the other two sites, with an average of 2.8 persons/ household (National Statistical Office of Thailand, 2020b). Therefore,

we increased the number of households selected from five to seven to ensure the intended sample size was reached in Thailand.

Table 2.1: Sample size calcuation with the key indicators of the highest prevalences and the formular used

Population	Expected number of participants	Indicator (estimated prevalence)	Required sample size
Overall	1500	Overweight (20%)	369
Age groups (years)			
15 or older	1050	Current drinker (55%)	570
under 5	150	Anemia (30%)	122
15-49	750	Injury or death caused by recent accident (20%)	414
50 or older	300	Hypertension (20%)	257

Note:
The formula used for calculating sample size is shown below. Assessing the sufficiency of the sample size for the key indicators of the highest prevalences ensures sufficient statistical power for indicators with lower prevalence. A degree of precision of 5% is applied for the sample size calculation overall and across age groups, except for the under 5 years and the 50 years or older groups, for which degrees of precision of 10% and 6% are applied, respectively.

$$n = \frac{\text{DEFF} \times (Np(1-p))}{\frac{d^2}{1.96^2}(N-1) + p(1-p)}$$

n: Sample size. DEFF: Design effect. Design effect of 1.5 is used to account for a slightly expected increase in variance due to clustering. By incorporating this, the required sample size is increased to maintain the desired level of precision. N: population size. p: expected prevalence of key indicators. d: degree of precision.

2.1.3 The rationale of sampling methods

The two-stage cluster sampling method was chosen to achieve a representative sample while balancing logistical feasibility and statistical robustness.

In the first stage of village selection, PPS ensures villages with larger populations are more likely to be selected, reducing sampling variances in settings with highly variable village sizes. The number of selected villages (n=75) aligns with the recommended range of 50-100 primary sampling units (PSU) for cluster sampling (ICF International, 2012; World Health Organization, 2017c). This helps

to minimise cluster effects and improve the precisions of survey estimates. In cluster sampling, individuals within the same PSU (e.g. village) tend to share common characteristics, such as socioeconomic status, healthcare access, and environmental exposures, leading to higher intra-cluster correlation (Cochran, 1977; Groves et al., 2009). Too few clusters can lead to overrepresentation of local patterns rather than capturing broader population variability, reducing the generalizability of findings. Additionally, a small number of clusters increases the design effect (Deff), which measures the impact of clustering on variance estimation. A higher Deff leads to increased standard errors, requiring a larger sample size to achieve the same level of statistical precision. By applying PPS and selecting a sufficient number of PSUs, we balanced survey efficiency with statistical robustness, ensuring sufficient geographic and demographic diversity while minimising the dominance of localised patterns.

The two-stage approach allowed us to develop household lists only after selecting villages, greatly reducing the workload. In our study areas, existing household data are often outdated or unreliable due to frequent internal migration (Diepart & Ngin, 2020; Jampaklay, 2020), while in some areas, such lists don't exist. Thus, compiling lists after village selection improved the efficiency of the workflow.

The selection of villages and households was also guided by logistical feasibility. In consultation with colleagues and local teams who are experienced in survey implementation, it was determined that surveying five households (20-25 members) per day was manageable, considering transportation, setup, and data collection time. Sampling 75 villages and five households per village ensured the targeted sample size while maintaining operational efficiency.

2.2 Questionnaire development

Most items on the questionnaire were adapted from well-validated and widely implemented questionnaires from DHS, STEP, and the World Health Survey (Chakraborty et al., 2016; Metrics for Management, 2016, 2022b; Metrics for Management, 2022a; World Health Organization, 2003, 2017c). Many of these surveys have been

previously implemented in the study countries, so the questionnaires with country adaptations are available to be used in our study. This approach also ensured the validity of the questionnaire with less intensive validation processes.

The questionnaire comprised four sections answered by household members based on their role, sex and age (Figure 2.2 Top).

- The household section was completed by the household head only, providing information on household characteristics and a list of all household members along with any illnesses and health-seeking behaviour in the past 30 days.
- The adult section was for household members aged 15 years and older and included questions on socio-demographic characteristics (e.g., age, sex, education, marital status, and occupation), disease history (e.g.,tuberculosis, diabetes, cardiovascular disease), self-perceived health status, health concerns, substance use (e.g., tobacco and alcohol), and other disease risk factors.
- The women's health section was for female household members aged 15 years and older and included questions on contraception use and utilisation of antenatal care and delivery services.
- The children's health section was answered by caretakers of children under 5 years, providing information on each child's vaccination and breastfeeding history.

2.2.1 Validation and translation

The questionnaire underwent adjustments and validation through pretests using behaviour coding and participant debriefing (Presser et al., 2004; Zouwen & Smit, 2004). This process aimed to ensure the questionnaire's suitability, comprehensibility, and appropriate length for administration. Each pretest included two components- mock interviews and a debriefing session. During mock interviews, the observer of each interview pair recorded the interaction problems for each

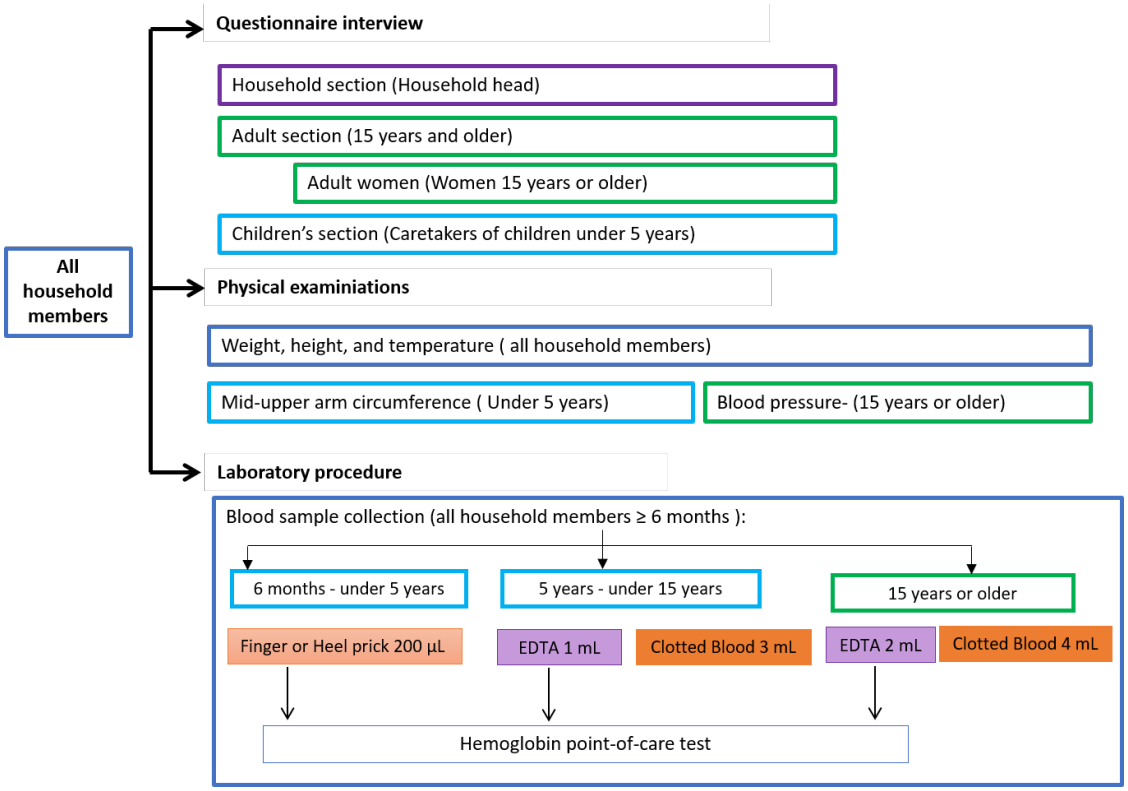


Figure 2.2: Flowchar of the survey components to be completed based on age and sex. This figure outlines the eligibility criteria for the different survey components, including questionnaire interviews, physical examinations, and laboratory procedures, which were administered based on participants' age and sex. EDTA: Blood sample collection tubes containing ethylenediaminetetraacetic acid.

question, such as "major change in wording", "question reading interrupted by the respondent", or "additional prompt was provided". The completion time for each section of the questionnaire was recorded. All interviewers, interviewees, and observers participated in the debriefing sessions. Two pretests were conducted. Details of the pretests, including the SOPs and the summary outcomes can be accessed online (https://figshare.com/s/c65046026bef6cf23f2c).

Pretest: Internal testing

The first pretest was conducted in English among peer researchers from the epidemiology department of MORU and the Mahidol-Oxford Translational Innovation Partnership. Three teams participated, completing all sections of the questionnaire (household head, adult, adult women, children). The completion time varied, with

the household head section taking between 15 to 40 minutes, the adult section 20-30 min, and the adult women and children section 5 minutes each. The pretest identified key issues, including the need for local adaptations (e.g. health facility list, sanitation facility or water source types, and commonly consumed alcoholic drinks), repetitive questions between the adult and household head section, and length of the household head section, requiring optimisation.

Pretest: Field testing in Thailand

Following adjustment from the first pretest, a second pretest was conducted among the targeted population in Thailand, including ethnic minorities who did not speak Thai (Figure 2.3). It took place in SEACTN villages that were not selected for the survey. The participants were recruited conveniently by the primary healthcare centre staff and the village health volunteers. While ensuring an adequate number of ethnic minorities who do not speak Thai (Table 2.2)

The questionnaire used in this pretest was in Thai and was translated by a professional translation company. Given the language barriers- as many local dialects were only spoken and lacked a written form, village health volunteers were recruited as interpreters, with the survey staff serving as interviewers and observers. This approach ensured effective communication and accurate data collection among participants who did not speak the official language. One-day training was conducted for interpreters, interviewers and observers before the pretest.

In this pretest, the household head section was optimised, reducing the average completion time to 30 min. The adult section had a median of 36 minutes (ranging from 17 to 75 minutes), with longer durations among Lahu speakers due to interpretation delays. The adult women and children section remained at 5-10 minutes each.

The pretest also suggested that subjective questions requiring respondents to evaluate frequency, level of difficulty, or quality of life were more challenging to answer. This implied that additional prompts and clarifications should be given as part of the questionnaire. The importance of translation into a spoken

language that could be read and easily understood by participants was also highlighted during the pretest. Consequently, these improvements were included in the questionnaire.

This pretest also evaluated the interpretation process. It demonstrated its impact on prolonged questionnaire administration time and the interpreters' lack of ability to accurately translate technical terms. For example, one interpreter mistakenly translated cholesterol level as diabetes, an issue that was identified and corrected during debriefing sessions. It suggested the process could benefit from more training for interpreters and accuracy checking during the interview. Corresponding procedures were implemented during data collection.

2.2.2 The final questionnaire and the translation

Based on both pretests, the questionnaire was improved in clarity and comprehensibility and achieved adequate length for administration. The anticipated total interview time per typical household (e.g. three adults and one child), including one household head section (30-60min), three adult sections (20-60 min/ each), two adult woman sections (5-10min/ each) and one child section (5-10min), was estimated to be 1.5-2 hours when conducted with two interviewers.

After the final adjustment, the questionnaire was also translated into Bengali and Khmer by professional translators or dedicated staff from partner organisations. All translations, including the questionnaire in Thai used during the pretest, were revised by local research teams to ensure accuracy and contextual relevance, as suggested by the second pretest.

2.3 Study procedures

This section focuses on the study procedures related to implementation and data collection. The overall study procedures and timeline are shown in the flowchart (Figure 2.4).



Figure 2.3: Photographs of questionnaire Pretest in Thailand.
The panel of images illustrates the questionnaire pretest conducted in Thailand. Top: the training session attended by interviewers, coders, and interpreters in preparation for the pretest. Bottom: the image depicts the pretest being carried out in a village, where ethnic Lahu participants were interviewed with the support of interpreters

Table 2.2: Number of interviews completed per section of the questionnaire during the pretest in Thailand.

Number of interviews	Thai speaker	Lahu speaker	Total
Household head	4	2	6
Adult	8	6	14
Adult women	5	4	9
Children	2	2	4

Note: Both Thai speakers and Lahu speakers who required interpretation during interviews were included in this pretest.

2.3.1 Preparations

To facilitate the implementation of the procedures, ensure standardised data collection across study sites, and improve efficiency, extensive planning and preparations were done specific to the context of each site.

Standard Operational Procedures

Twelve SOPs were developed for individual components of the survey, including field procedures, interview guidelines, physical examinations, and sample collection

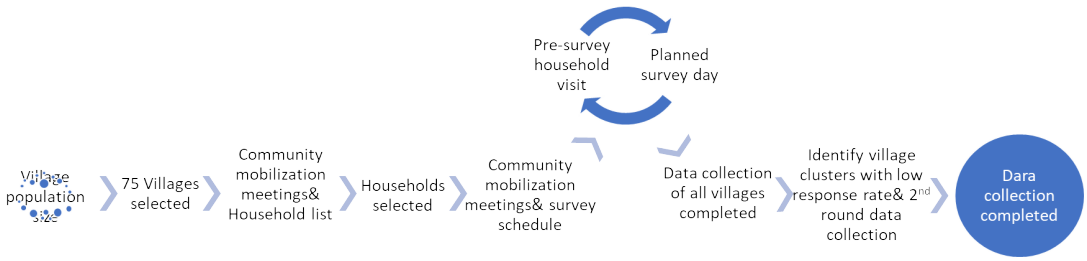


Figure 2.4: Study implementation procedures.
This figure outlines the key steps in study implementation, including population size estimation for sampling, community mobilisation, data collection, and follow-up with non-responders. Community mobilisation was conducted continuously throughout the data collection period to maximise participation and engagement.

and transportation. Training materials were developed, and two training sessions were delivered per site to all the study staff directly or using a train-the-trainer model where field supervisors and managers were trained first and then subsequently trained other field staff.

The Field procedure SOP was the essential reference for setting up the data collection in the villages. A flowchart laying out the suggested human resources, materials required, and participant flow provided an overview of the setup (Figure 2.5). It was the focus of the training, tested in the pilot period during implementation (See section Implementation pilot), and adapted according to the human resource arrangement and data collection setting of each site.

The key SOPs are described in the following sections: Informed consent, Questionnaire interview, Physical examination, and Blood sample collection.

Paper-based supporting documents

Data were collected electronically with Open Data Kit (ODK) on tablets, and each participant could have multiple case report forms (eCRF) (Figure 2.5). However, the restricted internet connection in the study sites, which prohibited real-time record linkage, required paper-based material to link all the components and ensure the completeness of data collection. Therefore, logbooks and other paper-based materials were developed to facilitate electronic data collection. The

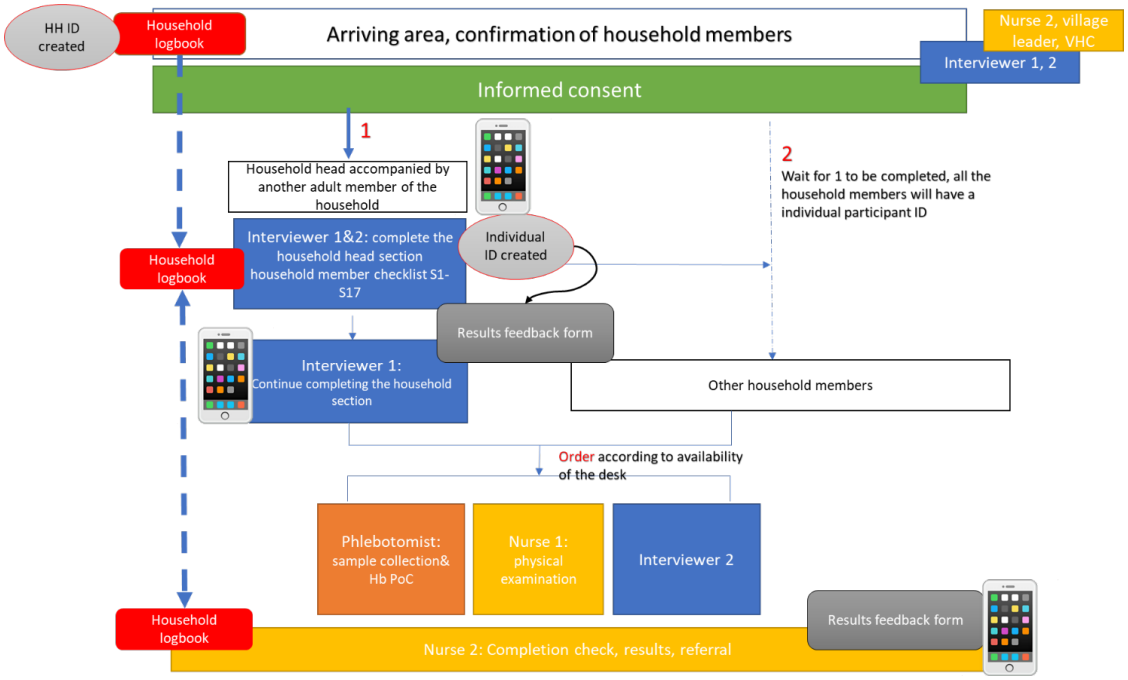


Figure 2.5: Flowchart of data collection setup.
This figure illustrates the recommended human resource allocation at each station, the participant flow, and the necessary documentation or devices required for each stage of data collection. While this setup served as a guideline, modifications were made based on site-specific contexts and insights gained from the pilot phase.Estimated time per participant: household heads 1.52 hours, other adults 11.5 hours, children under 15 years old 3040 minutes. Procedures were conducted simultaneously across stations, so each household typically completed the survey around 2 hours.

household logbook (Figure 2.6, top) and the results feedback form (Figure 2.6, middle) were two essential paper-based supporting documents.

Household logbook

Household logbooks were used at the beginning and end of the data collection procedures to ensure accurate tracking of participant attendance and survey completion.

- At the beginning: upon arrival at the survey location, the names of all the eligible household members were recorded in the logbook. Attendance was marked, and the return of signed informed consent forms was verified and marked.

- At the end (Check-out process): a dedicated study staff oversaw the check-

out process to confirm survey completion. Participant presented their results feedback form , and the staff ensured all assigned procedures were completed.

  - If all the eligible procedures were completed, and the physical examination results were recorded, the staff noted the survey completion in the notebook.
  - If any procedure was incomplete, the staff directed the participant to the appropriate survey station for completion, verified the procedure status with the corresponding station, or recorded the reason for incompletion (i.e. participant refusal).

- Contact information: The logbook also recorded the contact details of the household head and any eligible members who did not attend the survey. This allowed the research team to recontact non-respondents for participation later or arrange additional data collection sessions if necessary.

Results feedback form

The results feedback form was printed double-sided to facilitate survey procedure tracking and result dissemination.

- First side (procedure tracking): this side listed all survey components an individual was eligible to complete. During the household head interview, once basic demographic information of all the eligible members of the households was collected, the eCRF generated a summary of procedures that were to be completed for each eligible member according to their age and sex (Figure 2.6, bottom). The interviewer transcribed the information onto the results feedback form , which was then given to the participants. As participants progressed through each survey station, field staff marked the completion of each procedure, ensuring all necessary components were fulfilled.

- Second side (Result feedback): While all physical examination and haemoglobin test results were recorded in the eCRF, they were also filled out on this side of the form. While participants could retain this form for personal reference, at the end of the data collection, the results on the form were interpreted by the study nurse to the participants (Section 2.3.4).

2.3.2 Community mobilisation

Sensitisation materials

To facilitate awareness and participation, community sensitisation materials, including leaflets and posters, were developed to outline the study design, contents, and expected outcomes. These materials were distributed before or during community mobilisation activities to community members, participants, and health centres or community centres (Figure 2.7). They were used during the engagement sessions and hung at the health centres to explain the survey procedures and encourage participation (Kaehler et al., 2022; Pell et al., 2019).

Community engagement activities

Community mobilisation activities were conducted before data collection and tailored to the local context. Key stakeholders, such as village leaders, local health centre staff, and community health workers, were identified by site collaborators as contact points to facilitate engagement.

The main events involved community engagement meetings to introduce the study, explain its purpose, procedures, and the plan for dissemination results, and pre-household visits or phone calls to confirm appointments with selected households and address any questions or concerns before the scheduled survey day (Figure 2.8). These interactions, supported by local contacts, helped foster trust and cooperation with the survey teams.

Whenever possible, local health workers (e.g. health centre nurses, village health volunteers, or village health workers) were involved in data collection. Their participation, following prior training, facilitated certain survey procedures (e.g. physical

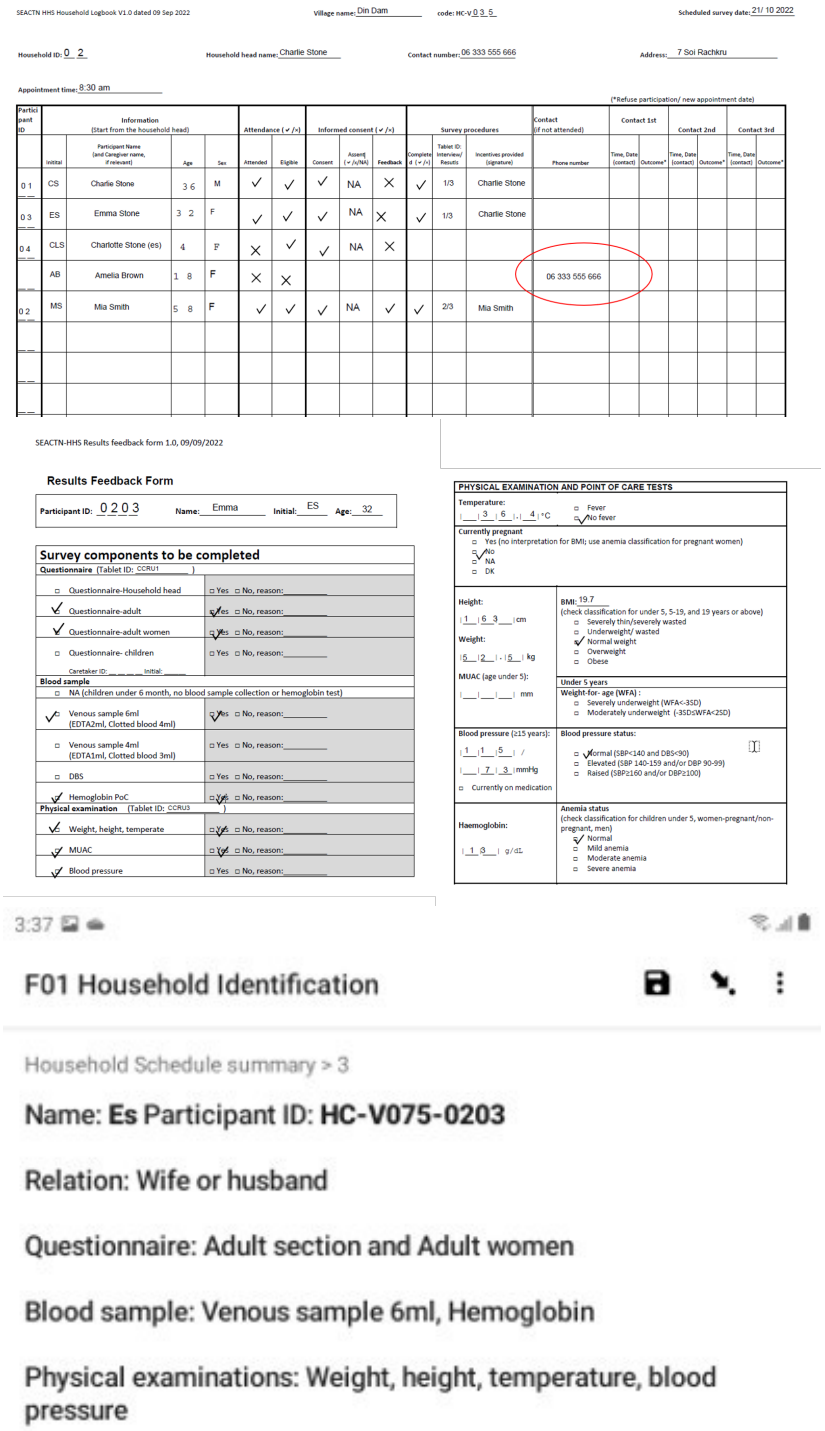


Figure 2.6: The template of the household logbook, results feedback form and eCRF eligibility summary page.
This figure presents the templates used for survey documentation, including the household logbook (top), the results feedback form (middle), and a screenshot of the summary page of eligibilities of survey components to be completed for individual participant from the electronic case report form (eCRF) (bottom). These templates and the eCRF were translated into local languages and adapted for each study site as necessary. All information displayed is dummy data generated for training purposes.

examinations, blood sample collection, and results feedback) and strengthened community trust in the study, ultimately improving participation and data quality.

2.3.3 Implementation pilot

A pilot data collection period of 2-4 weeks was conducted at each site before the official implementation to refine survey procedures and optimise data collection flow. The study coordinator (the doctoral candidate) actively participated throughout this phase. Initially, the data collection followed the original field process flowchart, which was then modified based on insights gained during the pilot phase to improve efficiency (Figure 2.5). The pilot phase objectives included:

- Ensuring adherence to standardised procedures: Field staff were closely supervised by the SEACTN site study coordinator and the doctoral candidate to ensure that all procedures were performed in the manner intended.
- Identifying logistic challenges and optimising the data collection flow: Participant flow and data collection procedures were observed to determine areas for improvement. During the pilot, the data collection schedule was not too intense, allowing time for the team to reflect, discuss and adjust activities for better efficiency.

This iterative process ensured the final implementation was streamlined, practical, and aligned with the study's objectives, minimising disruptions and maximising data quality.

2.3.4 Survey schedule

On the scheduled survey day for each village, stations were set up at a convenient location within or near the village (Figure 2.9). Household members arrived at the survey location according to their appointment time, and those who missed their scheduled slots were contacted and encouraged to participate later on the same day while the research team was still in the village.

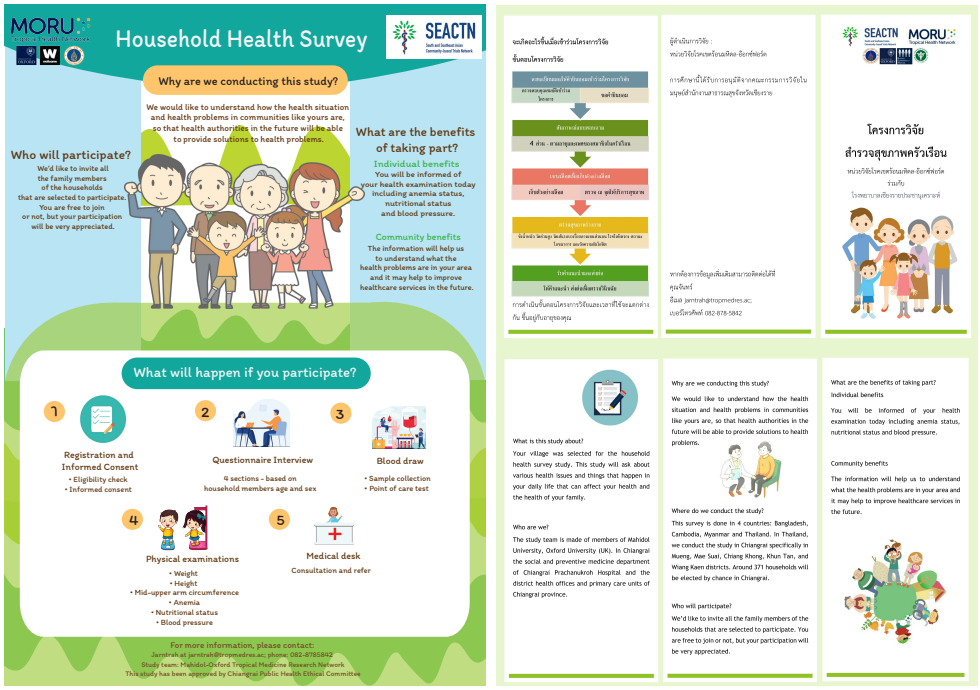


Figure 2.7: Examples of community mobilisation materials.
This figure presents the materials used for community engagement, including a poster (left) and a leaflet (outside: top right; inside: bottom). The poster and the exterior of the leaflet were originally designed in English but were translated into local languages for implementation. For example, the outside of the leaflet was translated into Thai for use in Thailand.

Informed consent

Participants were required to sign the informed consent form before undergoing any study-specific procedures (Appendix B: Protocol, questionnaire, informed consent and assent). The consent form was available in the official local language and was presented by trained study staff verbally explaining the study purpose, procedures and implications of participation. Participants were explicitly informed that participation was voluntary and that they could withdraw at any time (Figure 2.10).

For participants with language barriers, consent was interpreted in dialects. Sufficient time was given for individuals to consider participation and ask questions. Written consent was obtained from all participants or the caretakers for minors in compliance with local legal age regulations. If a participant was unable to write, a thumbprint was accepted as a valid signature. A copy of the signed Informed



Figure 2.8: Photographs of community mobilisation activities.
The images depict community mobilisation efforts conducted before data collection. Research staff, accompanied by village health volunteers or village heads, visited selected households to inform them about the study and encourage participation. These visits took place in Bangladesh (top left), Thailand (top right), and Cambodia (bottom)

Consent document was given to the participant.

In addition, assent was asked from children to enable the minor to understand, to the degree they are capable of, what their participation in the decision-making process would involve. According to local legislation, children 7-17 years in Bangladesh and Cambodia and 7 to 12 years in Thailand (participants aged 13 or older were required to sign informed consent) were required to sign an informed assent form in addition to their guardian's consent.



Figure 2.9: Photographs of field setup during data collection.
This image panel illustrates the field setup in Bangladesh (top) and Cambodia (bottom) during data collection. Adjustments were made based on the specific data collection locations within each village to ensure an efficient workflow

Questionnaire interview

The interview was conducted using electronic data collection tools. The process began with the household head, who provided demographic information on all household members who were eligible for the study. Based on the information, the eCRF automatically generated an eligibility summary page, in combination with the use of the Results Feedback From, guiding them through the necessary survey components (See Section 2.3.1). Questionnaire components and the eligibility were described in Section 2.2.

A question-by-question interview guide was developed for interviewers. Interviewers were trained using this guide, and hard copies were available in the field during data collection. The guide covered:

- General interviewer guidelines, such as making a positive impression, answering any questions from the respondent frankly, and not forming expectations.



Figure 2.10: Photographs of informed consent procedures.
This image panel illustrates the informed consent procedures in Thailand (top), Bangladesh (middle), and Cambodia (bottom). The consent process was first conducted with all eligible household members, followed by individual participants signing the consent form before participating in the survey

- Question-by-question guidance, addressing potential challenges on questions or options that were anticipated to be difficult for the interviewee to understand. It provided additional prompts and suggestions corresponding to anticipated scenarios.

- Showcard, used for certain questions (e.g. drinking water source, sanitation facility type, measurements for alcohol consumption) to aid participants in selecting responses based on images.

Physical examination

The physical examination was done according to participants' age (Figure 2.2, Middle). All participants underwent measurements for weight, height, and tympanic temperature measurements. Children under 5 years also had their mid-upper arm circumference (MUAC) measured with a MUAC tape. Adult household members (15 years and older) underwent blood pressure measurement using an automated sphygmomanometer (OMRON HEM-7121).

Weight was measured with digital scales (SECA 872) with an integrated mother/child function, allowing a child's weight to be measured while being held by an adult. Height measurements were carried out with measuring scales/boards (SECA 213). Children younger than 24 months were measured lying down on the board, while standing height was measured for older children (SECA 210). Tympanic temperature was measured with infrared thermometers (OMRON Ear Thermometer TH839).

All measurements were performed by experienced and trained staff. Consistency and comparability were ensured by using validated devices that were previously used in studies in similar settings and whenever possible, using the same models of devices across study sites.

Blood sample collection and point-of-care haemoglobin test

Blood samples were collected from participants aged six months and older (Figure 2.2, bottom). For participants aged 6 months to under five years, four dried blood spots (DBS) were collected via finger or heel prick. Participants aged five years and older provided venous blood samples, with four millilitres collected from those aged five to under 15 years and six millilitres from participants aged 15 years and older. After blood sample collection, haemoglobin levels were measured using the HemoCue® Hb 301 system (HemoCue®AB, Ängelholm, Sweden) to detect anaemia (Figure 2.11).

The venous blood samples were temporarily stored in cool boxes maintained between 4 °C and 8°C for a maximum of 24 hours before centrifugation in the field

laboratories. Aliquots of whole blood, serum, plasma, and packed red blood cells of these samples were stored at -20°C or below without freeze-thaw until analysis. DBS were air-dried in the laboratory for at least six hours, after which they were placed in a plastic zip-lock bag and stored at room temperature or at 4°C or below.

Information, consultation and referral

Upon completion of procedures, individual results (haemoglobin test and physical examinations) were recorded in the results feedback form (Section 2.3.1). Participants with abnormal results were referred to a study nurse who provided recommendations and further referrals following local guidelines if the participant requested.

Non-responders

During the scheduled day, eligible participants who were absent during their household's appointment time were contacted by the research staff and/ or the household members to encourage their attendance during the day while the research team were still present in the village. The contact information of household members who did not attend was recorded in the household logbook in case future contact was needed. If the entire household was absent, the key community contact person (e.g. village leader, village health worker) facilitated outreach efforts to re-establish contact and encourage participation.

At the end of the first round of data collection, the response rate of village clusters was calculated (Chapter 3). For clusters with a response rate lower than 85%, another round of data collection was organised, where the non-attenders were contacted, and another appointment was arranged that best suited their and the team's schedule. The clusters were primarily grouped by districts, sub-districts, or coverage areas of primary care units. Each cluster consisted of 2 to 18 villages, and this activity targeted only eligible participants who had not taken part in the first round. This represented a relatively small number of individuals per village, which could be reasonably reached by the research team in one day across



Figure 2.11: Photographs of blood sample collection procedures.
This image panel illustrates blood sample collection procedures across sites. Top left: a research staff in Thailand collecting venous blood from an adult participant; top right: a research staff in Cambodia performing a haemoglobin test using a Hemocue machine; bottom: a research staff in Cambodia taking dried-blood-spots from a participant under five years old

all the villages in a cluster. This facilitated the organisation and logistics of the second-round data collection.

2.4 Analysis of blood samples

Sample aliquots and dried blood spots (DBS) were shipped to central laboratories in Bangkok, Thailand, where trained staff conducted all analyses following validated SOPs. Malaria and febrile pathogen testing were performed at MORU laboratories, while hepatitis B, hepatitis C, and NCD tests were processed by an external commercial laboratory. The specific laboratory methods are detailed in subsequent chapters reporting disease prevalence. Below is an overview of the methods.

Malaria

Malaria quantitative polymerase chain reaction (qPCR) was performed for all participants to identify individuals with malaria parasites. The PCR methods typically have a detection level in the range of 100-1000 parasites per millilitre (Alemayehu et al., 2013). Genus-specific qPCR targeting Plasmodium *18S rRNA* genes were performed first to screen for positive individuals, and then species-specific assays were performed to differentiate the parasite species (*P. falciparum*, *P. vivax*, *P. malariae*, *P. ovale*, and *P. knowlesi* (Hofmann et al., 2015; Ngernna et al., 2019; Rosanas-Urgell et al., 2010; Wampfler et al., 2013).

Other pathogens associated with febrile illness

Serology tests for common pathogens causing fever were performed for all participants. Multiplex serology tests based on Luminex xMAP Intelliflex® System were developed and validated for measures of IgG and immunoglobulin M (IgM) of common pathogens causing fever, including Dengue, Chikungunya, Japanese encephalitis, Zika, SARS-CoV-2, *Plasmodium vivax*, *Plasmodium falciparum*, *Orientia tsutsugamushi*, *Rickettsia spp.*, and *Leptospira spp.*

Hepatitis B and C

All participants were tested for HBV surface antigen (HBsAg), and adult participants (15 years or older) were tested for HCV infection. Both tests were performed by chemiluminescence microparticle immunoassay (CMIA) on the Alinity i system (Abbott, United States). Participants with positive anti-HCV were tested for HCV RNA using real-time PCR on Cobas 6800 (Roche Diagnostics, Switzerland).

Non-communicable disease

Participants 15 years or older were tested for diabetes status using haemoglobin A1c by enzymatic methods and lipid profile through total cholesterol by enzymatic methods and high-density lipoprotein cholesterol by accelerator selective detergent method. All tests were performed on Alinity c system (Abbott, United States).

2.4.1 Sample storage

Samples were stored at -80°C at MORU in Bangkok, Thailand, for long-term use or for sending to collaborators outside of Thailand for future ethically approved studies with similar aims, including those involving genetic sequencing of pathogens. This was explained to participants or caretakers of participants during the informed consent process. They were able to refuse permission for use of the samples for future research without affecting their participation in this study.

2.4.2 The rationale for test selection

The rationale for including specific health conditions in the survey was detailed in Chapter 1. However, how the conditions should be measured, particularly the selection of blood tests, was also guided by operational and ethical considerations, including minimising potential harm related to sample collection and prioritising tests based on disease burden and relevance for different population groups, especially among children.

For participants aged 15 years or older, all the tests detailed in previous sections were performed. The tests required a 6ml of venous blood sample.

For children, only selected tests were conducted, and adjustments were made in sample type and volume to minimise discomfort. In consultation with local partners, it was decided:

- Children under 6 months were opted out of blood sampling.
- Children under 5 years underwent finger- or heel-prick blood collection, allowing for DBS sampling. Tests of febrile pathogen serology and HBsAg, given their significant health impact on children and suitability for using DBS samples, were performed.
- Children aged 5-14 years had a 4ml of venous blood sample collected. The restriction in blood volume increased the acceptability of blood draws, while the sample volume still allowed more essential tests- the serology test for febrile pathogens and HBsAg. As this age group have lower risks of non-communicable diseases, these tests were not performed within the restricted sample volume.

Special considerations were given to the hepatitis C test. At the time of protocol development, HCV treatment for children under 12 was not recommended by WHO guidelines at the time (World Health Organization, 2018a). As HCV test results were planned for individual feedback and given the lack of treatment recommendations for younger children, HCV testing was limited to participants aged 15 years or older. This approach was intended to mitigate potential distress for children who might test positive, while no treatment options could be offered.

2.5 Data collection and quality control

All data obtained through questionnaire interviews, physical examinations, and haemoglobin point-of-care tests were collected on tablets using an electronic data collection platform - Open Data Kit (Hartung et al., 2010). The eCRF had built-in validation rules to identify missing or potentially incorrect data. Stringent checks

were applied to variables used to estimate the study outcomes, such as recent fever history, diabetes history, and weight, preventing interviewers from proceeding to the next question if data were missing or outside defined ranges. Daily uploads were performed after each day's data collection whenever stable internet access was available, and the field supervisor cross-checked data completeness against the logbook before final submission.

Study monitoring was done by site supervisors and coordinators, the study coordinator (the doctoral candidate), and the MORU monitoring team. The doctoral candidate and the site team closely monitored the data updates throughout the survey. A real-time data dashboard was developed (Figure 2.12), enabling continuous progress tracking, identification of data discrepancies, and resolution of data issues by the site supervisors and the coordination team.

Additionally, data queries and quality reports were generated every two to four weeks by the doctoral candidate using R program (R Core Team 2024) across eCRFs to verify data accuracy, flag inconsistencies, and assess areas needing additional training and support, ensuring data integrity. Regular meetings were held every two weeks between site supervisors and the doctoral candidate, which provided a platform for issue resolution and process refinement throughout the study.

An external monitoring plan was also developed by the MORU monitoring team, including initial site visits, interim monitoring visits, and closeout visits across all three sites. These visits were accompanied by the doctoral candidates. They facilitated on-site assessments, discussions, and corrective actions, ensuring protocol adherence and data integrity.

2.6 Statistical analysis

A detailed statistical analysis plan (SAP) was developed and can be accessed online (https://figshare.com/s/c65046026bef6cf23f2c). All indicators and their definitions were clarified and categorised as primary or secondary outcomes corresponding to the primary and secondary objectives. All prevalences were

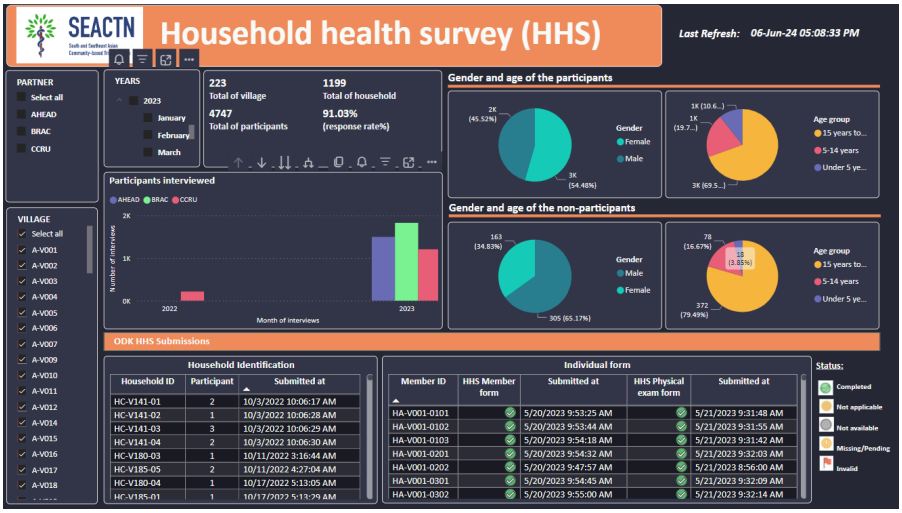


Figure 2.12: Real-time data collection dashboard.
The screenshot displays data collection dashboard, summarising the data collection progress based on data that was uploaded. It describes study participant demographics by age and sex, and the potential data errors. The dashboard was used for monitoring survey progress, ensuring data completeness, and detecting inconsistencies for timely resolution

calculated as the number of participants with that disease, pathogen or disability over the number of the participants who had data for that disease, pathogen, or disability overall for each site.

For each indicator, the numerator and denominator and the data sources were defined (i.e., questions from the interview, laboratory test, or physical examination). Varying across indicators, the most common denominators included the de jure population (the number of household members regardless of their participation), the survey attendees, the adult population (15 years or older), and children under 5 years old. Dummy tables for the main results tables and Directed Acyclic Graphs for analysis exploring the associations among key indicators were also developed. Certain indicators for specific age groups were investigated for risk factors, such as hypertension, overweight, diabetes, and hepatitis B and C. Other stratifications, including sex, severity of illness, or health-seeking behaviour, were also applied for some indicators. The overview of data sources and denominators used for each chapter is described in Figure 2.13.

R statistical software via R studio(R Core Team, 2024; RStudio Team, 2020)

was used for analysis. Results are presented by study country. For descriptive summaries, means and standard deviations (SD) or medians with interquartile range (IQR) for continuous variables and proportions for categorical variables were calculated. Outcomes were presented as an overall estimate by country and with 95% confidence intervals. Comparisons across participants' socio-demographic characteristics were made using the Student's t-test, Mann-Whitney U tests or chi-squared tests, as appropriate. Associations between disease status, risk factors, self-perceived health status, and other characteristics were explored through univariate and multivariable regression models and reported with 95% confidence intervals.

Weighting to account for sampling was not required for analysis due to the multi-stage cluster sampling design. This was because each village was selected with PPS, households were selected with approximately equal probability (i.e., randomly), and all members in a household were selected. Therefore, the overall probability of any person being selected was roughly equal (Department of Economic and Social Affairs, United Nations, 2008; World Health Organization, 2017c).

To minimise potential non-response bias, there were two rounds of data collection and an *a priori* statistical analysis plan for non-response was prepared. Non-responders (who were absent, refused participation, or for other reasons) were summarised by their age, sex, and relationship to the household head and compared with the responding participants to try and determine whether systematic differences existed. The response rate of each country was calculated to identify any study site with a lower than 85% non-response rate and considered for weighting for non-response by village clusters.

Details of the statistical analysis that are specific to each chapter are described in the methods section of the corresponding chapter.

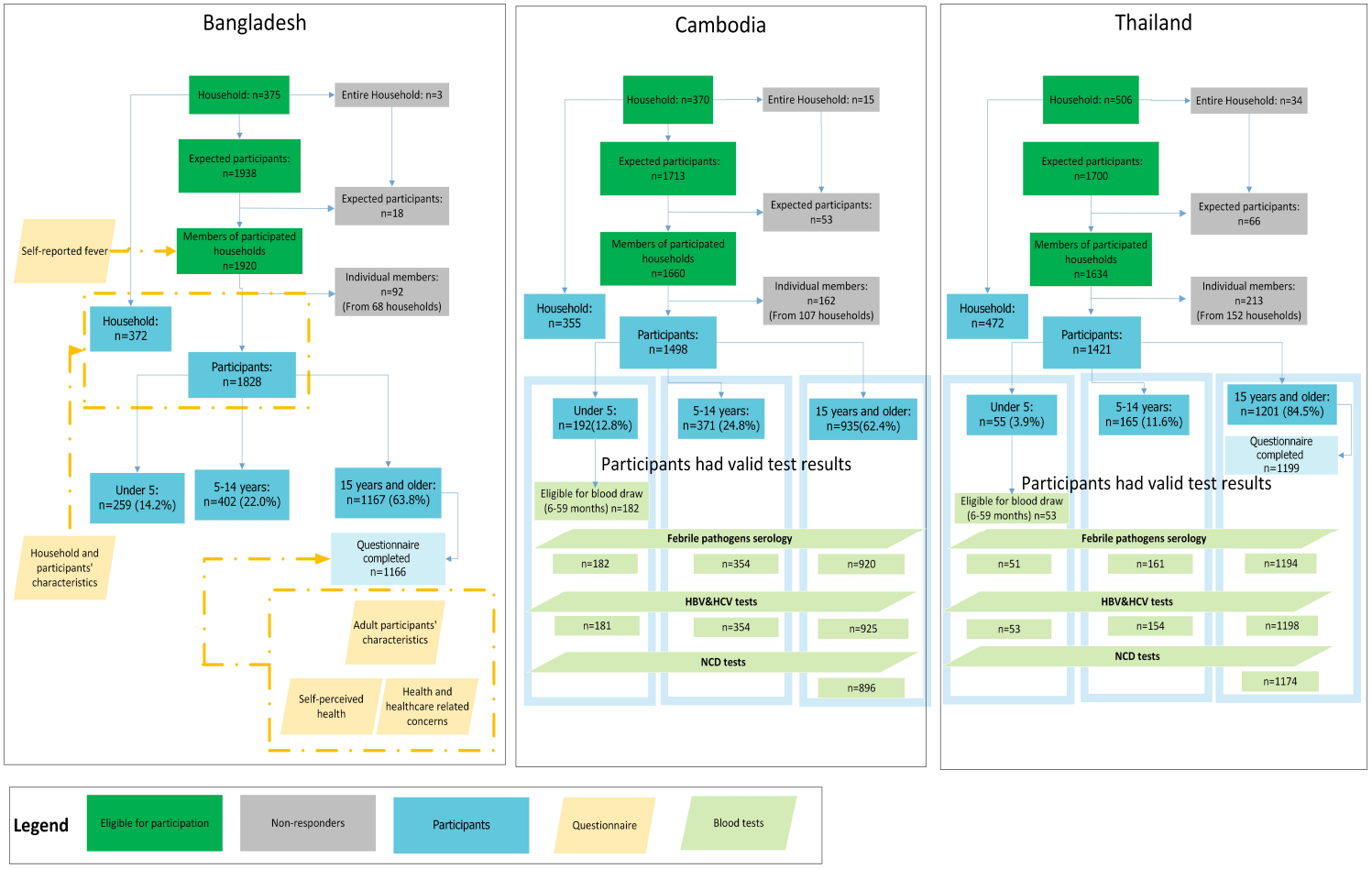


Figure 2.13: Overall participant flow and data sources by country and thesis chapter.
This figure presents the participant flow for Bangladesh, Cambodia, and Thailand, detailing data sources used across thesis chapters. The questionnaire sections analysed in each chapter were consistent across countries, though only indicated for Bangladesh. Laboratory data are described separately for Cambodia and Thailand due to sample variability, while results for Bangladesh were not available at the time of analysis and are therefore not included.

2.7 Ethical considerations

This study protocol was approved by the Oxford Tropical Research Ethics Committee (OxTREC Ref: 6-22), the National Research Ethics Committee of Bangladesh Medical Research Council (BMRC/NREC/2022-2025/69), the Cambodian National Ethics Committee for Health Research (23rd December 2022 NECHR), the Chiang Rai Provincial Public Health Research Ethical Committee (CRPPHO 75/2565).

2.7.1 Compensation

Each participant was provided with compensation for travel expenses and loss of work. The compensation was provided in the form of money, roughly two to five euros. Site partners determined what the appropriate amount was, and it was approved by the local ethical committee.

2.7.2 Confidentiality and privacy

Every effort was made to minimise the risk of disclosure of participants' information. During the survey process, no documents contained participants' names, except for a paper-based household logbook, which contained no survey data. It was kept with the survey staff during data collection and kept in secure storage only accessible to authorised personnel in the office. Participant's initials were used for identifying the participants during the survey procedure, but the initials were not used for analysis. There was no electronic link between the participant ID and their name. Publications, scientific presentations, or dissemination in the community of study findings will be presented without the identities of individual participants.

2.7.3 Results feedback

This study incorporated individual-level results feedback to ensure participants had access to their health information while maintaining ethical considerations that prioritise participant autonomy. In addition to immediate feedback on physical examinations and haemoglobin test results (Section 2.3.4), participants were also

given the option to receive their hepatitis B and C test results after laboratory analysis was completed.

Providing individual test results is important for participants' well-being, but in the study setting and resource-limited context, few tests yield reliable and actionable results within a feasible time frame. Following discussions with the site research teams, we recognised potential barriers to returning results, including logistic challenges, risks of misinterpretation and potential psychosocial distress. Given these considerations, we limited individual feedback to hepatitis B and C test results, as these are chronic infections, therefore results remain relevant even if received six months to one-year post-sample collection. The test results are also clinically meaningful, compared to other serological assays, such as IgG response to febrile pathogens that reflected past infections. Finally and most importantly, treatment to control or cure infections exists and participants could benefit from knowing their status and seeking care. However, we also acknowledged that treatments might not be widely available or accessible in the study countries, especially for rural communities, which could lead to emotional distress upon receiving positive results. For this reason, we found it more appropriate for the participants to decide whether they wanted to receive the test results or not.

During the informed consent process, we explicitly communicated the chronic nature of the infection, the time frame to receive the results and the potential treatment path before the participants decided whether to receive the results.

For participants who opted to receive their results, the following secure and confidential process was implemented:

- Separate identification and results: Participants' identities and test results were stored separately. Requests for the results were recorded in the survey's electronic database, where individuals can only be identified by a survey ID, which was used to link the test results to individual participants. The local research team maintain a separate record of survey IDs and participants' identities.

- Sealed envelope delivery: Once the results were available, they were placed in a sealed envelope labelled only with participant IDs. The local research team, in coordination with the community health worker or the health facilities, facilitated the confidential return of the envelope to the respective participant based on the separate identification list.

This approach ensured confidentiality, minimised risks of disclosure, and respected participants' autonomy in accessing their health information. Details on the results returning in Thailand are in Chapter 8.

2.8 Study documents and materials

The study methods with the study protocol have been published previously (Zhang, Htun, et al., 2024) (Appendix B). All the study-related documents and materials can be accessed from the online database (https://figshare.com/s/c65046026bef6cf23f2c), including:

1. Protocol, questionnaire, informed consent and assent
2. Standard Operational Procedures
    - Field procedures
    - Consent
    - Questionnaire interview (Showcard)
    - Compensation for participation in the survey
    - Laboratory guidelines & standard operating procedures
    - Measurement of height or length
    - Measurement of weight
    - Measurement of mid-upper arm circumference
    - Measurement of blood pressure
    - Measurement of tympanic temperature

- Unanticipated problem
- Protocol deviation

3. SOP training materials

- Study overview
- Field procedure and set-up
- How to complete Informed Consent Form
- Interview guide
- Data collection with Open Data Kit (ODK)
- Measuring body weight with digital scale
- Measuring height and length
- Measuring blood pressure with a sphygmomanometer
- Measuring mid-upper arm circumference with a MUAC tape
- Measuring tympanic temperature using an infrared thermometer
- Sample management, laboratory testing, and processing
- MACRO training (sample log data)

4. Questionnaire pretest

- SOPs
  - General SOP
  - Bangkok pretest Instruction- Internal
  - Chiang Rai Pretest Instruction & training material- Target population
- Pretets summaries
  - Bangkok pretest- Internal
  - Chiang Rai pretest- Target population

5. Statistical analysis plan

2.9 Conclusion

This chapter provided an overview of the survey design, including the study population, sampling strategy, data collection methods, and analytical approaches. Further details relevant to specific components of the study, such as disease-specific laboratory analyses, prevalence estimation, and healthcare access assessments are provided in the following chapters.

3

Participants' characteristics, self-perceived health status, and health-related concerns

Chapter outline

This chapter provided an overview of the demographic and socioeconomic characteristics of rural populations in the study sites in Bangladesh, Cambodia, and Thailand. It demonstrated the health perceptions and health-related concerns in these communities. It begins by describing the study population, including response rate, household characteristics such as wealth status and type of sanitation facility, and individual participant characteristics, including age and sex distribution, education, and work status. This is followed by an analysis of self-perceived health across sites, highlighting significant differences, particularly the higher proportion of individuals reporting less-than-good health in Cambodia. The chapter also identified the most commonly reported health-related concerns, with the cost of care being a key issue in Bangladesh and Cambodia, while a greater proportion of participants in Thailand did not report any concerns. The chapter then discusses the representativeness and the generalisability of the study findings, and the specific context of each study country. It also examines the associations between demographic and socioeconomic characteristics with self-perceived health, as well as health-related concerns in each country.

3. Participants' characteristics, self-perceived health status, and health-related concerns

3.1 Introduction

The rapid development of South and Southeast Asia has improved economic status, living conditions, and health systems, resulting in increased life expectancy across the region (A. Ahmed et al., 2023; Chongsuvivatwong et al., 2011; National Institute of Statistics (NIH) Cambodia et al., 2023; World Health Organization, 2019). Despite these achievements, challenges persist, particularly concerning modifiable health risks and equitable access to healthcare (Alam, 2022; Liverani et al., 2017; Moonpanane et al., 2022). These issues are often more pronounced in rural areas due to known disparities in resource allocation. For example, a large proportion of households still lack basic access to water, sanitation, and hygiene (WASH) facilities, and face barriers to accessing quality health services (A. Ahmed et al., 2023; National Institute of Statistics (NIH) Cambodia et al., 2023); Moreover, the rapid development has created gaps in our understanding of the most updated context in health and healthcare. Geographic variations in population structures, socio-economic conditions, health risk factors, and access to healthcare services across different regions of each country further complicate the picture (Chongsuvivatwong et al., 2011). Addressing these disparities requires locally relevant insights reflecting the diversity of circumstances and challenges to ensure that interventions are tailored to the specific needs of the rural population.

While it is challenging to comprehensively understand all aspects of health and healthcare, self-perceived health status and self-reported health-related concerns, risk factors, and healthcare availability, could be evaluated effectively using questionnaires. Self-perceived health status, though lacking specificity, provides a broad overview of health, and has been shown to correlate with morbidity and mortality thereby serving as a predictor of long-term healthcare needs (Benyamini & Idler, 1999; Idler & Benyamini, 1997; K. Van Ginneken & Groenewold, 2012). Self-reported concerns offer valuable insights into the needs of the community. Incorporating the analysis of the association between socioeconomic backgrounds and these outcomes could further guide the design of targeted solutions.

3. Participants' characteristics, self-perceived health status, and health-related concerns

This chapter aims to provide a comprehensive overview of the study population and their health-related concerns. Specifically, it aims to:

1. Assess the representativeness of the study sample to the coverage area.
2. Describe the household and population characteristics of the study area.
3. Summarise self-perceived health status and major health-related concerns, including risk factors and healthcare service accessibility, availability and quality among the rural population.
4. Analyse the characteristics of participants who report less-than-good health or express specific major concerns compared to those who do not.

This chapter offers an in-depth understanding of the study population and establishes a foundation for the subsequent chapters determining the prevalence of diseases and healthcare utilisation patterns in these communities.

3.2 Methods

Data collection dates and duration varied across sites, starting in Thailand (October 3, 2022- August 22, 2023), followed by Cambodia (April 7, 2023- December 10, 2023) and Bangladesh (April 17, 2023- December 7, 2023).

3.2.1 Household characteristics

Household characteristics were collected through questionnaire interviews with the household head. The ethnicity of household members was determined based on the household head's self-identification. Ethnicity groups with lower frequency were collapsed to ensure the robustness of statistical comparisons, the breakdown of ethnicity is detailed in Appendix C, Table1).

Data on the household facilities was collected, including the type of main drinking water source, cooking fuel, and sanitation facilities. These facilities were then categorised in alignment with the definitions used in the Demographic and

Health Survey (DHS) (Croft, Trevor N., Aileen M. J. Marshall, Courtney K. Allen, et al., 2018). The types of drinking water source and sanitation facilities were then categorised as 'improved', 'other improved', or 'unimproved types'; and cooking fuel was categorised as clean fuel and solid fuel. Details of the facility classified under each category are provided in Table 3.4. In summary, improved and other improved drinking water sources and sanitation facilities were defined as those capable of protecting the water source from contamination and separating human waste from human contact to ensure hygiene. Clean fuels were defined as those producing minimal fine particulate matter and carbon monoxide household emissions, ensuring a cleaner indoor air environment (World Health Organization, 2014a; World Health Organization, 2017a).

3.2.2 Participants characteristics

The usual household members or visitors who slept in the households were invited to join the survey. Regardless of their participation, demographic information, including age, sex, relationship to the household head, and education level for individuals aged 5-14 years, was provided by the household head during the interview. Survey participants were those who provided consent and completed survey procedures.

The de jure population refers to household members reported by the household head as usual members of the household. This population is defined as a group of people who live together, share household arrangements, and acknowledge one adult as the head of the household (Croft, Trevor N., Aileen M. J. Marshall, Courtney K. Allen, et al., 2018). The daily lives of the de jure population are significantly influenced by household characteristics, such as living conditions and socioeconomic factors.

Adult participants (15 years or older) were individually interviewed and provided information on their education level, marital status, and work status in the past 12 months. Work status was categorised as follows:

3. Participants' characteristics, self-perceived health status, and health-related concerns

- Employee: includes government and non-government employee, business owner, business household assistant, and other self-employed.
- Agriculture worker: includes landowner and farmer, agriculture labourer on others' land, and other agriculture work.
- Labourer: includes industrial, day labourer, transport labourer, paid domestic worker, and blacksmith/goldsmith/other skilled labourer.
- Unpaid work: includes student and homemaker/household work.
- Not working: includes retired, unable to work, and unemployed but able to work.

Marital status was categorised as: never or not currently married (including never married, separated, divorced, widowed), currently married or cohabitating, and refused to answer the question.

3.2.3 Socioeconomic status (SES)

The EquityTool, an asset-based wealth index, was used to assess household wealth status as proxies for socioeconomic position (Metrics for Management, 2016, 2022b; Metrics for Management, 2022a). This tool comprises a subset of 7-14 questions derived from the wealth index used in the DHS or Multiple Indicator Survey (MICS), tailored to each study country. The wealth index assigns households a relative wealth value based on a weighted checklist of 20 to 25 easy-to-assess household assets and access to services (Rutstein & Johnson, 2004). The EquityTool generates national wealth quintiles benchmarked to the year when the DHS or MICS data were collected, with strong agreement to the outcomes of the full wealth index (kappa$>$ 0.75%). This tool offers a reliable and efficient method for assessing wealth status, particularly in rural areas of low- and middle-income contries (LMICs) where household income often fluctuates seasonality (Howe et al., 2012). The reduced number of questions of the EquityTool also shortens interview time and improves its practicality.

3. Participants' characteristics, self-perceived health status, and health-related concerns

For this study, the EquityTool was adapted based on the wealth index results from the 2017 DHS for Bangladesh, the 2014 DHS for Cambodia, and the 2019 MICS for Thailand, and the wealth quintile of the household that benchmarked to the year of the survey was used. For the analysis of our study, the quintiles were recategorised into three levels: poor (combining the two lowest quintiles), middle (the middle quintile), and rich (combining the two highest quintiles).

Household wealth status was used alongside other socioeconomic indicators, including marital status, education attainment, and work status, to describe the socioeconomic status (SES) of household members. These indicators have been widely reported in the literature as proxies for SES and are associated with disease prevalence, health-seeking behaviour, and other health-related outcomes (S. M. Ahmed et al., 2000; Allen et al., 2017; Ashour, 2017).

3.2.4 Self-perceived health

Adult participants were asked about their perceptions of overall health and specific domains of health, including ability to carry out work or household activities, mobility, self-care, body ache or pain, concentration, vision, sleeping, and depression. These questions were adapted from the World Health Survey with the descriptions and options detailed below (K. Van Ginneken & Groenewold, 2012).

- Overall health:
  - Response options: Very good, good, moderate, bad, or very bad
  - Question: In general, how would you rate your health today?
- Domains of health:
  - Response options: No difficulty, mild difficulty, moderate difficulty, severe difficulty, or extreme difficulty/cannot do it at all.
  - Questions:

3. Participants' characteristics, self-perceived health status, and health-related concerns

1. Work/ household activities: Overall in the last 30 days, how much difficulty did you have with work or household activities?
2. Mobility: Overall in the last 30 days, how much difficulty did you have with moving around, such as walking or climbing steps
3. Self-care: Overall in the last 30 days, how much difficulty did you have with self-care, such as washing or dressing yourself?
4. Body ache/ pain: Overall in the last 30 days, how much bodily ache or pain did you have?
5. Concentration: Overall in the last 30 days, how much difficulty did you have with concentrating or remembering things?
6. Vision: In the last 30 days, how much difficulty did you have in seeing, even when you wear glasses or contact lenses?
7. Sleeping: Overall in the last 30 days, how much of a problem did you have with sleeping, such as falling asleep, waking up frequently during the night or waking up too early in the morning?
8. Depression: Overall in the last 30 days, how much of a problem did you have with feeling sad, low, or depressed?

Overall health status was further categorised as 'Less-than-good' when participants reported moderate, bad, or very bad overall health status (K. Van Ginneken & Groenewold, 2012). Domains of health were also categorised as 'Having difficulties' when participants reported mild to extreme difficulties (Pattanaphesaj et al., 2018). Disability was defined as participants reporting 'Extreme difficulties or Cannot do it at all' to any of the questions on mobility, self-care, body ache or pain, concentrating, and vision (Mitra et al., 2011).

3.2.5 Health-related concerns

Adult participants were asked six questions regarding health and its determinants, focusing on health services, lifestyle, and physical environment- factors that may represent shared concerns within the community and influence overall community

health (Evans & Stoddart, 1990). These questions explored aspects of health services, including accessibility, availability, quality, and health risk factors related to household and work environment. The definitions of health services-related concerns were based on the WHO Service Availability and Readiness Assessment (World Health Organization, 2015). Household and work-related risk factors were informed by the most commonly reported concerns identified during a questionnaire pretest conducted in Chiang Rai, Thailand (Chapter 2). These aspects, predefined options, and brief definitions are outlined below.

1. Health service accessibility: service is provided somewhere, but you cannot receive it.

    - Affordability: Cost of care
    - Geographic accessibility: challenges in travelling to the service provider, such as long distance, travel time, poor transportation, and health conditions preventing travel.
    - Language barrier: Inability to communicate effectively due to language differences.
    - Cultural barrier: Mismatch between cultural practices and healthcare services.
    - Other, specify
    - No concern

2. Health service availability: service is not provided, or some elements required for providing the service are insufficient or absent

    - Physical presence of service: Services are not provided, or not provided all the time, or at the preferred healthcare facilities, such as no dental care in the primary care unit.
    - Health facility: such as lack of health centres or hospitals

3. Participants' characteristics, self-perceived health status, and health-related concerns

- Health care professionals: insufficient doctors/nurses/paramedical professionals
- Beds or equipment: shortage of essential medical infrastructures
- Medication: medications insufficient or unavailable
- Other, specify
- No concern

3. Health service quality: service is available and accessible but does not meet satisfaction or safety standards.

    - Safety: Care fails to void harm to patients.
    - Timely: excessive waiting time or delays in receiving services
    - Efficient: ineffective use of available resources
    - Other, specify
    - No concern

4. Household-related risks to health: Risk factors within or around the participant's house that could harm their health or others.

    - House: issues related to the house, e.g. the wall, roof, or floor.
    - Amenities: problems with household amenities, such as toilet, cooking stove, mosquito net, drinking water)
    - Animals: health risks posed by animals, e.g. free-range pigs
    - Other, specify
    - No concern

5. Work-related risks to health: Risk factors associated with participants' work environment or the nature of their work.

    - Physical injuries: Risk of accident or injuries.

3. Participants' characteristics, self-perceived health status, and health-related concerns

- Chemical exposures: risks from hazardous substances.
- Exposure to the natural environment: risks such as mosquito bites or snake bites.
- Other, specify
- No concern

6. Other concerns

- Presence of disease or symptoms: illness affecting participants themselves or others
- Other, specify
- No other concerns

The questions were asked with prompts to guide participants (Chapter 2). Participants responded based on their own experiences, those of their families, or their community. Predefined options were not read out aloud to participants, instead, interviewers selected the most appropriate options based on the answers from the participants. If no predefined options were suitable, responses could be recorded as free text. Multiple options could be selected. After completing all questions, participants were asked to identify three concerns among those they reported, reflecting the issues they considered most important concerning health and its determinants.

3.2.6 Non-responders and sample representativeness

Two types of non-responders were considered. Firstly, when the entire households refused participation, the expected number of participants, which was estimated based on available sources of each site (e.g. village household book, registration records) (Section 2.1.2,Chapter 2), were considered as non-responders. Secondly, for households where at least one member participated in the survey, the eligible participants were reported by the household head, and the non-responders were

treated as absentees from the survey among all those who were eligible (with counts updated from the original sampling frame based on the household head's report).

The household response rate was calculated by dividing the number of households that entirely refused participation by the total number of expected households. The participant response rate was calculated by dividing the sum of the expected number of participants from the households that refused participation and the number of absentees (as calculated based on the household head reports) by the total number of eligible participants.

Basic demographic information, including age and sex, and the reasons for the non-participation of the non-responders were collected for the non-responders in the households where at least one member participated. This information was obtained during the interviews with the household head. At the individual level, age and sex distribution were compared between respondents and non-respondents to identify potential selection bias.

To confirm the representativeness of the study sample, the age and sex distribution of study participants were compared with the population distribution of each country. The most recent census data for the rural population was sought as the primary reference. For Cambodia, we identified the 2019 census (National Institute of Statistics, 2022a). For Thailand, the 2010 census was used; however, due to its age- 13 years before the study- additional data from the household and population registration records in the study province of the study data collection year (2023) were obtained to provide a more recent reference (National Statistical Office of Thailand, 2012, 2023). For Bangladesh, rural-specific estimations were unavailable, so the national population distribution from the 2022 census was used (Bangladesh Bureau of Statistics, 2023).

3.2.7 Statistical analysis

Response rates were summarised by site. Chi-square or Fisher's exact test was used to compare participants and non-responders to assess potential selection bias.

3. Participants' characteristics, self-perceived health status, and health-related concerns

Household and participant characteristics, self-perceived health status, and health-related concerns were summarised using frequency and percentages for categorical data, and medians and with interquartile ranges (IQRs), and minimum and maximum values where applicable, for continuous variables.

Associations between the sociodemographic characteristics of adult participants and the less-than-good self-perceived overall health or the major health-related concerns reported in each country were explored using logistic regression, respectively. The demographic and SES variables were those commonly used in previously conducted similar studies, including age groups (15-29, 30-39, 40-49, 50-59, and 60+), sex, ethnicity, household size, relationship to the household head, marital status, education level, work status, and household wealth status (Ir et al., 2010; Mipatrini et al., 2019; Tareque et al., 2015). Ethnicity was not assessed in Cambodia, as 97% of households identified as Khmer- the country's main ethnicity. Univariate analysis was conducted first. Multivariable analysis included variables with a p-value<0.2 from the univariate analysis. Age groups and sex were controlled in the multivariable analysis. Variance inflation factor (VIF) was tested to avoid potential collinearity, ensuring VIF<5 in the multivariable model (Fox & Monette, 1992; N. Shrestha, 2020). The goodness of fit of the multivariable model was checked using Hosmer-Lemeshow test where the p-value was ensured to be bigger than 0.05 (Hosmer & Lemesbow, 1980). The crude odds ratio was reported in Appendix C, Table 5-8. Adjusted odds ratios (aOR), 95% confidence interval (CI), and p-value were reported. A p-value<0.05 was considered significant for all tests.

3.3 Results

3.3.1 Population

Among the 75 selected villages per site, all were surveyed as planned in Bangladesh, while 74 were sampled in Cambodia and Thailand (Appendix C: Table 1). One village in Mueng district, Thailand was excluded due to security considerations. One village in Samlout district, Cambodia was not sampled separately as it had

been administratively dissolved and merged with other villages, which differed from the village list initially obtained. This resulted in a selection of 375 households with an estimated 1930 individuals from Bangladesh, 370 households with 1713 individuals from Cambodia, and 506 households with 1700 individuals from Thailand (Chapter 2. Figure 2.13).

3.3.2 Response rate

The household response rate was 99.2% (n=372) in Bangladesh, 95.9% (n=355) in Cambodia, and 93.3% (n=472) in Thailand (Table 3.1). The participant response rate was 94.3% (n=1828) in Bangladesh, 87.4% (n=1498) in Cambodia, and 83.6% (n=1421) in Thailand. As response rates were above or very close to 85%, the results in this analysis were not weighted, as stated *a priori* in the Statistical Analysis Plan (Chapter 2).

Approximately 16-25% of the non-responders were from households where no member participated (Table 3.1). As a result, no information was available on reasons for non-response, age and sex for these individuals. Among the non-responders from households where at least one member participated, the most commonly cited reason for non-participation was unavailability due to school or work (Bangladesh: 64.1%, n=59; Cambodia: 66.7%, n=108; Thailand: 74.6%, n=159) (Table 3.2). Other, less frequently reported reasons included physical illness (Bangladesh: 1.1%, n=1; Cambodia: 0.6%, n=1; Thailand: 0.5%, n=1) and mental illness (Bangladesh: 5.4%, n=5; Cambodia: 3.7%, n=6; Thailand: 3.3%, n=7). The age, sex, and relationship to the household head of these non-responders were significantly different from those of responders (Table 3.3). Non-responders were mostly those aged 5-49 years (Bangladesh: 85.9%, n=79; Cambodia: 83.3%, n=135; Thailand: 65.7%, n=140), which was consistent with the observation on the common reason for non-participation being unavailable due to work or school.

3. Participants' characteristics, self-perceived health status, and health-related concerns

Table 3.1: Response rate, by site.
The table describes the response rate at both household and individual participant levels and includes information on the number of expected or eligible participants, responders, and non-responders.

	Bangladesh		Cambodia		Thailand	
	HH	**INDIV**	**HH**	**INDIV**	**HH**	**INDIV**
Response rate						
Response rate, %	***99.2***	***94.3***	***95.9***	***87.4***	***93.3***	***83.6***
Expected participation, n	375	1938	370	1713	506	1700
Number of responders, n	372	1828	355	1498	472	1421
Non-responders						
Total non-responders, n	3	110	15	215	34	279
Entire household non-response, n (%)	3	18 (16.4)	15	53 (24.7)	34	66 (23.7)
Members of households non-response, n (%)	68	92 (83.6)	107	162 (75.3)	152	213 (76.3)

Note:
HH: household, INDIV: individual
* In Cambodia and Thailand, only 74 villages were sampled. In Bangladesh and Cambodia, 5 households were selected from each village. In Thailand,7 households were selected from 68 villages, and 5 households were selected from 6 villages
† Non-responders- Entire household non-response: the number of households where no members participated, and the expected number of eligible participants according to available sources
‡ Non-responders- Members of households non-response: the number of households where at least one member participated, but some eligible members did not, and the number of absentees among eligible members as repoted by the household heads.

Table 3.2: Reasons for non-response to the survey.
Data was only collected among the non-respondents who were from households where at least one member participated in the survey.

	Bangladesh N = 92	Cambodia N = 162	Thailand N = 213
Reasons,n (%)			
Not available at the time (work or school)	59 (64.1)	108 (66.7)	159 (74.6)
Physical illness or disability	1 (1.1)	1 (0.6)	1 (0.5)
Mental illness or disability	5 (5.4)	6 (3.7)	7 (3.3)
Other reason	2 (2.2)	1 (0.6)	0 (0.0)
Dont know	25 (27.2)	46 (28.4)	46 (21.6)

Note:
The non-responders from the households where no member participated were not described here (Bangladesh: n=18, Cambodia: n=53, Thailand: n=66)

Table 3.3: Comparison of characteristics between respondents and non-respondents, by site

Characteristics/ Participation	Bangladesh			Cambodia			Thailand		
	No N = 92	Yes N = 1,828	p-value	No N = 162	Yes N = 1,498	p-value	No N = 213	Yes N = 1,421	p-value
Sex			<0.001			<0.001			<0.001
Male	70 (76.1)	811 (44.4)		111 (68.5)	742 (49.5)		123 (57.7)	608 (42.8)	
Female	22 (23.9)	1,017 (55.6)		51 (31.5)	756 (50.5)		90 (42.3)	813 (57.2)	
Age	26 (18,38)	21 (10,39)	0.004	26 (17,37)	25 (9,44)	0.2	30 (14,51)	52 (31,63)	<0.001
Age groups (year)			<0.001			<0.001			<0.001
0-4	3 (3.3)	259 (14.2)		4 (2.5)	192 (12.8)		11 (5.2)	55 (3.9)	
5-14	8 (8.7)	402 (22.0)		23 (14.2)	371 (24.8)		46 (21.6)	165 (11.6)	
15-49	71 (77.2)	920 (50.3)		112 (69.1)	624 (41.7)		94 (44.1)	448 (31.5)	
50+	10 (10.9)	247 (13.5)		23 (14.2)	311 (20.8)		62 (29.1)	753 (53.0)	
Relationship to the household head			<0.001			<0.001			<0.001
Head	0 (0.0)	372 (20.4)		0 (0.0)	355 (23.7)		0 (0.0)	472 (33.2)	
Wife/ husband	22 (23.9)	259 (14.2)		39 (24.1)	259 (17.3)		35 (16.4)	259 (18.2)	
Son/ daughter	49 (53.3)	771 (42.2)		77 (47.5)	525 (35.0)		88 (41.3)	252 (17.7)	
Other	21 (22.8)	426 (23.3)		46 (28.4)	359 (24.0)		90 (42.3)	438 (30.8)	

[1] n (%); Median (Q1,Q3)

[2] Pearson's Chi-squared test; Wilcoxon rank sum test

Note:
Relationship to the household head- Other includes Son-in-law/ daughter-in-law, grandchild, Parent, Parent-in-law, Brother or sister, Other relatives, Adopted/ Foster/ Stepchild, Not related

3.3.3 Household characteristics

In Bangladesh, Cambodia, and Thailand, 372, 355, and 472 households participated in the survey, respectively (Table 3.4). The median household size was 5 in Bangladesh (IQR: 4, 6, Min/ Max: 1/ 19), 4 in Cambodia (IQR: 3,6, Min/ Max: 1/ 13), and 3 in Thailand (IQR: 2, 5, Min/ Max: 1/ 11). The majority of households had 3-5 members (in Bangladesh: 54.8%, Cambodia: 62.8%, Thailand: 46.0%). In Thailand, a high percentage of households had only 1-2 members (38.1%), consisting mostly elderly individuals without children or grandchildren. Among these small households, 80.9% (n=152/188) included only the head and/ or their wife or husband, with a median age of 61 years for both the household head (IQR: 53, 68, Min/Max: 21/84), and their spouse (IQR: 54, 67, Min/Max: 21/84). Almost all Cambodian households were from the country's main ethnic group- Khmer (96.6%). In Bangladesh and Thailand, while the main ethnic groups- Bangali (80.4%) and Thai (57.8%)- were the majority, notable proportions were of minority groups. The most common ethnic minority groups were Marma (12.9%) in Bangladesh, and Akha (11.7%) and Lahu (11.7%) in Thailand (Appendix C. Table 2).

SES, measured by the wealth quintiles, varied between countries. About one-third of the households in each site fell within the middle wealth quintile (Bangladesh: 31.5%, Cambodia: 29.0%, Thailand: 30.5%) (Table 3.4. In Cambodia, a lower proportion of households were from the 'poor' category (14.9%), and a higher proportion were from the 'rich' category (56.1%), compared to the more even distribution observed in Bangladesh and Thailand. In terms of access to resources and facilities, solid fuel was the main cooking fuel for 54.8% of Bangladeshi households, 80.0% of Cambodian households, and 36.9% of Thai households. 'Unimproved' drinking water sources were used among 0.3% of Bangladeshi households, 54.4% of Cambodian households, and 6.6% of Thai households. 'Unimproved' or no sanitation facilities were reported in 35.5% of Bangladeshi households, 22.8% of Cambodian households, and 0.6% Thai households. The breakdown of the 'unimproved' and 'improved' facilities is described in Appendix C. Table 2)

Table 3.4: Households' characteristics, by site

Characteristic	Bangladesh N = 372	Cambodia N = 355	Thailand N = 472
Household size (de jure)			
Median (Q1, Q3)	5 (4, 6)	4 (3, 6)	3 (2, 5)
Min, Max	1, 19	1, 13	1, 11
1-2 persons	34 (9.1)	35 (9.9)	180 (38.1)
3-5 persons	204 (54.8)	223 (62.8)	217 (46.0)
6 or more	134 (36.0)	97 (27.3)	75 (15.9)
Ethnicity			
Bangladesh			
Bengali	299 (80.4)	-	-
Other (Bangladesh)	73 (19.6)	-	-
Cambodia			
Khmer/Cham/other (Cambodia)	-	355 (100.0)	-
Thailand			
Thai	-	-	273 (57.8)
Akha	-	-	55 (11.7)
Lahu	-	-	53 (11.2)
Other (Thailand)	-	-	91 (19.3)
Household wealth status			
Poor	105 (28.2)	53 (14.9)	168 (35.6)
Middle	117 (31.5)	103 (29.0)	144 (30.5)
Rich	150 (40.3)	199 (56.1)	160 (33.9)
Cooking fuel			
Clean	168 (45.2)	71 (20.0)	298 (63.1)
Solid	204 (54.8)	284 (80.0)	174 (36.9)
Drinking water source			
Improved	37 (9.9)	11 (3.1)	72 (15.3)
Other improved	334 (89.8)	151 (42.5)	369 (78.2)
Unimproved	1 (0.3)	193 (54.4)	31 (6.6)
Sanitation facility			
Improved	9 (2.4)	0 (0.0)	263 (55.7)
Other improved	231 (62.1)	274 (77.2)	206 (43.6)
Unimporved	121 (32.5)	18 (5.1)	3 (0.6)

No facility/ open defecation	11 (3.0)	63 (17.7)	0 (0.0)

[1] Household wealth status: category 'Poor' corresponds to the wealth status of the household of the lowest 2 quintiles of the country, 'Middle' corresponds to the middle quintile, and 'Rich' corresponds to the highest 2 quintiles, evaluated by EquityTool (https://www.equitytool.org/about-the-equitytool/).
[2] Cooking fuel: clean fuel include electricity and Liquefied Petroleum; solid fuel include: charcoal and wood
[3] Improved drinking water source includes: Piped into dwelling
[4] Other improved drinking water sources includes: piped water- piped to yard/plot, piped to neighbour, public tap/standpipe, tube well or borehole, protected well, protected spring, rainwater, tanker truck, cart with small tank, bottled water
[5] Unimproved drinking water source includes: unprotected well, surface water (river/ dam/ Lake/ pond/ stream/ canal/ irrigation channel), and other sources
[6] Improved sanitation facility include: flush or pour flush toilet: flush to piped sewer system
[7] Other improved sanitation facility includes: Flush or pour flush toilet: flush to septic tank, flush to pit latrine, flush, don't know where, ventilated improved pit latrine, pit latrine with slab, and composting toilet.
[8] Unimproved sanitation facility includes: Pit latrine without slab/open pit, bucket toilet, and hanging toilet/hanging latrine.

3.3.4 Participants characteristics

A total of 1828, 1498, and 1421 participants were surveyed in Bangladesh, Cambodia, and Thailand, respectively (Table 3.5). Almost all participants were the de jure population of the households (Bangladesh: 99.1%, Cambodia: 100%, Thailand 99.9%). In Bangladesh and Cambodia, the majority of participants were the son or daughter of the household head (Bangladesh: 42.2%, Cambodia: 35%), followed by the household head (Bangladesh: 20.4%, Cambodia: 23.7%) and other relatives (Bangladesh: 23.3%, Cambodia: 24.0%). In Thailand, most participants were the household head (33.2%), followed by other relatives (30.8%), wife or husband of the head (18.2%) and son or daughter (17.7%).

Slightly fewer men participated in the survey across sites (Bangladesh: 44.4%, Cambodia: 49.5%, Thailand: 42.8%). The median age of participants was 21 years in Bangladesh (IQR: 10, 39), 25 years in Cambodia (IQR: 9, 44), and 52 years in Thailand (IQR: 31, 63). Thailand had the highest proportion of participants aged 50 or older (53.0%) compared to Bangladesh (13.5%) and Cambodia (20.8%). In contrast, Thailand had the lowest proportion of children under 5 (3.9%) and those

aged 5-14 years (11.6%), compared to Bangladesh (under 5: 14.2%; 5-14 years: 22.0%) and Cambodian (under 5: 12.8%, 5-14 years: 24.8%).

The age distribution by sex for each country is shown in Figure 3.1. When compared with the most recent census data available, the survey population demonstrated good representation in Bangladesh and Cambodia. However, in Thailand, the survey sample had a higher proportion of participants aged 55 and older, while individuals aged 15 to 55 were underrepresented compared to the rural population distribution obtained from the 2010 census and the 2022 household and population registration of Chiang Rai province.

Table 3.5: Participants' characteristics, by site. Additional characteristics were included for children 5-14 years old and adults 15 years or older.

Characteristics, n (%)	Bangladesh N = 1,828	Cambodia N = 1,498	Thailand N = 1,421
De jure population	1,812 (99.1)	1,498 (100.0)	1,419 (99.9)
Age (years)			
Median (Q1, Q3)	21 (10, 39)	25 (9, 44)	52 (31, 63)
Min, Max	0, 90	0, 92	0, 94
Age group (years)			
0-4	259 (14.2)	192 (12.8)	55 (3.9)
5-14	402 (22.0)	371 (24.8)	165 (11.6)
15-49	920 (50.3)	624 (41.7)	448 (31.5)
50+	247 (13.5)	311 (20.8)	753 (53.0)
Sex-Male	811 (44.4)	742 (49.5)	608 (42.8)
Relationship to the household head			
Head	372 (20.4)	355 (23.7)	472 (33.2)
Wife/ husband	259 (14.2)	259 (17.3)	259 (18.2)
Son/ daughter	771 (42.2)	525 (35.0)	252 (17.7)
Other	426 (23.3)	359 (24.0)	438 (30.8)
Ethnicity			
Bangladesh			
Bengali	1,534 (83.9)	-	-
Other (Bangladesh)	294 (16.1)	-	-
Cambodia			
Khmer/Cham/other (Cambodia)	-	1,498 (100.0)	-
Thailand			
Thai	-	-	758 (53.3)
Akha	-	-	211 (14.8)
Lahu	-	-	153 (10.8)
Other (Thailand)	-	-	299 (21.0)
Household wealth status			
Poor	527 (28.8)	231 (15.4)	493 (34.7)

Table 3.5: Participants' characteristics, by site. Additional characteristics were included for children 5-14 years old and adults 15 years or older. *(continued)*

Characteristics, n (%)	Bangladesh N = 1,828	Cambodia N = 1,498	Thailand N = 1,421
Middle	516 (28.2)	421 (28.1)	428 (30.1)
Rich	785 (42.9)	846 (56.5)	500 (35.2)
Children (5-14 years)	**402 (22.0)**	**371 (24.8)**	**165 (11.6)**
Among children			
Currently attending school	383 (95.3)	355 (95.7)	163 (98.8)
Current level attending			
Early childhood	30 (7.8)	43 (12.1)	28 (17.2)
Primary	268 (70.0)	283 (79.7)	116 (71.2)
Secondary	84 (21.9)	28 (7.9)	19 (11.7)
Higher	1 (0.3)	0 (0.0)	0 (0.0)
Don't know	0 (0.0)	1 (0.3)	0 (0.0)
Highest level attended			
Early childhood	1 (5.3)	0 (0.0)	0 (0.0)
Primary	3 (15.8)	6 (37.5)	0 (0.0)
Secondary	0 (0.0)	0 (0.0)	1 (50.0)
Don't know	15 (78.9)	10 (62.5)	1 (50.0)
Adults (age>=15 years)	**1,167 (63.8)**	**935 (62.4)**	**1,201 (84.5)**
Among adults			
Marital status			
Currently married/cohabitating	838 (71.9)	697 (74.5)	910 (75.9)
Never/not currently married	328 (28.1)	238 (25.5)	288 (24.0)
Refuse to answer	0 (0.0)	0 (0.0)	1 (0.1)
Education level			
Never attended school	395 (33.8)	202 (21.6)	284 (23.6)
Primary school uncompleted	179 (15.3)	337 (36.0)	175 (14.6)
Primary school completed	321 (27.5)	192 (20.5)	340 (28.3)
Secondary school completed/ higher	272 (23.3)	204 (21.8)	402 (33.5)
Work status in the past 12 months			
Agriculture	139 (11.9)	422 (45.1)	734 (61.2)
Labourer	171 (14.7)	110 (11.8)	81 (6.8)
Employee	146 (12.5)	129 (13.8)	122 (10.2)
Unpaid work	653 (56.0)	225 (24.1)	173 (14.4)

3. Participants' characteristics, self-perceived health status, and health-related concerns

Don't work	57 (4.9)	49 (5.2)	89 (7.4)

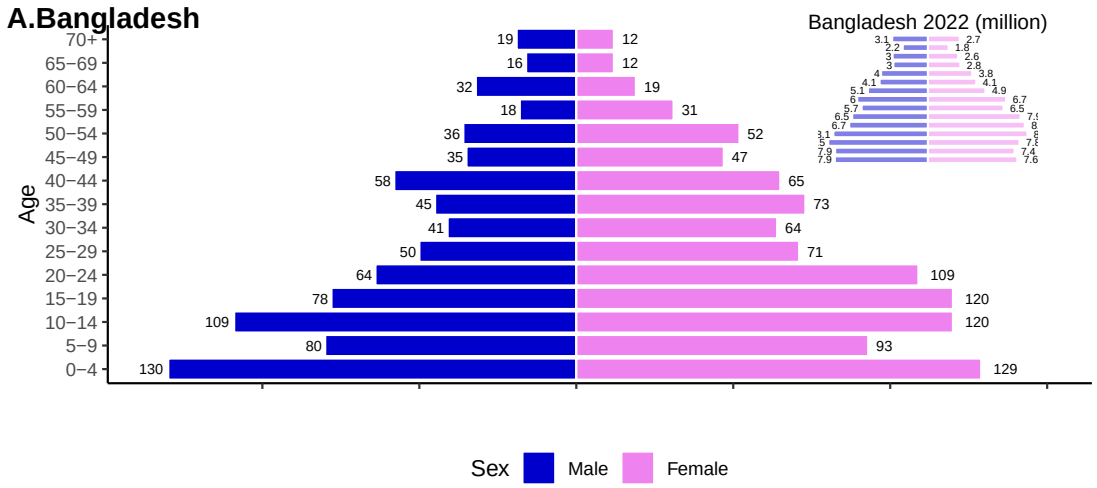
[1] n (%)

Note:
Children (5-14 years): the description of education level was only among the participants of this age group (Bangladesh: n=402, Cambodia: n=371, Thailand: n=165).
Adult (age>=15 years): The characteristics of adult participants are described below were only among the participants of this age group and have completed the questionnaire (Bangladesh: n=1166,Cambodia: n=935, Thailand: n=1199).

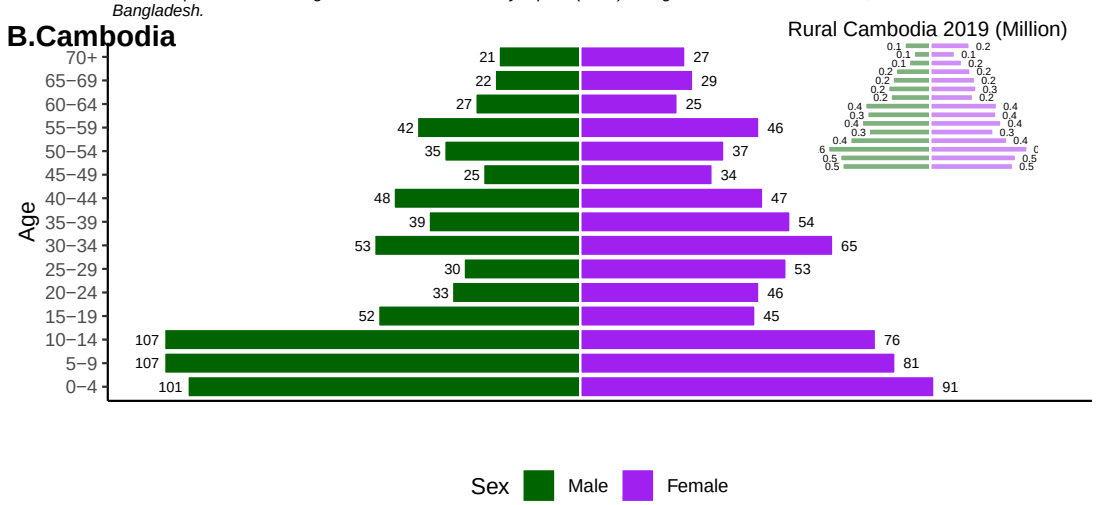
[*] Current level attending: among those who are currently attending school

[†] Highest level attending: among those who are not currently attending School

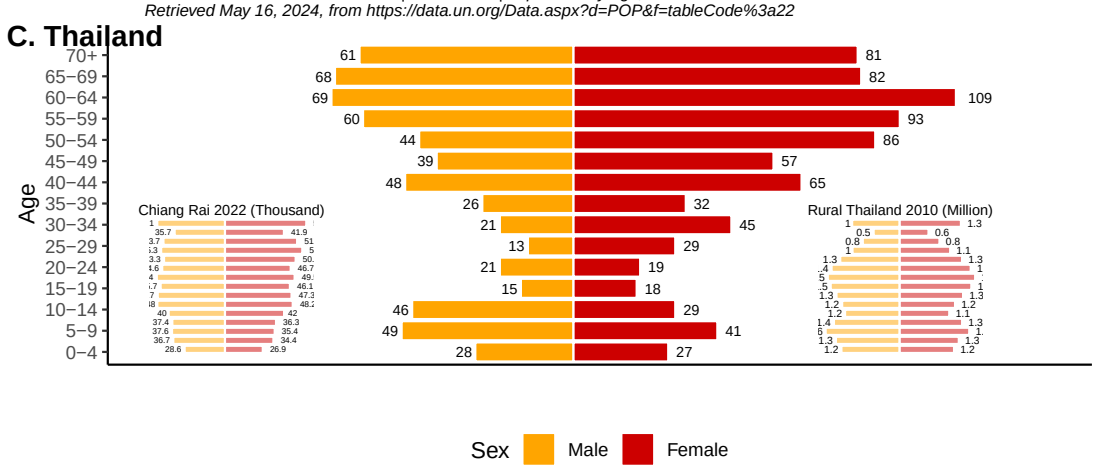
3. Participants' characteristics, self-perceived health status, and health-related concerns



Source:Population & Housing Census 2022: Preliminary report. (2022). Bangladesh Bureau of Statisitcs, Bangladesh.



Source: Rural Cambodia 2019: UNdata | record view | Population by age, sex and urban/rural residence. Retrieved May 16, 2024, from https://data.un.org/Data.aspx?d=POP&f=tableCode%3a22



Source: Rural Thailand 2010: UNdata | record view | Population by age, sex and urban/rural residence.Retrieved May 16, 2024, from https://data.un.org/Data.aspx?d=POP&f=tableCode%3a22;
Chiang Rai province 2020: National Statistical Office of Thailand. (2022). Number of Population from Registration by Age, Sex, Region and Province:2021−2022. Retrieved May 10, 2024, from http://statbbi.nso.go.th/staticreport/page/sector/en/01.aspx

Figure 3.1: Age and sex distribution of the study participants from Bangladesh, Cambodia, and Thailand.
The population distribution from official records of each country was displayed alongside the main figures, the sources are displayed at the bottom of each figure.

(Figure 3.1 legend continued.) A similar age distribution was observed between the study and reference populations in Bangladesh (A) and Cambodia (B), though a gap was observed for children aged 5-9 years old in the Bangladeshi site, and a lower proportion of adults aged 15-49 years old in the Cambodian site. The Thai site (C) displayed a different distribution with a higher proportion of older population compared to the references.

3.3.5 Self-perceived health status and health-related concerns among adult participants

Among adult participants (15 years or older) who completed the questionnaire interview, 1166 were from Bangladesh, 935 from Cambodia, and 1199 from Thailand. The median age of adult participants was 34 (IQR: 22, 45) in Bangladesh, 39 (IQR: 28, 55) in Cambodia, and 55 (IQR: 43, 64) in Thailand (Appendix C Table 3). Similar to the overall participants distribution, fewer adult men participated in the survey (Bangladesh 42.1%, Cambodia: 45.7%, Thailand: 40.5%). The majority of adults were married or cohabitating (Bangladesh: 71.9%, Cambodia:74.5%, Thailand: 75.9%) (Table 3.5). In terms of education level, 33.8% of Bangladeshi, 21.6% of Cambodian, and 23.5% of Thai never attended school. Meanwhile, 23.3% of Bangladeshi, 21.8% of Cambodian, and 33.5% of Thai had completed secondary or higher education. The most common work status was agriculture work in Cambodia (45.5%) and Thailand (61.2%), and in Bangladesh, it was unpaid work (56%). Other characteristics of adult participants, including household-level variables that could be applied to the members of the household (i.e. ethnicity, household wealth status, and household size), and the details of marital status and work status were described in Appendix C, Table 3.

Self-perceived health status

Overall less-than-good health was reported by 78.7% of Cambodian adults, 42.5% of Thai adults, and 18.8% of Bangladeshi adults (Figure 3.2). These included the participants who reported moderate, bad, or very bad overall health status,

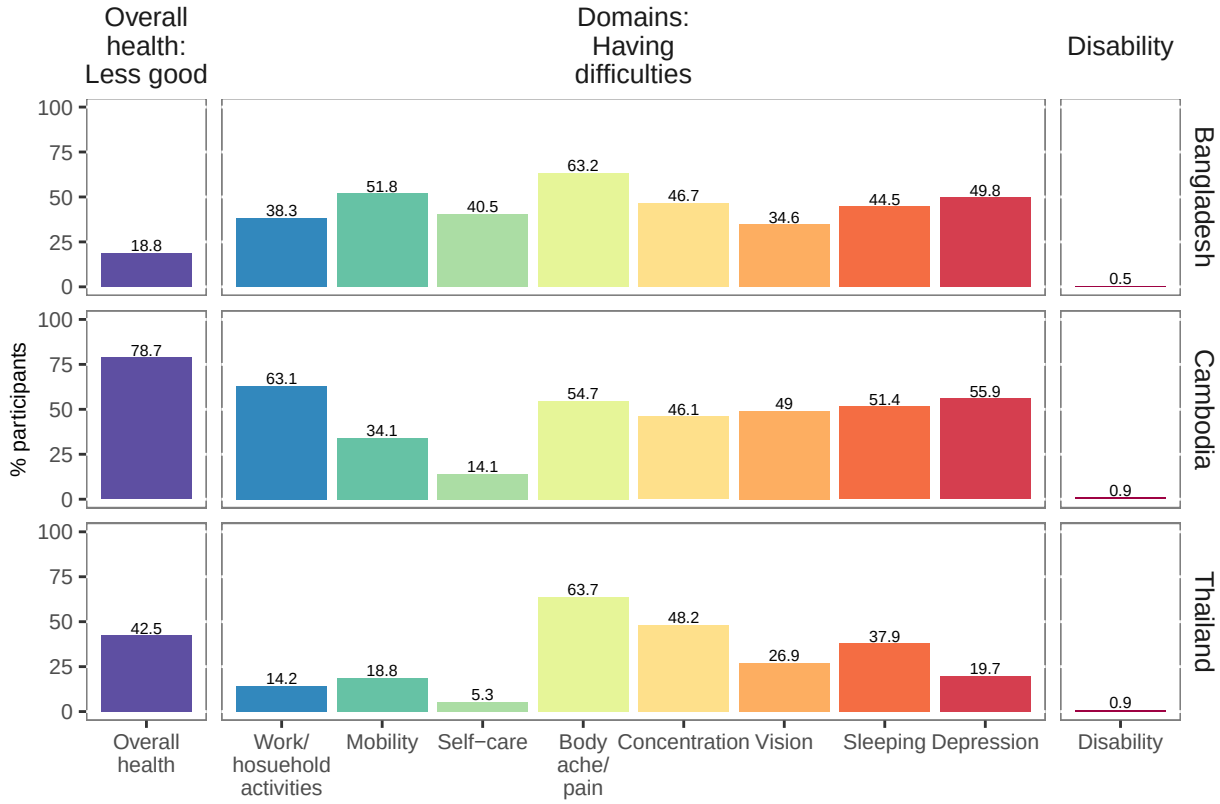


Figure 3.2: Proportions of adult participants reported having less-than-good health status, difficulties of each health domain, and disability.
Health domains include work/ household activities, mobility, self-care, concentration, vision, sleeping, body ache/ pain, and depression. Disability is defined as when individuals report extreme or cannot do any of the following domains: mobility, self-care, concentration, and vision.

with a considerate proportion reporting moderate overall health (Cambodia: 62.5%, Thailand: 40.4%, Bangladesh: 14.7%) (Appendix C, Table 4).

Existing body ache or pain was commonly reported by 63.2% of Bangladeshi adults, 54.7% of Cambodian adults and 63.7% of Thai adults (Figure 3.2). Other widely reported aspects rated with difficulty varied by country. In Bangladesh, these included mobility (51.8%) and concentration (46.7%). In Cambodia, work/ household activities (63.1%) and depression (55.9%) were frequently reported. In Thailand, concentration (48.2%) and sleeping (37.9%) were mostly reported. The details of difficulty levels were described in Appendix C Table 4.

Less-than-good health was significantly associated with increased age across all

countries from the multivariable logistic regression analysis (Table 3.6). Compared to 15-39 years, the odds of having less-than-good health increased progressively with older age groups. In addition, in Bangladesh, individuals working in non-agriculture sectors compared with those working in agriculture (labourer: aOR: 3.8, 95%CI: 1.9, 8.0, had unpaid work: aOR: 3.7, 95%CI: 1.8, 8.0; don't work aOR: 6.1, 95%CI: 2.7, 14) had higher odds of reporting less-than-good health. In Cambodia, characteristics associated with higher odds of reporting less-than-good health include: being women compared to men (aOR: 1.7, 95%CI: 1.1, 2.6), currently married or cohabiting compared to never or not currently married (aOR: 2.7, 95%CI: 1.6, 4.4), being from a household from the 'Rich' quintiles compared to the middle quintile (aOR: 2.0, 95%CI: 1.3, 3.0). In Thailand, those who completed primary school compared to those who completed secondary or higher education (aOR: 1.7, 95%CI: 1.2, 2.4), those who don't work compared to those in agriculture work (aOR: 1.6, 95%CI: 1.0, 2.7) was related to higher OR of reporting less-than-good health. Conversely, belonging to an ethnic minority groups, i.e. Akha (aOR: 0.5, 95%CI: 0.3, 0.9), Lahu (aOR: 0.6 95%CI: 0.3, 0.9) or other ethnic minorities (aOR: 0.7, 95%CI: 0.4, 1.0) compared to Thai was associated with lower odds of reporting less-than-good health.

Table 3.6: Participants' characteristics associated with reporting less good overall health, by site

Variables	Bangladesh			Cambodia			Thailand		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Age groups									
15-29	35 (7.1%)	Reference	–	126 (48.6%)	Reference	–	21 (18.4%)	Reference	–
30-39	37 (16.6%)	2.6 (1.4, 4.7)	0.002	173 (82.0%)	2.7 (1.6, 4.7)	<0.001	37 (29.8%)	2.0 (1.1, 3.9)	0.030
40-49	50 (24.4%)	4.4 (2.3, 8.3)	<0.001	137 (89.0%)	4.3 (2.2, 8.6)	<0.001	68 (32.5%)	1.8 (1.0, 3.3)	0.078
50-59	48 (35.0%)	6.6 (3.4, 13)	<0.001	156 (97.5%)	25 (9.1, 87)	<0.001	142 (50.4%)	3.2 (1.7, 6.2)	<0.001
60+	49 (44.5%)	8.7 (4.2, 19)	<0.001	144 (95.4%)	12 (5.1, 32)	<0.001	241 (51.4%)	3.2 (1.7, 6.4)	<0.001
Sex									
Male	72 (14.7%)	Reference	–	322 (75.4%)	Reference	–	197 (40.6%)	Reference	–
Female	147 (21.8%)	1.3 (0.7, 2.3)	0.4	414 (81.5%)	1.7 (1.1, 2.6)	0.015	312 (43.8%)	1.1 (0.9, 1.5)	0.4
Household size									
1-2 persons	20 (37.0%)	Reference	–	51 (91.1%)		–	149 (52.8%)	Reference	–
3-5 persons	102 (19.2%)	0.6 (0.3, 1.2)	0.12	407 (78.7%)		–	250 (40.5%)	0.8 (0.6, 1.1)	0.12
6 or more	97 (16.7%)	0.5 (0.2, 1.0)	0.050	278 (76.8%)		–	110 (36.9%)	0.7 (0.5, 1.1)	0.10
Relationship to the household head									
Head	88 (23.7%)	Reference	–	313 (88.2%)	Reference	–	208 (44.2%)	Reference	–
Wife/ husband	60 (23.4%)	0.9 (0.6, 1.3)	0.5	229 (89.5%)	1.0 (0.6, 1.8)	>0.9	116 (45.0%)	1.0 (0.7, 1.4)	>0.9
Son/ daughter	22 (7.1%)	0.9 (0.4, 1.7)	0.7	96 (50.8%)	0.8 (0.4, 1.5)	0.5	36 (28.6%)	1.1 (0.6, 1.8)	0.8
Other	49 (21.5%)	1.0 (0.6, 1.6)	>0.9	98 (72.6%)	1.0 (0.5, 1.8)	0.9	149 (43.4%)	1.0 (0.7, 1.4)	>0.9

Table 3.6: Participants' characteristics associated with reporting less good overall health, by site *(continued)*

Variables	Bangladesh			Cambodia			Thailand		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Marital status									
Never/not currently married	55 (16.8%)		–	133 (55.9%)	Reference	–	128 (44.4%)		–
Currently married/cohabitating	164 (19.6%)		–	603 (86.5%)	2.7 (1.6, 4.4)	<0.001	381 (41.9%)		–
Education level									
Secondary school completed/ higher	23 (8.5%)	Reference	–	138 (67.6%)	Reference	–	130 (32.3%)	Reference	–
Never attended school	122 (31.0%)	1.4 (0.8, 2.6)	0.2	188 (93.1%)	1.9 (0.9, 4.1)	0.10	122 (43.4%)	1.4 (0.8, 2.2)	0.2
Primary school uncompleted	32 (17.9%)	1.2 (0.6, 2.3)	0.6	275 (81.6%)	1.2 (0.7, 2.0)	0.5	70 (40.0%)	0.7 (0.5, 1.1)	0.2
Primary school completed	42 (13.1%)	1.2 (0.7, 2.1)	0.6	135 (70.3%)	1.1 (0.6, 1.8)	0.8	187 (55.0%)	1.7 (1.2, 2.4)	0.004
Work status									
Agriculture	15 (10.8%)	Reference	–	339 (80.3%)	Reference	–	303 (41.3%)	Reference	–

Table 3.6: Participants' characteristics associated with reporting less good overall health, by site *(continued)*

Variables	Bangladesh			Cambodia			Thailand		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Labourer	33 (19.3%)	3.8 (1.9, 8.0)	<0.001	85 (77.3%)	1.2 (0.6, 2.2)	0.6	36 (44.4%)	1.1 (0.7, 1.8)	0.7
Employee	10 (6.8%)	1.0 (0.4, 2.3)	>0.9	104 (80.6%)	0.9 (0.5, 1.7)	0.8	50 (41.0%)	1.1 (0.7, 1.7)	0.7
Unpaid work	132 (20.2%)	3.7 (1.8, 8.0)	<0.001	160 (71.1%)	0.6 (0.4, 1.1)	0.090	71 (41.0%)	1.0 (0.7, 1.5)	0.9
Don't work	29 (50.9%)	6.1 (2.7, 14)	<0.001	48 (98.0%)	6.3 (1.1, 120)	0.092	49 (55.1%)	1.6 (1.0, 2.7)	0.047
Wealth status									
Middle	60 (18.1%)		–	186 (73.5%)	Reference	–	146 (40.7%)		–
Poor	57 (17.7%)		–	100 (78.1%)	1.6 (0.9, 3.0)	0.12	158 (40.7%)		–
Rich	102 (19.9%)		–	450 (81.2%)	2.0 (1.3, 3.0)	0.003	205 (45.5%)		–
Ethnicity									
Bengali	186 (19.4%)		–			–			–
Other (Bangladesh)	33 (16.0%)		–			–			–
Thai			–			–	357 (49.8%)	Reference	–
Akha			–			–	44 (29.1%)	0.5 (0.3, 0.9)	0.011
Lahu			–			–	36 (30.8%)	0.6 (0.3, 0.9)	0.023
Other (Thailand)			–			–	72 (33.8%)	0.7 (0.4, 1.0)	0.054

[1] n (%)

Abbreviations: CI = Confidence Interval, OR = Odds Ratio, aOR = Adjusted Odds Ratio, CI = Confidence Interval

Note:
The table shows the frequency of all variables tested, and the adjusted odds ratio and p-value of variables included in the multivariable logistic regression. Only the variables with p-value>0.2 from the univariate analysis were tested in the multivariable model.
Participants who refused to answer the question on marital status were excluded from the analysis (Thailand: n=1).

Health-related concerns

Adult participants were asked to rank their top three health-related concerns from the issues they had prespecified. Table 3.7 shows the frequency of factors ranked as the top concerns. Overall, 38.8% of participants from Thailand did not report any specific concerns, therefore had none to rank. In comparison, the proportion was 2.5% in Bangladesh and 2.1% in Cambodia.

Health service accessibility in terms of cost of care was the most frequently reported top concern in Bangladesh (46.1%) and Cambodia (82.1%). In Bangladesh, this was followed by health risks related to household amenities (41.7%), and health risks related to exposure to the natural environment due to work (36.4%). In Cambodia, it was followed by concerns about the efficiency of health services (66.6%) and their safety (50.4%). In Thailand, the most highly ranked concerns were the timeliness of health service (20.9%), the presence of disease (18.8%), and health risks related to chemical exposure at work (13.0%).

Table 3.7: Major health-related concerns, by site.
Participants selected three concerns from the issues they had pre-specified, reflecting what they considered the most important issues. This table summarises the frequency of each factor selected as one of the most important issues.

Health-related factors	Bangladesh N = 1,166	Cambodia N = 935	Thailand N = 1,199
No specific-concern			
	29 (2.5%)	20 (2.1%)	465 (38.8%)
Health service accessbility			
Cost of care	538 (46.1%)	768 (82.1%)	147 (12.3%)
Geographic accessibility	224 (19.2%)	110 (11.8%)	128 (10.7%)
Language barrier	77 (6.6%)	2 (0.2%)	104 (8.7%)
Culture barrier	2 (0.2%)	0 (0.0%)	3 (0.3%)
Other	0 (0.0%)	4 (0.4%)	13 (1.1%)
Health service availibility			
Presence of service	107 (9.2%)	6 (0.6%)	10 (0.8%)
Health facility	100 (8.6%)	0 (0.0%)	8 (0.7%)
Healthcare professionals	102 (8.7%)	8 (0.9%)	51 (4.3%)
Beds or equipment	2 (0.2%)	10 (1.1%)	22 (1.8%)
Medication	104 (8.9%)	21 (2.2%)	19 (1.6%)
Other	0 (0.0%)	0 (0.0%)	4 (0.3%)
Health service quality			
Safety	47 (4.0%)	471 (50.4%)	16 (1.3%)
Timeliness	270 (23.2%)	42 (4.5%)	251 (20.9%)

Table 3.7: Major health-related concerns, by site.
Participants selected three concerns from the issues they had pre-specified, reflecting what they considered the most important issues. This table summarises the frequency of each factor selected as one of the most important issues. *(continued)*

Health-related factors	Bangladesh N = 1,166	Cambodia N = 935	Thailand N = 1,199
Efficiency	28 (2.4%)	623 (66.6%)	4 (0.3%)
Other	1 (0.1%)	0 (0.0%)	11 (0.9%)
Household-related			
House	139 (11.9%)	1 (0.1%)	11 (0.9%)
Amenities	486 (41.7%)	2 (0.2%)	1 (0.1%)
Animals	44 (3.8%)	0 (0.0%)	18 (1.5%)
Other	0 (0.0%)	31 (3.3%)	10 (0.8%)
Work-related			
Physical injuries	293 (25.1%)	52 (5.6%)	130 (10.8%)
Chemical exposures	22 (1.9%)	222 (23.7%)	156 (13.0%)
Exposure to natural environment	424 (36.4%)	55 (5.9%)	132 (11.0%)
Other	1 (0.1%)	9 (1.0%)	6 (0.5%)
Disease and others			
Presence of disease or symptoms	273 (23.4%)	181 (19.4%)	225 (18.8%)
Other concerns	0 (0.0%)	3 (0.3%)	7 (0.6%)

[1] n (%)

The association between reporting each of these most commonly reported major health-related concerns and participant characteristics was analysed using logistic regression. The frequencies, the aOR and p values are presented in Table 3.8 for Bangladesh, Table 3.9 for Cambodia, and Table 3.10 for Thailand. In general, being female and having characteristics indicative of lower SES, such as a lower education level, being an ethnic minority, or living in a household with poor wealth status- were associated with an increased likelihood of reporting the top concerns. Conversely, individuals of higher SES were less likely to report these concerns. However, exceptions were observed in the associations with SES. In Bangladesh, adults who did not complete primary school, compared to those who had secondary school or higher education, were associated with reduced odds of reporting work-related exposure to the natural environment (aOR: 0.5, 96%CI: 0.3-0.8) (Table 3.8). Similarly, in Thailand, adults who never attended school or did not complete primary school were associated with lower odds of reporting health

service timeliness as a top concern (Never attended school: aOR: 0.6, 96%CI: 0.3-1.0; Primary school uncompleted: aOR: 0.5, 96%CI: 0.3-0.9) (Table 3.10). Additionally, in Bangladesh, adults from households with 'rich' wealth status had increased odds of reporting work-related exposure to the natural environment as a concern (aOR:1.6. 95%CI: 1.2, 2.1).

Country-specific associations were also observed. In Bangladesh, household amenity-related risks were less likely to be reported by the other household members (aOR: 0.5, 95%CI: 0.3, 0.8). In Cambodia, currently married adults were more likely to report all three top concerns (healthcare cost: aOR: 1.7, 95%CI: 1.1, 2.6; healthcare efficacy: aOR: 1.9, 95%CI: 1.3, 2.8; healthcare safety: aOR: 1.8, 95%CI: 1.3, 2.5) (Table 3.9).

Engagement in non-agriculture work showed varying associations with the concerns in Cambodia and Thailand. In Cambodia, adults working as labourers were more likely to report concerns related to healthcare cost (aOR: 2.2, 95%CI: 1.1, 4.7), and employees had higher odds of reporting healthcare safety (aOR:1.6, 95%CI: 1.1, 2.5). In Thailand, employees (aOR: 2.7, 95%CI: 2.6, 4.3) and those who had unpaid work (aOR: 2.7, 95%CI: 1.7, 4.1) had higher odds of reporting the presence of disease as a concern. However, these groups had lower odds of reporting work-related chemical exposure as a concern (employee: aOR: 0.3, 95%CI: 0.1, 0.7; unpaid work: aOR: 0.2, 95%CI: 0, 0.4).

Table 3.8: Participants' characteristics associated with reporting the three most reported major concerns in Bangladesh (i.e. Cost of healthcare, Household amenity-related risk, Work-related exposure to the natural environment)

Variables	Cost of healthcare			Household-related risk: Amenity			Work-related risk: Exposure to nature		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Age groups									
15-29	200 (40.7%)	Reference	–	224 (45.6%)	Reference	–	195 (39.7%)	Reference	–
30-39	106 (47.5%)	1.0 (0.6, 1.4)	0.8	84 (37.7%)	0.7 (0.5, 1.0)	0.085	76 (34.1%)	0.9 (0.6, 1.3)	0.5
40-49	94 (45.9%)	0.8 (0.5, 1.3)	0.4	89 (43.4%)	1.0 (0.6, 1.5)	>0.9	76 (37.1%)	1.0 (0.6, 1.6)	>0.9
50-59	83 (60.6%)	1.6 (1.0, 2.6)	0.078	49 (35.8%)	0.8 (0.5, 1.3)	0.4	38 (27.7%)	0.7 (0.4, 1.1)	0.12
60+	55 (50.0%)	1.0 (0.6, 1.8)	>0.9	40 (36.4%)	1.2 (0.6, 2.1)	0.6	39 (35.5%)	1.0 (0.6, 1.6)	0.9
Sex									
Male	222 (45.2%)	Reference	–	199 (40.5%)	Reference	–	182 (37.1%)	Reference	–
Female	316 (46.8%)	1.6 (1.0, 2.3)	0.031	287 (42.5%)	0.7 (0.5, 1.1)	0.10	242 (35.9%)	1.0 (0.8, 1.3)	>0.9
Ethnicity									
Bengali	447 (46.6%)		–	467 (48.6%)	Reference	–	353 (36.8%)		–
Other (Bangladesh)	91 (44.2%)		–	19 (9.2%)	0.1 (0.1, 0.2)	<0.001	71 (34.5%)		–
Household size									
1-2 persons	23 (42.6%)		–	17 (31.5%)	Reference	–	14 (25.9%)	Reference	–
3-5 persons	246 (46.4%)		–	208 (39.2%)	0.9 (0.4, 1.8)	0.7	192 (36.2%)	1.6 (0.8, 3.1)	0.2
6 or more	269 (46.2%)		–	261 (44.8%)	1.0 (0.5, 2.1)	>0.9	218 (37.5%)	1.5 (0.8, 3.0)	0.2
Relationship to the household head									
Head	193 (51.9%)	Reference	–	165 (44.4%)	Reference	–	139 (37.4%)	Reference	–

Table 3.8: Participants' characteristics associated with reporting the three most reported major concerns in Bangladesh (i.e. Cost of healthcare, Household amenity-related risk, Work-related exposure to the natural environment) *(continued)*

Variables	Cost of healthcare			Household-related risk: Amenity			Work-related risk: Exposure to nature		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Wife/ husband	117 (45.7%)	0.7 (0.5, 1.0)	0.074	97 (37.9%)	0.7 (0.5, 1.0)	0.064	77 (30.1%)	0.7 (0.5, 1.0)	0.047
Son/ daughter	126 (40.6%)	1.0 (0.7, 1.6)	>0.9	144 (46.5%)	0.8 (0.5, 1.2)	0.3	122 (39.4%)	0.8 (0.5, 1.3)	0.4
Other	102 (44.7%)	0.9 (0.6, 1.3)	0.6	80 (35.1%)	0.5 (0.3, 0.8)	0.001	86 (37.7%)	0.8 (0.6, 1.2)	0.4
Marital status									
Never/not currently married	129 (39.3%)	Reference	–	147 (44.8%)		–	128 (39.0%)		–
Currently married/cohabitating	409 (48.8%)	1.3 (1.0, 1.9)	0.087	339 (40.5%)		–	296 (35.3%)		–
Education level									
Secondary school completed/ higher	80 (29.4%)	Reference	–	111 (40.8%)		–	123 (45.2%)	Reference	–
Never attended school	225 (57.1%)	2.2 (1.5, 3.4)	<0.001	160 (40.6%)		–	126 (32.0%)	0.7 (0.5, 1.1)	0.087

Table 3.8: Participants' characteristics associated with reporting the three most reported major concerns in Bangladesh (i.e. Cost of healthcare, Household amenity-related risk, Work-related exposure to the natural environment) *(continued)*

Variables	Cost of healthcare			Household-related risk: Amenity			Work-related risk: Exposure to nature		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Primary school uncompleted	95 (53.1%)	1.9 (1.2, 3.0)	0.004	75 (41.9%)		–	50 (27.9%)	0.5 (0.3, 0.8)	0.005
Primary school completed	138 (43.0%)	1.5 (1.0, 2.2)	0.027	140 (43.6%)		–	125 (38.9%)	0.8 (0.6, 1.2)	0.3
Work status									
Agriculture	79 (56.8%)	Reference	–	36 (25.9%)	Reference	–	53 (38.1%)		–
Labourer	94 (55.0%)	1.1 (0.7, 1.8)	0.7	77 (45.0%)	0.9 (0.5, 1.7)	0.8	56 (32.7%)		–
Employee	53 (36.3%)	0.7 (0.4, 1.1)	0.13	49 (33.6%)	0.7 (0.4, 1.3)	0.3	52 (35.6%)		–
Unpaid work	284 (43.5%)	0.6 (0.4, 1.0)	0.049	302 (46.2%)	1.8 (1.0, 3.3)	0.069	243 (37.2%)		–
Don't work	28 (49.1%)	0.7 (0.4, 1.5)	0.4	22 (38.6%)	0.9 (0.4, 1.9)	0.7	20 (35.1%)		–
Wealth status									
Middle	166 (50.0%)	Reference	–	118 (35.5%)	Reference	–	102 (30.7%)	Reference	–
Poor	183 (56.8%)	1.3 (0.9, 1.8)	0.12	180 (55.9%)	1.6 (1.2, 2.3)	0.005	101 (31.4%)	1.0 (0.7, 1.4)	0.9
Rich	189 (36.9%)	0.7 (0.5, 0.9)	0.015	188 (36.7%)	0.8 (0.6, 1.2)	0.3	221 (43.2%)	1.6 (1.2, 2.1)	0.003

[1] n (%)

Abbreviations: CI = Confidence Interval, OR = Odds Ratio, aOR = Adjusted Odds Ratio, CI = Confidence Interval

Note:

The table shows the frequency of all variables tested, and the adjusted odds ratio and p-value of variables included in the multivariable logistic regression. Only the variables with p-value>0.2 from the univariate analysis were tested in the multivariable model.

Table 3.9: Participants' characteristics associated with reporting the three most reported major concerns in Cambodia (i.e. Cost, safety and efficiency of healthcare)

Variables	Healthcare: Cost			Healthcare: Efficacy			Healthcare: Safety		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Age groups									
15-29	216 (83.4%)	Reference	–	175 (67.6%)	Reference	–	125 (48.3%)	Reference	–
30-39	176 (83.4%)	0.7 (0.4, 1.2)	0.2	143 (67.8%)	0.7 (0.5, 1.1)	0.2	112 (53.1%)	1 (0.6, 1.4)	0.8
40-49	137 (89.0%)	1.1 (0.5, 2.1)	0.9	107 (69.5%)	0.8 (0.5, 1.3)	0.3	74 (48.1%)	0.8 (0.5, 1.2)	0.3
50-59	120 (75.0%)	0.4 (0.2, 0.8)	0.004	103 (64.4%)	0.7 (0.4, 1.1)	0.11	86 (53.8%)	1.1 (0.7, 1.7)	0.8
60+	119 (78.8%)	0.7 (0.4, 1.3)	0.2	95 (62.9%)	0.7 (0.4, 1.1)	0.12	74 (49.0%)	0.9 (0.6, 1.5)	0.7
Sex									
Male	332 (77.8%)	Reference	–	254 (59.5%)	Reference	–	187 (43.8%)	Reference	–
Female	436 (85.8%)	1.9 (1.3, 2.8)	<0.001	369 (72.6%)	1.8 (1.4, 2.5)	<0.001	284 (55.9%)	1.6 (1.2, 2.1)	<0.001
Household size									
1-2 persons	40 (71.4%)	Reference	–	31 (55.4%)	Reference	–	28 (50.0%)		–
3-5 persons	425 (82.2%)	1.7 (0.8, 3.2)	0.13	341 (66.0%)	1.6 (0.9, 2.9)	0.12	257 (49.7%)		–
6 or more	303 (83.7%)	1.8 (0.9, 3.4)	0.11	251 (69.3%)	1.8 (1.0, 3.3)	0.056	186 (51.4%)		–
Relationship to the household head									
Head	288 (81.1%)		–	229 (64.5%)		–	176 (49.6%)		–
Wife/ husband	217 (84.8%)		–	178 (69.5%)		–	140 (54.7%)		–
Son/ daughter	155 (82.0%)		–	122 (64.6%)		–	88 (46.6%)		–

Table 3.9: Participants' characteristics associated with reporting the three most reported major concerns in Cambodia (i.e. Cost, safety and efficiency of healthcare) *(continued)*

Variables	Healthcare: Cost			Healthcare: Efficacy			Healthcare: Safety		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Other	108 (80.0%)		–	94 (69.6%)		–	67 (49.6%)		–
Marital status									
Never/not currently married	184 (77.3%)	Reference	–	138 (58.0%)	Reference	–	98 (41.2%)	Reference	–
Currently married/cohabitating	584 (83.8%)	1.7 (1.1, 2.6)	0.025	485 (69.6%)	1.9 (1.3, 2.8)	<0.001	373 (53.5%)	1.8 (1.3, 2.5)	0.001
Education level									
Secondary school completed/ higher	156 (76.5%)	Reference	–	136 (66.7%)		–	113 (55.4%)	Reference	–
Never attended school	169 (83.7%)	1.5 (0.8, 2.7)	0.2	142 (70.3%)		–	101 (50.0%)	0.8 (0.5, 1.3)	0.4
Primary school uncompleted	286 (84.9%)	1.5 (0.9, 2.4)	0.12	214 (63.5%)		–	167 (49.6%)	0.8 (0.5, 1.2)	0.3
Primary school completed	157 (81.8%)	1.2 (0.7, 2.0)	0.6	131 (68.2%)		–	90 (46.9%)	0.7 (0.5, 1.1)	0.2

Table 3.9: Participants' characteristics associated with reporting the three most reported major concerns in Cambodia (i.e. Cost, safety and efficiency of healthcare) *(continued)*

Variables	Healthcare: Cost			Healthcare: Efficacy			Healthcare: Safety		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Work status									
Agriculture	347 (82.2%)	Reference	–	273 (64.7%)	Reference	–	201 (47.6%)	Reference	–
Labourer	100 (90.9%)	2.2 (1.1, 4.8)	0.027	70 (63.6%)	1.1 (0.7, 1.7)	0.8	45 (40.9%)	0.9 (0.6, 1.3)	0.5
Employee	105 (81.4%)	1.0 (0.6, 1.8)	>0.9	96 (74.4%)	1.5 (1.0, 2.4)	0.063	81 (62.8%)	1.6 (1.1, 2.5)	0.030
Unpaid work	178 (79.1%)	0.7 (0.4, 1.1)	0.15	149 (66.2%)	1.0 (0.7, 1.5)	>0.9	119 (52.9%)	1.2 (0.8, 1.7)	0.4
Don't work	38 (77.6%)	0.8 (0.4, 1.9)	0.6	35 (71.4%)	1.7 (0.8, 3.6)	0.15	25 (51.0%)	1.2 (0.6, 2.4)	0.6
Wealth status									
Middle	204 (80.6%)		–	162 (64.0%)		–	112 (44.3%)	Reference	–
Poor	109 (85.2%)		–	80 (62.5%)		–	65 (50.8%)	1.4 (0.9, 2.2)	0.14
Rich	455 (82.1%)		–	381 (68.8%)		–	294 (53.1%)	1.3 (1.0, 1.8)	0.086

[1] n (%)

Abbreviations: CI = Confidence Interval, OR = Odds Ratio, aOR = Adjusted Odds Ratio, CI = Confidence Interval

Note:

The table shows the frequency of all variables tested, and the adjusted odds ratio and p-value of variables included in the multivariable logistic regression. Only the variables with p-value>0.2 from the univariate analysis were tested in the multivariable model.

Table 3.10: Participants' characteristics associated with reporting the three most reported major concerns in Thailand (i.e.Timeliness of healthcare, presence of disease, and work-related concern to chemical exposure)

	Healthcare: timeliness			Presence of disease			Work-related risk: chemical exposure		
Variables	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Age groups									
15-29	27 (23.7%)	Reference	–	31 (27.2%)	Reference	–	10 (8.8%)	Reference	–
30-39	40 (32.3%)	1.6 (0.9, 3.0)	0.11	29 (23.4%)	1.0 (0.5, 1.9)	>0.9	26 (21.0%)	2.1 (0.9, 4.9)	0.091
40-49	54 (25.8%)	1.6 (0.9, 2.9)	0.2	42 (20.1%)	0.9 (0.5, 1.7)	0.7	38 (18.2%)	1.7 (0.8, 4.0)	0.2
50-59	54 (19.1%)	1.3 (0.7, 2.5)	0.5	49 (17.4%)	0.8 (0.4, 1.5)	0.4	43 (15.2%)	1.6 (0.7, 3.9)	0.3
60+	76 (16.2%)	1.2 (0.6, 2.4)	0.6	74 (15.8%)	0.6 (0.3, 1.3)	0.2	39 (8.3%)	1.0 (0.4, 2.4)	>0.9
Sex									
Male	83 (17.1%)	Reference	–	75 (15.5%)	Reference	–	79 (16.3%)	Reference	–
Female	168 (23.6%)	1.5 (1.1, 2.0)	0.020	150 (21.0%)	1.4 (1.0, 2.0)	0.037	77 (10.8%)	0.7 (0.5, 1.1)	0.11
Household size									
1-2 persons	40 (14.2%)	Reference	–	59 (20.9%)		–	39 (13.8%)		–
3-5 persons	126 (20.4%)	1.2 (0.8, 1.8)	0.4	106 (17.2%)		–	82 (13.3%)		–
6 or more	85 (28.5%)	1.7 (1.0, 2.7)	0.033	60 (20.1%)		–	35 (11.7%)		–
Ethnicity									
Thai	119 (16.6%)	Reference	–	119 (16.6%)	Reference	–	70 (9.8%)	Reference	–
Akha	32 (21.2%)	1.3 (0.7, 2.2)	0.4	31 (20.5%)	1.1 (0.6, 2.0)	0.7	24 (15.9%)	1.3 (0.7, 2.2)	0.4
Lahu	35 (29.9%)	2.5 (1.4, 4.3)	0.001	31 (26.5%)	1.6 (0.9, 2.9)	0.11	17 (14.5%)	1.1 (0.6, 2.1)	0.7
Other (Thailand)	65 (30.5%)	2.1 (1.4, 3.4)	<0.001	44 (20.7%)	1.2 (0.7, 1.9)	0.6	45 (21.1%)	2.0 (1.2, 3.1)	0.005

Table 3.10: Participants' characteristics associated with reporting the three most reported major concerns in Thailand (i.e.Timeliness of healthcare, presence of disease, and work-related concern to chemical exposure) *(continued)*

Variables	Healthcare: timeliness			Presence of disease			Work-related risk: chemical exposure		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Relationship to the household head									
Head	84 (17.8%)	Reference	–	99 (21.0%)	Reference	–	82 (17.4%)	Reference	–
Wife/ husband	51 (19.8%)	1.1 (0.7, 1.7)	0.6	50 (19.4%)	0.9 (0.6, 1.3)	0.5	31 (12.0%)	0.7 (0.4, 1.1)	0.13
Son/ daughter	27 (21.4%)	0.9 (0.5, 1.6)	0.7	32 (25.4%)	0.7 (0.4, 1.3)	0.3	13 (10.3%)	0.7 (0.3, 1.5)	0.4
Other	89 (25.9%)	1.6 (1.1, 2.3)	0.023	44 (12.8%)	0.5 (0.3, 0.7)	<0.001	30 (8.7%)	0.7 (0.4, 1.0)	0.080
Marital status									
Never/not currently married	59 (20.5%)		–	65 (22.6%)	Reference	–	28 (9.7%)	Reference	–
Currently married/cohabitating	192 (21.1%)		–	160 (17.6%)	0.8 (0.6, 1.2)	0.4	128 (14.1%)	1.1 (0.7, 1.9)	0.6
Education level									
Secondary school completed/ higher	105 (26.1%)	Reference	–	84 (20.9%)	Reference	–	53 (13.2%)		–

Table 3.10: Participants' characteristics associated with reporting the three most reported major concerns in Thailand (i.e.Timeliness of healthcare, presence of disease, and work-related concern to chemical exposure) *(continued)*

Variables	Healthcare: timeliness			Presence of disease			Work-related risk: chemical exposure		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value
Never attended school	61 (21.7%)	0.6 (0.3, 1.0)	0.038	57 (20.3%)	1.2 (0.7, 2.1)	0.5	31 (11.0%)		–
Primary school uncompleted	23 (13.1%)	0.5 (0.3, 0.9)	0.017	24 (13.7%)	0.8 (0.5, 1.5)	0.6	28 (16.0%)		–
Primary school completed	62 (18.2%)	0.8 (0.5, 1.1)	0.2	60 (17.6%)	1.1 (0.7, 1.7)	0.7	44 (12.9%)		–
Work status									
Agriculture	148 (20.2%)		–	109 (14.9%)	Reference	–	129 (17.6%)	Reference	–
Labourer	18 (22.2%)		–	13 (16.0%)	1.1 (0.6, 2.1)	0.8	12 (14.8%)	0.9 (0.4, 1.7)	0.8
Employee	29 (23.8%)		–	37 (30.3%)	2.7 (1.6, 4.3)	<0.001	7 (5.7%)	0.3 (0.1, 0.7)	0.009
Unpaid work	34 (19.7%)		–	52 (30.1%)	2.7 (1.7, 4.1)	<0.001	4 (2.3%)	0.2 (0.0, 0.4)	<0.001
Don't work	22 (24.7%)		–	14 (15.7%)	1.4 (0.7, 2.6)	0.4	4 (4.5%)	0.3 (0.1, 0.9)	0.046
Wealth status									
Middle	77 (21.4%)		–	80 (22.3%)	Reference	–	59 (16.4%)	Reference	–
Poor	74 (19.1%)		–	73 (18.8%)	0.7 (0.5, 1.0)	0.086	59 (15.2%)	0.8 (0.5, 1.3)	0.4
Rich	100 (22.2%)		–	72 (16.0%)	0.7 (0.5, 1.0)	0.030	38 (8.4%)	0.5 (0.3, 0.8)	0.006

[1] n (%)

Abbreviations: CI = Confidence Interval, OR = Odds Ratio, aOR = Adjusted Odds Ratio, CI = Confidence Interval

Table 3.10: Participants' characteristics associated with reporting the three most reported major concerns in Thailand (i.e.Timeliness of healthcare, presence of disease, and work-related concern to chemical exposure) *(continued)*

Variables	Healthcare: timeliness			Presence of disease			Work-related risk: chemical exposure		
	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value	Freq	aOR (95% CI)	p-value

Note:
The table shows the frequency of all variables tested, and the adjusted odds ratio and p-value of variables included in the multivariable logistic regression. Only the variables with p-value>0.2 from the univariate analysis were tested in the multivariable model.
Participants who refused to answer the question on marital status were excluded from the analysis (n=1).

3.4 Discussion

Our study is representative of the study sites situated in the rural areas of South and Southeast Asia. The findings suggested restricted socioeconomic development in these areas, although varying across sites, reflected by big proportions of illiterate adults and the lack of access to improved water and sanitation facilities. This study also highlighted distinct characteristics of each site, such as older age structure in Thailand, and the absence of ethnic minority groups in Cambodia. Variations in perceptions of health and concerns related to health, healthcare, and risk factors were identified across countries. In Cambodia, almost 80% of adults reported less-than-good health, compared to about 40% in Thailand and 20% in Bangladesh, while the existence of body ache or pain was commonly reported across all countries. Regarding health-related concerns, almost 40% of adults in Thailand did not report any concerns, contrasting with about 2% in Bangladesh and Cambodia. In both countries, the cost of care was among the most reported concerns. The findings presented in this chapter provide essential context for interpreting disease prevalence results discussed in subsequent chapters (Chapters 4-6) and serve as a foundation for designing targeted interventions that address the specific needs of these communities.

3.4.1 Study representativeness

*The high response rate—approximately 85% across all study sites—provides assurance that our study samples were generalisable to the population of each study coverage area. This was supported by the use of a two-stage cluster sampling strategy, which was designed to ensure site-representative samples. The age-sex distribution of our survey population was broadly consistent with that of national rural reference data, selecting specifically the census data for rural regions where available Figure (3.1). While some differences were observed, these were expected due to contextual factors, including outdated reference data and internal migration patterns. Where possible, these considerations have been factored into the

interpretation of the findings. The distributions from Bangladesh and Cambodia were particularly similar to our study sample. It could be explained by the use of the most recent rural population census of Cambodia from 2019, which is closely aligned with our study year and the context (National Institute of Statistics, 2022a). Although the rural estimate from the 2022 Bangladesh census was not available, the demonstrated similarities between the rural and urban populations in the 2018 DHS supported the validity of the alignment (Bangladesh Bureau of Statistics, 2023; Population Research et al., 2020).

The distribution of age by sex indicated that our study samples were generalisable to the population of each study coverage area. This was supported by the high response rate—approximately 85% across all study sites—and the use of a two-stage cluster sampling strategy designed to ensure site-representative samples. The age-sex distribution of our survey population was broadly consistent with that of national rural reference data, selecting specifically the census data for rural regions where available (Figure 3.1). While some differences were observed, these were expected due to contextual factors, including outdated reference data and internal migration patterns. These considerations were factored into the interpretation of the findings. The distributions from Bangladesh and Cambodia were particularly similar to our study sample. It could be explained by the use of the most recent rural population census of Cambodia from 2019 which is closely aligned with our study year and the context (National Institute of Statistics, 2022a). Although the rural estimate from the 2022 Bangladesh census was not available, the demonstrated similarities between the rural and urban populations in the 2018 DHS supported the validity of the alignment (Bangladesh Bureau of Statistics, 2023; Population Research et al., 2020). However, a gap was noted for children aged 5- 9 years in our study population compared to national distributions. This may reflect differences in the age and sex structure of the study population relative to the national rural profile, or underrepresentation of this age group in the study sample. However, given the high response rate and site-representative sampling strategy, this is unlikely to substantially affect overall prevalence estimates, as this age group

represents a relatively small proportion of the total population. In Thailand, our study sample showed a higher proportion of older adults and fewer participants aged 15-55 years old compared with the rural census from 2010 and the household registration records of Chiang Rai province from 2022 (National Statistical Office of Thailand, 2012, 2023). Given Thailand's growing ageing population, the 2010 rural census might no longer reflect the current population structure (Moroz et al., 2022). However, the larger proportion of the population aged 30-54 years in the 2010 census corresponds to a higher proportion of individuals aged 55 and older in our study and the household registration data from more than a decade later. Discrepancies between the household registration data and our study data may be explained by the expected 30% differences between the actual households and the household registration records, and the internal migration of the working-age population to urban centres, leaving older adults in rural areas (Attavanich et al., 2019; Borompichaichatkul, 2021). Overall, the agreements between our study population and the rural population supports the representativeness of our findings within the study coverage areas, and potentially a broader rural population within each country.

3.4.2 Characteristics of the study sites

These rural areas were resource-limited, as reflected in restricted access to safe water, sanitation and hygiene (WASH), although variations exist across sites. While more than 90% of Thai households had access to 'improved' drinking water sources and sanitation facilities, more than half of Cambodian households did not have 'improved' drinking water sources and about 20% did not have any sanitation facilities. Similarly, in Bangladesh, nearly 30% of households did not have access to 'improved' sanitation facilities. Unsafe drinking water and inadequate sanitation facilities were associated with a substantial burden of diseases, particularly diarrhoeal diseases among children under 5 (Amebelu et al., 2021). In these study countries, an estimated 28-35% of the under 5 deaths were attributable to diarrhoeal disease due to inadequate WASH (World Health Organization, 2023). Unsafe WASH services

could also contribute to other infectious diseases and their sequelae, and exposure to toxic chemicals. All of which could further strain healthcare services (Landrigan et al., 2018; Prüss-Ustün et al., 2019). To address the current burden of diarrhoeal disease and reduce the burden of health services, continuous efforts are required to ensure widespread accessibility of adequate WASH.

The demographic and SES variables used in our study, such as ethnicity, adult participants' education level, and work status, are widely used in health research (Aekplakorn et al., 2018; Allen et al., 2017; Islam et al., 2023; Lynch et al., 2021). These characteristics reflected the unique context of each site. Ethnic composition varied significantly across study sites. In Cambodia, the study population was predominantly Khmer, the ethnic majority of the country, in contrast to 20% of the Bangladeshi study population and 40% Thai study population comprised ethnic minority groups distinct from the Bengali and Thai ethnic majorities. These minority groups often have their own languages, cultures, or religions and experience disparity in health outcomes and healthcare access (Apidechkul et al., 2016; Masud Ahmed, 2001; Moonpanane et al., 2022; Zakaria et al., 2021). Education attainment is a key social determinant of health. Lower levels of education are usually associated with poor health outcomes and shorter life expectancy (Raghupathi & Raghupathi, 2020). While the mechanisms of this association are complex and not yet fully understood, several factors may contribute. Limited education could restrict access to resources, reduce opportunities to adopt healthy behaviours, and increase vulnerability to adverse environments such as neighbourhoods and unsafe work environments. Across the study site, approximately 20-30% of adults reported never attending school. It highlighted a substantial gap in educational attainment which could affect health outcomes and healthcare access across the study population. Work status showed additional variations. Agriculture was the main work status in Cambodia and Thailand, while homemaking or household work predominated in Bangladesh.

The definition of "rural" may vary across countries. In this study, all sites were selected by local partners to represent predominantly rural, remote, and

underserved communities. The demographic and SES variables presented in this chapter provided a nuanced understanding of the study context, which is critical for interpreting disease prevalence findings discussed in later chapters. Given the contextual differences between sites, the results of the subsequent chapters are presented separately by site to reflect local realities. They also highlight the importance of exercising caution when making direct comparisons across sites, as results should be interpreted within the specific context of each country.

3.4.3 Self-perceived health and associated factors

Our study addressed a gap in understanding self-perceived health among the general population in the region, where a few studies have been conducted, and most have focused on older adults (Zhang, Kozlowski, et al., 2024). In rural areas, limited healthcare access often results in underdiagnosis of diseases. Self-perceived health can be an efficient tool for gathering data that can serve as an indicator of health, and predict morbidity, mortality, and healthcare needs (Benyamini & Idler, 1999; Guidet et al., 2020; Idler & Benyamini, 1997; Makovski et al., 2019). For example, body ache and pain were commonly reported across countries, aligning with the high burden of musculoskeletal disorders, particularly lower back pain, as reported in the Global Burden of Disease Study (Global Burden of Disease Collaborative Network, 2022; Zhang, Kozlowski, et al., 2024). Additionally, in Cambodia, almost 80% of adults reported less-than-good health, a much higher proportion compared to 20% in Bangladesh and 40% in Thailand. These differences may reflect variations in disease burden and healthcare accessibility. The perception of health was also associated with participants' characteristics. Across countries, older age was consistently associated with less-than-good health, aligning with findings from previous studies (Janssen et al., 2019; Pattanaphesaj et al., 2018). Our study did not observe a consistent association between SES and self-rated overall health. Factors associated with increased odds of reporting less-than-good health included participants from households with 'rich' wealth status in Cambodia and those engaged in non-agriculture work in both Bangladesh and Thailand.

Conversely, in Thailand, ethnic minority groups were associated with decreased odds of reporting less-than-good health. These findings may reflect the differences in how SES interacts with health perceptions in the specific context of our study areas. Previous studies suggested that the perceptions of health can be influenced by complex dynamics of factors, including health systems, living standards, and culture, which can vary significantly across countries (Janssen et al., 2019; Tseng et al., 2003). Overall, these findings highlighted the complexity of country-specific context in shaping health perceptions. They could be useful references for future studies in the study area to assess the impact of specific conditions or shifts in health perceptions over time.

3.4.4 Health-related concerns

The likelihood of reporting health concerns varied across countries, potentially reflecting differences in universal healthcare coverage (UHC). Thailand introduced their UHC program in 2002, commonly referred to as the "30-baht scheme", which originally required a small copayment and has since evolved to remove copayment and expand coverage (Tangcharoensathien et al., 2018). By 2019, Thailand has achieved 85% UHC and 12.1% out-of-pocket expenditure, contrast sharply with Bangladesh and Cambodia, where UHC is approximately 50% with 70-95% out-of-pocket expenditure (Tangcharoensathien et al., 2018; World Health Organization. Regional Office for South-East Asia, 2019b; World Health Organization. Regional Office for South-East Asia, 2019a; World Health Organization. Regional Office for the Western Pacific, 2018). Higher UHC could reduce financial barriers to accessing essential healthcare services, promoting early diagnosis and intervention (Kaikeaw et al., 2023; Sen, 2015). This disparity is reflected in our findings that in Thailand 40% of adult participants report no concerns, compared to just 2% in Bangladesh and Cambodia. Moreover, the cost of healthcare was one of the most frequently reported concerns in Bangladesh (46.1%) and Cambodia (82.1%). The association between higher household wealth and decreased odds of reporting concerns about cost of care further highlights inequities in healthcare access in the absence of robust

UHC (Kolesar et al., 2020). These findings indicated the importance of expanding UHC for financial risk protection and equitable healthcare service access.

SES is closely linked to health-related concerns, reflecting the disparities in healthcare access and individuals' ability to recognise health risks. In our study, in general, lower SES is associated with increased odds of reporting the top concerns within each country. For example, participants from 'poor' households in Bangladesh were more likely to report house amenity-related health risks, and ethnic minorities in Thailand were more likely to report concerns about the timeliness of healthcare services and work-related risk of chemical exposure. These findings are consistent with the literature on health and healthcare access disparities among people with lower SES (Apidechkul et al., 2016; Kaikeaw et al., 2023; Razzaque et al., 2010). However, some exceptions were observed. For instance, in Bangladesh, adults with lower education attainment were less likely to report risks from exposure to the natural environment due to work, and in Thailand, they were less likely to report concerns about the timeliness of healthcare services. Lower education level may be associated with lower health literacy, which can reduce the ability to assess healthcare quality and recognise potential health hazards (Nutbeam, 1986; Stormacq et al., 2019). Given the generally low education attainment in our study population, implementing health promotion and education initiatives for rural populations could empower individuals to better understand and address health risks, and may enable them to make informed decisions in health and healthcare (Paakkari & Okan, 2020; Pantoja et al., 2017).

The likelihood of reporting concerns was also associated with broader social determinants of health, including sex, marital status, household roles, and work status. Women were significantly more likely to report various concerns across countries, consistent with previous research highlighting women's greater health consciousness and less power in health-related decision-making shaped by sociocultural norms (Hiller et al., 2017; Neyhouser et al., 2018). In Cambodia, married adults were more likely to report all commonly reported top concerns- cost, safety and efficacy of healthcare services. This aligns with previous studies linking marital

status with more proactive health-seeking behaviour and reduced risk of mortality (Leung et al., 2022; Umberson, 1992; Verbrugge, 1979). In Bangladesh household amenity-related concerns were less likely to be reported by sons or daughters of the household head, likely reflecting the greater responsibility of the household heads regarding domestic issues. Work status also played a role in shaping these concerns. In Thailand, non-agriculture workers were less likely to report risks of chemical exposure, likely due to the high pesticide exposure associated with agriculture work (Laohaudomchok et al., 2020). Meanwhile, in Cambodia, non-agriculture workers were more likely to report concerns about healthcare cost and safety. This may reflect their comparatively higher socioeconomic status, as non-agriculture workers generally have higher incomes than those working in agriculture sectors (National Institute of Statistics, 2022b). These patterns might also arise from other contextual factors, such as variations in health insurance schemes and education. While our study could not fully explore these complex relationships, future quantitative research could provide a deeper understanding of how these social determinants shape health concerns.

In Cambodia, beyond concerns about the cost of care, the most commonly reported issues were related to the quality of healthcare, specifically efficacy and safety. These concerns reflect participants' perception that healthcare services might not deliver optimal outcomes within the available resources or might even pose potential harm. These findings are consistent with existing literature suggesting universal issues in accessing quality health services, including insufficient knowledge and efforts among healthcare providers, unreliable laboratory results, and substandard medicines (Gryseels et al., 2019; Han et al., 2022; Liverani et al., 2017). Addressing these issues is critical for improving healthcare quality in rural Cambodia. It will not only enhance treatment outcomes but also help to rebuild public trust in the health system, encouraging timely and appropriate care-seeking behaviour.

3.4.5 Limitations

Our study had several limitations. First, we were not able to obtain the demographic characteristics of the non-responders from households where no one participated in the survey. Among the non-responders for whom we had data, significant differences in age, sex and relationship to the household head were observed compared to the responders, suggesting potential non-response bias. However, the generalisability of the survey samples remains robust. The high response rate - nearly 85% across all sites - likely mitigates the risk of selection bias. Meanwhile, the overall age and sex distributions of our study sample aligned with the recent rural estimates of each study country. Our study findings are representative of each study site, and potentially to broader rural areas of the study countries.

Several household characteristics, such as household wealth status and ethnicity, were assigned to all individuals recruited from the household, including both usual members and visitors. While these characteristics typically reflect the common characteristics of the usual members, they may be less relevant to visitors. However, since more than 99% of the participants were de jure population- comprised of the usual members of the selected households, the potential impact on the results is minimal.

The wealth status of the households that participated in our study was distributed towards the higher national quintiles evaluated by EquityTool, particularly in Bangladesh and Cambodia. This might be due to the significant time lapse- six years for Bangladesh and nine years for Cambodia- between the DHS used to construct the EquityTool and the data collection time of our survey. While the questions in the EquityTool elicited durable asset ownership and household characteristics, the rapid economic development in these countries likely contributed to the under-representation of lower wealth quintiles and over-representation of higher wealth quintiles in our sample (National Institute of Statistics (NIH) Cambodia et al., 2023). To cope with the shifting wealth status towards the richer quintiles, we have combined the two lowest quintiles and the two highest quintiles in the analysis.

This adjustment reduced the impact of sparse data in individual quintiles, so that the results were more reflective of broader economic trends by mitigating the over and under-representations of the richer or poorer wealth status. Specifically for Cambodia, a newer version of the EquityTool based on DHS 2021–2022 became available after our data collection. We explored the feasibility of applying this updated tool to our dataset in consultation with the EquityTool developers. However, changes in methodology and index survey questions made this incompatible with our existing data. To further strengthen our socioeconomic analysis, we also included other socioeconomic indicators—such as household WASH access, work status, and education level of adult participants—to provide a more comprehensive understanding of household and individual-level wealth.

The wealth quintiles provided a direct assessment of SES capturing the relative wealth of households within each country. However, these results are country-specific, therefore direct cross-country comparisons are inherently limited. For example, because the average incomes are different across countries, the households of the first quintile in Cambodia would have different annual incomes compared to those in Thailand.

Our study provided an initial assessment of the most worrying health-related concerns in these rural communities. However, due to the quantitative nature of the study, we could not explore the deeper context of these concerns. For example, while the timeliness of health services was one of the top concerns in Thailand, it was unclear whether this issue affect particular levels of healthcare facilities and specific types of services, or represents a broader systemic problem. Addressing such questions would require qualitative research methods, which are more suited for exploring these issues in depth. Nevertheless, our study, with its large sample size relative to typical qualitative studies, effectively identified the common concerns in the community and their scope. These findings could direct targeted interventions addressing the identified issues and provide a foundation for future more detailed investigations.

3.5 Conclusion

The study provided an overview of the demographic, socioeconomic, and health-related characteristics of the rural population in Bangladesh, Cambodia, and Thailand, highlighting shared challenges and site-specific variations. The study sample was representative, and the findings could be generalised to the larger population of the study areas. These rural areas face resource limitations reflected in low education attainment and insufficient access to WASH, while variations in age structures and ethnic composition suggest the unique context of each site. Self-perceived health indicated substantial differences, with a higher proportion of Cambodian adults reporting less-than-good health, suggesting a greater disease burden and issues in healthcare services in Cambodia. Health–related concerns also varied across countries, with the cost of care being a predominant issue in Cambodia and Bangladesh, accompanied by concerns about healthcare efficiency and safety in Cambodia. In contrast, fewer Thai adults reported concerns, likely reflecting the benefits of higher universal health coverage that reduced financial barriers to healthcare access. These findings could direct targeted interventions aiming at health system improvement while providing essential context for interpreting disease prevalence in the subsequent chapters.

4

Self-reported fever, health-seeking behaviour, and seroprevalence of febrile pathogens

Chapter outline

This chapter explores the burden of febrile illnesses in rural communities across Southeast Asia in the context of declining malaria incidence. It focuses on self-reported fever prevalence, healthcare-seeking behaviour, and seroprevalence of key febrile pathogens in the study sites in Bangladesh site, Cambodia site, and Thailand site. Using community-based surveys and multiplex serological assays, we assessed patterns of healthcare utilisation and population-level exposure to viral, bacterial, and parasitic infections. The chapter begins with findings on self-reported fever and care-seeking behaviour by country, highlighting gaps in public healthcare access and potential underrepresentation of febrile illness in surveillance systems. This was followed by analyses of the seroprevalence of nine pathogens, age-dependent seroprevalence and factors that are associated with seropositivity. The chapter concludes with a discussion of the implications of these results for the improvement of healthcare access, surveillance coverage, and further research on the transmission dynamics of these infections.

4.1 Introduction

Febrile illnesses are a significant public health concern in Southeast Asia, particularly in rural areas where access to healthcare is limited, and a diverse range of pathogens contribute to the disease burden (Coker et al., 2011). With declining malaria incidence due to expanded diagnostic and treatment programs, there is a need to understand the non-malaria causes of fever (Mayxay et al., 2015; Shrestha et al., 2018). However, fever is a common feature of many infections, and accurate and prompt diagnosis can be challenging in resource-limited contexts (Chappuis et al., 2013; Dittrich et al., 2018; Lim et al., 2015). Healthcare systems and socio-economic disparities also influence treatment-seeking behaviours and disease management, further complicating the understanding of febrile illness epidemiology.

Community-based surveys on self-reported fever and health-seeking behaviour are relevant for understanding how individuals perceive and respond to fever. Such studies help to identify barriers to accessing healthcare and assess patterns of healthcare utilisation that are associated with disease and patient characteristics. The information can guide targeted interventions to improve healthcare access. It can also be used to adjust facility-based incidence data to generate more accurate population-level estimates (Andrews et al., 2020).

Seroprevalence studies complement these efforts by providing a detailed understanding of population-level exposure to febrile pathogens. They address the hidden burden of diseases that may not be diagnosed due to a lack of awareness of the diseases or diagnosis methods (Shrestha et al., 2018). Serology tests can identify individuals who were asymptomatic or experienced mild symptoms and did not seek healthcare, thus addressing underestimations of disease prevalence estimated from surveillance (Arnold et al., 2018). They also offer an approach for monitoring immunity levels in a population and do not require that people be tested during the narrow symptomatic period, which is particularly useful in cross-sectional surveys. Recent advances in microsphere-based multiplex immunoassays allow simultaneous detection of antibodies to multiple pathogens with minimal

sample volumes (Aiemjoy et al., 2020; Chan et al., 2022). This technology provides a unique advantage in identifying vulnerable populations who experience multiple pathogen exposures.

In this study, we report the prevalence of self-reported fever in the 30 days prior to data collection and present healthcare utilisation patterns associated with fever episodes. We also assessed IgG antibody responses to a panel of antigens covering viral, bacterial, and *Plasmodium* pathogens, and described age-dependent seroprevalence and pathogen-specific risk factors for exposure.

4.2 Methods

4.2.1 Study population

For the analysis of self-reported fever and health-seeking behaviour, the de jure population (i.e. usual members) were included. Relevant information for all usual members of the household was provided by the household head during the questionnaire interview, regardless of whether individual household members participated in the survey.

The prevalence of self-reported fever in the 30 days before the survey was analysed among all de jure household members. However, the first iteration of the questionnaire, used in 23 villages in Thailand, covered 404 de jure members of the participating households and did not distinguish between multiple episodes of acute conditions within the recall period. Therefore, analysis of fever episodes was restricted to the members of the households who participated in the survey after a revised questionnaire was implemented on 30 January 2023.

The analysis of seroprevalence was conducted among survey participants aged six months or older who were eligible to provide blood samples. Participants who did not have laboratory results on antibody response were excluded from the analysis.

The overall participant flow and denominators for the analysis included in this chapter are described in Figure 2.13.

4.2.2 Geographic locations and seasonality

Administration districts where the surveyed villages are located were used to describe the geographic distribution of the participants. The districts of each country were: Bangladesh: Cox's Bazar and Bandarban; Cambodia: Pailin, Koas Krala, Rukhakiri, Samlot; Thailand: Muang, Mae Suai, Chiang Khong, Khun Tan, Wiang Kean (Chapter 2. Figure 2.1). In Bangladesh, due to larger numbers of villages being covered within Cox's Bazar district, it was further divided into subdistricts to better represent geographic variation. The districts included in the analysis were Bandarban, Chakaria, and Ukhiya.

We categorised the data collection time into rainy or dry seasons based on regional climatic patterns. For Thailand and Chakaria and Ukhiya, Bangladesh, the rainy season was defined as June to October, and for Cambodia and Bandarban, Bangladesh, it was defined as May to September. The remaining months of the year were categorised as the dry season.

4.2.3 Self-reported fever and health-seeking behaviour

Self-reported fever and health-seeking behaviour were analysed at the household member level. Household heads were interviewed to collect information on household wealth status and ethnicity and details of all usual household members, including their age, sex, and history of acute illness episodes in the past 30 days before the survey (See Chapter 2 and Chapter 3).

For each reported acute episode, the following information was collected:

- Self-reported symptoms or diagnoses. If multiple episodes occurred during the recall period, each was recorded. Predefined symptom options were based on previously conducted surveys in similar contexts (Baird, S. et al., 2019; Shwe Sin Ei et al., 2019; World Health Organization, 2009). Symptoms were then grouped into categories:
  - Fever

4. Self-reported fever, health-seeking behaviour, and seroprevalence of febrile pathogens

  - Neurological presentation: convulsion and persistent headache
  - Respiratory presentations: persistent cough, running nose, difficulty or fast breathing, difficulty swallowing/ throat pain,
  - Digestive presentations: stomach pain, nausea, vomiting, could not eat, watery diarrhoea; bloody stools, and constipation
  - Skin presentations: rash, irritation, open sores
  - Other: thirst/ sweating, musculoskeletal pain, difficulty seeing or other eye complaints, gynaecology-obstetrics conditions, feeling tired, could not sleep, and other acute illnesses.

- Self-perceived severity of each episode. Severity was self-reported with options: serious, moderate, slight, or 'Don't know'.

- Self-reported health-seeking behaviour for each episode. For each episode, participants reported whether care was sought and, if so, the source of care for each visit. The sources of care were defined according to country-specific health systems, and the options were adapted from the Demographic and Health Survey or Multiple Indicator Survey of each country (National Institute of Statistics et al., 2015; National Statistical Office of Thailand, 2020a; Population Research et al., 2020).

  - We first summarised them into categories that apply to the health systems of all study countries, including: Public primary care units, Secondary hospitals, Tertiary hospitals, Other public sector, NGO clinics (only for Bangladesh), Private care (practice/clinic/ hospital), Traditional healers/ religious leaders, Self-bought medication (pharmacies/ shops/markets), Relatives/ friends, Other sources, or No care sought.
  - The sources of care were further categorised into broader groups: Public care (& NGO clinics), Private care, Self-bought medicine/ other, and No care.

4.2.4 Blood sample and Laboratory methods

Blood samples were collected at the time of the survey. Dried blood spots (DBS) from finger pricks were collected from children aged six months to four years, and venous samples were collected from older participants. DBS or serum were analysed for IgG responses to nine pathogens. The multiplex bead-based assay was performed using magnetic beads with Luminex® Intelliflex technology (Luminex Cor, Austin, TX).

Briefly, 50μL of 1/100 diluted serum in phosphate buffered saline with 1% bovine serum albumin and 0.05% (v/v) Tween-20 (PBT buffer) were added to wells containing 50μL of antigen-coupled beads premix (500 microspheres/region/well) in a 96-well plate. The plate was incubated for 30 min, at room temperature on a shaker. Subsequently, the plate was placed on a magnetic plate separator to capture magnetic beads and to perform three washes with 100μL of PBT buffer per wash. For IgG detection, the microspheres were incubated with 100μL of 1/120 PE-conjugated anti-human IgG Fc (0.5 mg/ml, Abcam) in the dark, at room temperature on a plate shaker for 15 minutes. The microspheres were washed three times with PBT buffer using a magnetic plate separator. Lastly, 100μL of PBT buffer was added to each well before being analysed on the Intelliflex® system. Results were measured as median fluorescent intensity (MFI). A series of controls in each plate consists of a blank (no serum), a negative control (healthy serum), and six positive controls of well-defined serum, to account for plate-to-plate variation.

The assay targeted a range of antigens associated with known febrile pathogens, including dengue virus (DENV), Japanese encephalitis virus (JEV), Zika virus (ZIKAV), chikungunya virus (CHIKV), *Plasmodium falciparum*, *Plasmodium vivax*, *Orientia tsutsugamushi, Rickettsia*, and *Leptospira.* The targeted antigens were: for flaviviruses, the non-structure protein 1 of DENV serotype 1-4 (DENV1 NS1, DENV2 NS1, DENV3 NS1, DENV4 NS1), JEV NS1, and ZIKAV NS1 (Fisher et al., 2023); CHIKV virus-like particle (CHIKV-VLP) (Noranate et al., 2014);

the merozoite surface protein-1 for *Plasmodium falciparum* (PvMSP1) and *Plasmodium vivax* (PfMSP1) (Wang et al., 2016); for *O. tsutsugamushi*, the 56-kDa antigen of the Gilliam, Kato, and Karp strains (TSA56FL-Gilliam, OT-TSA56FL-Kato, OT-TSA56FL-Karp) (Blacksell et al., 2008); autotransporter protein of *Rickettsia* conorii (OmpB-conorii) and *Rickettsia* typhi (OmpB-typhi) (Do et al., 2009); *Leptospira* immunoglobulin-like protein ANI (LigANI) and the immunodominant lipoprotein 32 (LipL32) that target pathogenic strains of Leptospira (Evangelista et al., 2017; G. L. Murray, 2013; Rosa et al., 2019). The pathogens were selected based on antigen availability and known circulation in the region.

The background from the buffer-only blank is subtracted from the result for each antigen, and values are reported as an average median fluorescence intensity with background subtracted (MFI-bg) (Aiemjoy et al., 2020; Chan et al., 2022).

4.2.5 Statistical analysis

Categorical variables were described as frequencies with percentages and continuous variables using median plus interquartile range (IQR). The prevalence of self-reported fever and seroprevalence with 95% binomial exact confidence intervals (95%CI) were calculated for each country.

We compared the source of care seeking (public sector, private sector, self-bought medicine, no care) for self-reported fever episodes across age groups (<5, 5-14, 15-50, 50+), sex (men, women), and self-reported severity of the episode (serious, moderate, slight, don't know) using the chi-square or Fisher's exact test. We assessed the association between self-reported fever and sociodemographic factors, including age groups, sex, household wealth status (poor, middle, rich), and ethnicity in Bangladesh (Bengali, other ethnic minorities), rainy or dry season at the period of data collection, and geographic districts using logistic regression models with households as a random effect. Ethnicity was not assessed in Cambodia, as 97% of households identified as Khmer- the country's main ethnicity (Chapter 3). The source of care seeking for self-reported fever was not performed for Thailand due to the very low number of fever episodes. To explore other factors that might be

associated with self-reported fever, variables with p < 0.20 in univariate analysis were included in an adjusted model (Mickey & Greenland, 1989). The variance inflation factor (VIF) was checked to avoid potential collinearity, ensuring VIF<5 (Fox & Monette, 1992).. Adjusted odds ratios (aOR) with 95% confidence intervals (CI) and p-values were reported. A p-value<0.05 was considered significant for all tests. Unadjusted odds ratios are reported in Appendix D, Table 1.

For pathogens tested with more than one antigen (DENV, *O. tsutsugamushi, Rickettsia, Leptospira*), a participant was classified as seropositive if they tested seropositive for any of the associated antigens. Finite mixture models were used to fit a Gaussian distribution for the log10 transformed MFI-bg values for results from all sites(Benaglia et al., 2010; Chan et al., 2022). Seropositivity cut-offs were defined as the mean plus three standard deviations of the first component (Aiemjoy et al., 2020; Chan et al., 2022). When estimating the seropositivity cutoffs, all samples from the study population of all three sites were included, except for the seropositivity cutoffs of flaviviruses (i.e. DENV, JE, ZIKAV) and *Rickettsia*. For these pathogens, we restricted the population to age less than 15 years at the time of data collection to ensure a sufficient number of unexposed population (Appendix D. Figure 1).

To generate age-dependent seroprevalence curves for each pathogen within each country, scatterplots were generated to visualise the shape of age and seropositivity relationship. Then, general additive models (GAM) with cubic splines to allow for nonlinear associations and random effect for household were used to estimate the relationship between seropositivity and age (Wood, 2017). The final number of knots for each exposure model was assessed by both visual inspection and by using Akaike's Information Criterion (AIC). Each model was restricted to 3-5 knots.

Associations between the seropositivity of each pathogen and sociodemographic factors (the same set as used for the self-reported fever analysis) were assessed using logistic regression with households as random intercepts. However, due to low prevalence, associations were generally not explored for *P. falciparum* and *P. vivax*, except for *P. falciparum* in Bangladesh. Multivariable models were adjusted

for age and included fractional polynomial terms (quadratic and cubed) to account for the non-linear relationship with seroprevalence. Variables with p<0.20 in the univariate analysis were also included in the final model. The adjusted odds ratio with 95% confidence intervals (CI), and p-values were reported as a figure. The crude odds ratio and p-values are reported in Appendix D. Table 4.

We analysed the correlation of IgG responses to antigens of flavivirus and CHIKV using Pearson's correlation (Hunsawong et al., 2022). To address the cumulative exposure to multiple infections with older age and high transmission of dengue, which could mask the potential correlation, the analysis was restricted to participants under 15 (Appendix D. Figure 2). A correlation coefficient ranging from 0.5-0.69 was interpreted as a moderate correlation, and a coefficient >0.69 was considered a strong correlation (Hinkle et al., 1988). This approach aimed to provide information on the potential cross-reactivity of antibody responses to this group of viruses.

4.3 Results

4.3.1 Self-reported fever prevalence

Among 1920 participants from the de jure population of the households in the Bangladeshi site, 1660 participants in the Cambodian site, and 1634 participants in the Thai site, self-reported fever in the past 30 days was reported by 17.1% in Bangladesh, 6.1% in Cambodia, and 0.8% in Thailand (Table 4.1). In both Bangladesh and Cambodia, older age groups were significantly less likely to report fever when compared with 0-4-year-old (Table 4.2). District level differences were observed within a country. In Cambodia, residents of Rukhariki (aOR: 9.7, 95%CI: 2.2, 42.7) had higher odds of reporting fever compared to those residing in Pailin.

4.3.2 Health-seeking behaviour in fever episodes

Individuals could report multiple fever episodes. In Bangladesh, 355 fever episodes were reported, and 102 were reported in Cambodia (Table 4.3). In Thailand, due to

a questionnaire revision, only 3 out of 14 individuals who reported fever (fever only: n=2; fever with other symptoms: n=1) were included in this fever episode analysis, resulting in a total of 4 episodes. Therefore, for the Thai site, the frequencies and associated characteristics are presented, but no further analysis was conducted.

In Cambodia, all individuals reporting a fever in the last 30 days experienced only a single episode. In Bangladesh, 86.2% of episodes were single occurrences, though oneindividual experienced up to four episodes (2 episodes: n=18 participants, 3 episodes: n=3 participants, 4 episodes: n=1 participants); in Thailand, two episodes were single occurrences, and one individual experienced two episodes. Most fever episodes were reported as slight (Bangladesh: 29.6%, Cambodia: 42.2%) or moderate (Bangladesh: 58.6%, Cambodia: 42.2%) severity. More than half of them had concomitant conditions (Bangladesh: 81.4%; Cambodia: 76.5%), and the most common ones were respiratory symptoms (Bangladesh: 71.3%; Cambodia: 66.7%).

Table 4.1: The prevalence of self-reported acute conditions in the 30 days before the survey among the de jure population, by site. The conditions were reported by the household head for all the usual members of the households regardless of their attendance to the survey.

Conditions	**Bangladesh** N = 1,920	**95% CI**	**Cambodia** N = 1,660	**95% CI**	**Thailand** N = 1,634	**95% CI**
Fever	328 (17.1)	15.4- 18.8	102 (6.1)	5.04- 7.41	14 (0.9)	0.47- 1.43
Fever						
Acute conditions						
Fever only	52 (2.7)	2.03- 3.54	22 (1.3)	0.83- 2.00	2 (0.1)	0.01- 0.44
Other symtoms without fever						
Fever with other symptoms	276 (14.4)	12.8- 16.0	80 (4.8)	3.84- 5.96	12 (0.7)	0.38- 1.28
Respiratory symptoms	40 (2.1)	1.49- 2.83	21 (1.3)	0.78- 1.93	5 (0.3)	0.10- 0.71
Digestive symptoms	12 (0.6)	0.32- 1.09	26 (1.6)	1.03- 2.29	3 (0.2)	0.04- 0.54
Other acute conditions	68 (3.5)	2.76- 4.47	66 (4.0)	3.09- 5.03	6 (0.4)	0.13- 0.80
No acute illness	1,472 (76.7)	74.7- 78.5	1,445 (87.0)	85.3- 88.6	1,606 (98.3)	97.5- 98.9

[1] n (%)

Abbreviation: CI = Confidence Interval

Note:

De jure population: all usual members of selected households, including those who did not participate in the survey
Respiratory symptoms include persistent cough, running nose, difficult or fast breathing, difficulty swallowing/ throat pain
Digestive symptoms include stomach pain, nausea, vomiting, could not eat; Watery diarrhoea; Bloody stools; Constipation
Other acute conditions include persistent headaches; Thirst/ sweating; Skin disease, such as rash, irritation, open sores; Convulsion/ seizure; Musculoskeletal pain; Difficulty seeing or other eye complaints; gyn-obstetrics; Feeling tired; Could not sleep; and other acute illness.

Table 4.2: Participants' characteristics associated with self-reported fever in the 30 days before the survey.
Logistic regression was only conducted for Bangladesh and Cambodia, presented with adjusted odds ratio (aOR) and corresponding p-value. For Thailand, only the frequencies are shown. Logistic regression was not performed due to the small number of cases.

	Bangladesh			Cambodia			Thailand
Variables	Freq	aOR (95%CI)	p-value	Freq	aOR (95%CI)	p-value	Freq
Age groups							
0-4	100 (38.2%)	Reference		34 (17.3%)	Reference		1 (1.5%)
5-14	72 (17.6%)	0.2 (0.1,0.3)	<0.001	33 (8.4%)	0.2 (0.1,0.5)	<0.001	7 (3.3%)
15-29	65 (12.1%)	0.2 (0.1,0.2)	<0.001	5 (1.5%)	0.0 (0.0,0.1)	<0.001	0 (0.0%)
30-49	64 (14.1%)	0.2 (0.1,0.3)	<0.001	18 (4.4%)	0.1 (0.0,0.2)	<0.001	1 (0.3%)
50+	27 (10.5%)	0.1 (0.1,0.2)	<0.001	12 (3.6%)	0.1 (0.0,0.3)	<0.001	5 (0.6%)
Sex							
Male	156 (17.7%)	–	–	61 (7.2%)	Reference		8 (1.1%)
Female	172 (16.6%)	–	–	41 (5.1%)	0.6 (0.4,1.1)	0.117	6 (0.7%)
Season							
Dry season	83 (17.7%)	–	–	24 (5.4%)	–	–	5 (0.4%)
Rainy season	245 (16.9%)	–	–	78 (6.4%)	–	–	9 (2.5%)
Ethnicity (Bangladesh)							
Bengali	298 (18.5%)	Reference		–	–	–	–
Other (Bangladesh)	30 (9.7%)	0.5 (0.2,1.1)	0.075	–	–	–	–
Ethnicity (Thailand)							
Thai	–	–	–	–	–	–	3 (0.4%)
Akha	–	–	–	–	–	–	9 (3.7%)
Lahu	–	–	–	–	–	–	1 (0.6%)
Other (Thailand)	–	–	–	–	–	–	1 (0.3%)
Household wealth status							
Middle	77 (14.3%)	Reference		36 (7.6%)	–	–	7 (1.4%)
Poor	117 (21.0%)	1.5 (0.9,2.7)	0.115	10 (4.0%)	–	–	2 (0.4%)

Table 4.2: Participants' characteristics associated with self-reported fever in the 30 days before the survey.
Logistic regression was only conducted for Bangladesh and Cambodia, presented with adjusted odds ratio (aOR) and corresponding p-value. For Thailand, only the frequencies are shown. Logistic regression was not performed due to the small number of cases. *(continued)*

Variables	Freq	aOR (95%CI)	p-value	Freq	aOR (95%CI)	p-value	Freq
Rich	134 (16.2%)	1.2 (0.7,1.9)	0.551	56 (6.0%)	–	–	5 (0.9%)
District (Bangladesh)							
Bandarban	61 (12.4%)	Reference		–	–	–	–
Chakaria	116 (17.5%)	0.9 (0.4,1.9)	0.809	–	–	–	–
Ukhiya	151 (19.7%)	1.3 (0.6,2.6)	0.496	–	–	–	–
District (Cambodia)							
Pailin	–	–	–	18 (4.0%)	Reference		–
Koas Krala	–	–	–	15 (3.5%)	0.7 (0.2,2.7)	0.555	–
Rukhakiri	–	–	–	25 (14.4%)	9.7 (2.2,42.7)	0.003	–
Samlot	–	–	–	44 (7.2%)	2.2 (0.7,7.0)	0.197	–
District (Thailand)							
Muang	–	–	–	–	–	–	2 (0.9%)
Chiang Khong	–	–	–	–	–	–	3 (1.2%)
Khun Tan	–	–	–	–	–	–	0 (0.0%)
Mae Suai	–	–	–	–	–	–	9 (1.5%)
Wiang Kean	–	–	–	–	–	–	0 (0.0%)

Note:
Logistic regression for self-reported fever was not performed for Thailand due to the low number of fever episodes. Variables with $p < 0.20$ in univariate analysis were included in multivariable analysis, with adjustment for age groups
Univariate analysis was included in Appendix D. Table 1.1

4. Self-reported fever, health-seeking behaviour, and seroprevalence of febrile pathogens

According to self-reported information, the majority of fever episodes were followed by care seeking at some type of healthcare service (Bangladesh: 79.7%, Cambodia: 87.3%, Thailand: 100%). For most episodes, care was sought only once (Bangladesh: 69.3%; Cambodia: 78.4%, Thailand: 100%) (Table 4.3). Patterns of care-seeking varied according to geographic districts (Figure 4.1, Appendix D. Table 2). In Bangladesh, 30.6% (n=37/121) of fever episodes in Chakaria did not seek care, compared to 13.8% (n=22/160) in Ukhiya and 17.6% (n=13/74) in Bandarban (Figure 4.1). In Cambodia, 50.0% (n=9/18) of episodes in Pailin did not seek care, compared to 4.2% (n=1/24) in Rukhakiri, 6.7% (n=1/15) Koas Krala, and 6.8% (n=3/44) in Samlot.

The first source of care sought varied by country. In Bangladesh, the highest proportion had self-bought medicine (38.6%), followed by private care facilities (27.9%). In Cambodia, private care facilities were the most common first source of care (66.7%). In Thailand, three of the four fever episodes sought care at a primary care unit (Table 4.3). Episodes reported with the severity as 'Slight' had higher proportions of 'No care' (Bangladesh: 40%, n=42; Cambodia: 30.2%, n=13). All episodes reported as 'Serious' sought care of some type (Bangladesh: n=42, Cambodia: n=15) (Figure 4.1).

In Bangladesh, the use of self-bought medicine was relatively consistent across severity (31.0%- 46.7%), with a decreasing trend as severity increased and a concomitant increase in access to private care (Slight: 10.5%, n=11; Moderate: 34.6%, n=72; Serious: 38.1%, n=16) and public health facilities (Slight:2.9%, n=3; Moderate: 14.9%, n=31; Serious: 31.0%, n=13). In Cambodia, private care was the predominant type of healthcare access across all severity levels (Slight: 46.5%, n=20; Moderate: 86.0%, n=37; Serious: 73.3%, n=11). Meanwhile, although public health facilities were less commonly used, their utilisation increased with fever severity (Slight:11.6%, n=5; Moderate: 11.6%, n=5; Serious: 26.7%, n=4). Fever episodes with concomitant conditions had higher proportions of seeking care at private care facilities (Bangladesh: 32.9%, n=95; Cambodia: 79.2%, n=61),

while fever-only episodes had higher proportions of care-seeking at public facilities (Bangladesh: 18.2%, n=12; Cambodia: 25.0%, n=6) in both countries.

Table 4.3: Descriptions of self-reported fever episodes in the 30 days before the survey

Characteristic	**Bangladesh** N = 355	**Cambodia** N = 102	**Thailand** N = 4
Sex			
Male	169 (47.6)	61 (59.8)	4 (100.0)
Female	186 (52.4)	41 (40.2)	0 (0.0)
Age			
<5	113 (31.8)	34 (33.3)	0 (0.0)
5-14	75 (21.1)	33 (32.4)	3 (75.0)
15-49	137 (38.6)	23 (22.5)	0 (0.0)
50+	30 (8.5)	12 (11.8)	1 (25.0)
Severity of the episode			
Serious	42 (11.8)	15 (14.7)	0 (0.0)
Moderate	208 (58.6)	43 (42.2)	2 (50.0)
Slight	105 (29.6)	43 (42.2)	2 (50.0)
Don't know	0 (0.0)	1 (1.0)	0 (0.0)
Fever and concomitant conditions			
Fever only	66 (18.6)	24 (23.5)	2 (50.0)
Fever with other symptoms	289 (81.4)	78 (76.5)	2 (50.0)
Details of fever concomitant conditions			
Respiratory presentation	**253 (71.3)**	**68 (66.7)**	**2 (50.0)**
Persistent cough	154 (43.4)	27 (26.5)	2 (50.0)
Runny nose	209 (58.9)	63 (61.8)	2 (50.0)
Difficulty or fast breathing	10 (2.8)	7 (6.9)	0 (0.0)
Difficulty swallowing/ throat pain	6 (1.7)	22 (21.6)	0 (0.0)
Digestive presentation	**10 (2.8)**	**11 (10.8)**	**0 (0.0)**
Stomach pain/nausea/vomiting/could not eat	5 (1.4)	10 (9.8)	0 (0.0)
Watery diarrhoea	4 (1.1)	1 (1.0)	0 (0.0)
Bloody stools	1 (0.3)	0 (0.0)	0 (0.0)
Neuological presentation	**51 (14.4)**	**18 (17.6)**	**0 (0.0)**
Persistent headaches	50 (14.1)	18 (17.6)	0 (0.0)
Convulsion/ seizure	1 (0.3)	0 (0.0)	0 (0.0)
All other acute conditions	**74 (20.8)**	**12 (11.8)**	**0 (0.0)**
Thirst/ sweating	0 (0.0)	1 (1.0)	0 (0.0)
Skin disease (e.g. rush/irritation/open sores)	19 (5.4)	0 (0.0)	0 (0.0)
Musculoskeletal pain	15 (4.2)	0 (0.0)	0 (0.0)
Feeling tired	23 (6.5)	1 (1.0)	0 (0.0)
Could not sleep	5 (1.4)	0 (0.0)	0 (0.0)
Gyn-obstetrics presentations	3 (0.8)	1 (1.0)	0 (0.0)
Difficulty seeing or other eye complaint	1 (0.3)	0 (0.0)	0 (0.0)
Other	16 (4.5)	9 (8.8)	0 (0.0)

Table 4.3: Descriptions of self-reported fever episodes in the 30 days before the survey *(continued)*

Characteristic	**Bangladesh** N = 355	**Cambodia** N = 102	**Thailand** N = 4
Number of times sought care			
0	72 (20.3)	14 (13.7)	0 (0.0)
1	246 (69.3)	80 (78.4)	4 (100.0)
2	29 (8.2)	5 (4.9)	0 (0.0)
3	4 (1.1)	2 (2.0)	0 (0.0)
4	2 (0.6)	0 (0.0)	0 (0.0)
5	2 (0.6)	1 (1.0)	0 (0.0)
Sources of care (the 1st time)			
No care	72 (20.3)	14 (13.7)	0 (0.0)
Primary care unit	7 (2.0)	14 (13.7)	3 (75.0)
Secondary hospital	28 (7.9)	1 (1.0)	0 (0.0)
Other public sector	2 (0.6)	0 (0.0)	0 (0.0)
NGO clinic (Bangladesh)	10 (2.8)	0 (0.0)	0 (0.0)
Private care (practice/clinic/hospital)	99 (27.9)	68 (66.7)	1 (25.0)
Self-bought medicine	137 (38.6)	5 (4.9)	0 (0.0)

[1] n (%)

Note:
Fever episodes were described among 1920 individuals from Bangladesh, 1660 from Cambodia, and 1230 from Thailand whose household heads were interviewed using the revised questionnaire. 404 individuals from 23 villages in Thailand who used the original questionnaire were excluded
All fever episodes were included (e.g. two fever episodes reported for an individual were counted as 2 and each episode was described)

4.3.3 Seroprevalence

We collected blood samples from 1709 participants in Bangladesh, 1456 participants in Cambodia and 1406 participants in Thailand. We observed a low to moderate correlation among IgG responses of antigens of arboviruses (i.e. DENV, ZIKAV, JEV, CHIKV) (Appendix D. Figure 1).

It was possible to determine the cutoffs of seropositivity for all antigens except LipL32 for *Leptospira* (Figure 4.2). Using the cut-offs, overall estimated seroprevalence of DENV was 27.6% (95%CI: 25.5- 29.7 in Bangladesh, 75.3% (95%CI: 73.0-77.5) in Cambodia and 70.1(95%CI: 67.6- 72.4) in Thailand (Appendix Table 2). Estimated JEV seroprevalence was 20.3% (95%CI: 18.4- 22.3) in Bangladesh, 65.7%

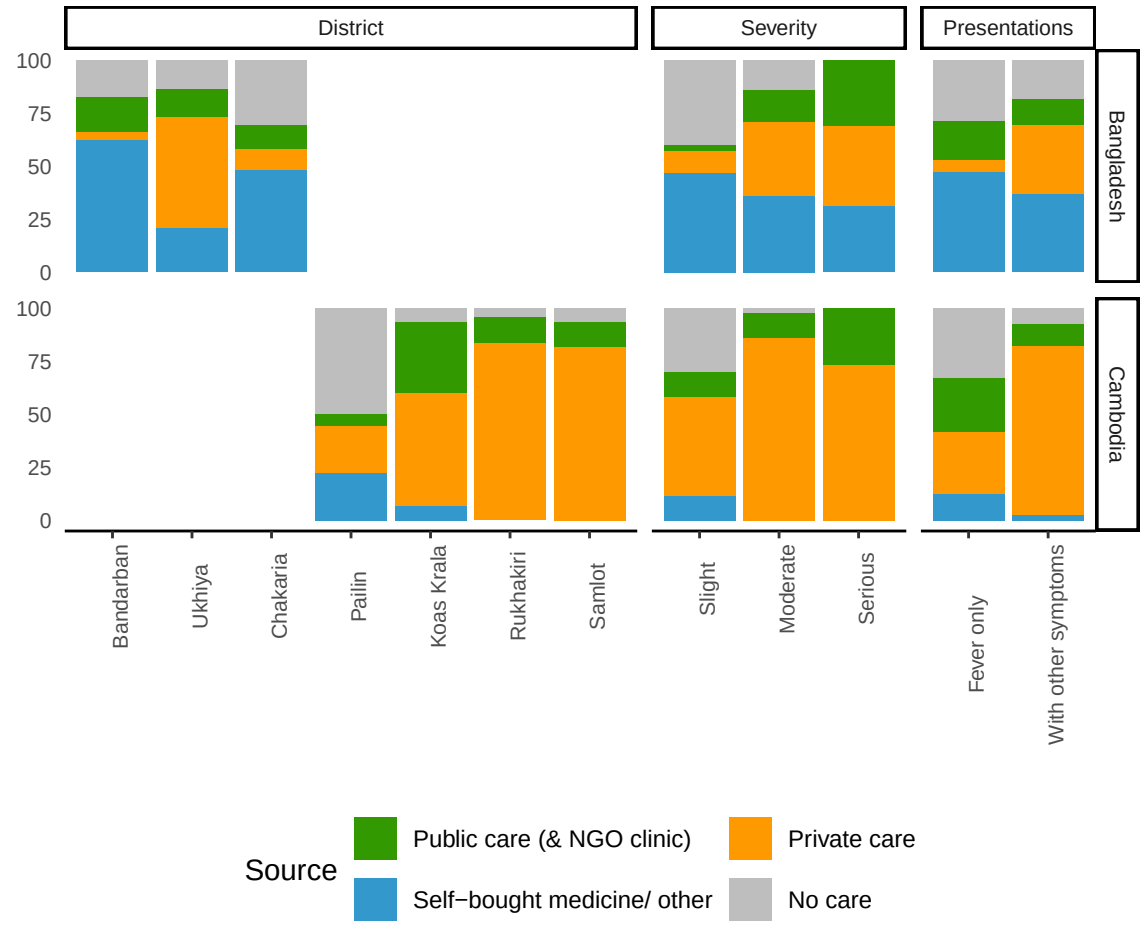


Figure 4.1: Fever episodes and the source of care-seeking, by self-reported presentations, severity of fever episodes, and by geographic district of the household, for Bangladesh and Cambodia

(95%CI: 63.2- 68.2) in Cambodia and 76.5 (95%CI: 74.2- 78.7) in Thailand. ZIKAV seroprevalence was 6.6% (95%CI: 5.43- 7.83) in Bangladesh, 44.9% (95%CI: 42.3- 47.5) in Cambodia and 32.4% (95%CI: 30.0- 34.9) in Thailand. CHIKV seroprevalence was 1.7% (95%CI: 1.1- 2.4) in Bangladesh, 33.3% (95%CI: 30.9- 35.8) in Cambodia and 6.2% (95%CI: 4.99- 7.58) in Thailand. Among bacterial pathogens, *O. tsutsugamushi* seroprevalence was 9.2% (95%CI: 7.9- 10.7) in Bangladesh, 25.3% (95%CI: 23.1- 27.6) in Cambodia and 29.7% (95%CI: 27.3- 32.2) in Thailand. For *Rickettsia,* the seroprevalence was 36.4% (95%CI: 34.1- 38.7) in Bangladesh, 24.5% (95%CI: 22.3- 26.7) in Cambodia and 44.5% (95%CI: 41.8- 47.1) in Thailand. *Leptospira* seroprevalence was 35.3% (95%CI: 33.1- 37.7) in Bangladesh, 26.2%

(95%CI: 24.0- 28.6) in Cambodia and 37.7% (95%CI: 35.2- 40.3) in Thailand. *Plasmodium* species showed lower seroprevalence than other pathogens overall, while Bangladesh had a seroprevalence of 24.2% (95%CI: 22.2- 26.3) for *P. falciparum*. In Cambodia, *P. falciparum* seroprevalence was 11.2% (95%CI: 9.62- 12.9), and in Thailand was 5.9% (95%CI: 4.7- 7.3). *P. vivax seroprevalence* was 3.2% (95%CI: 2.4- 4.2) in Bangladesh, 2.5% (95%CI: 1.8- 3.5) in Cambodia and 0.7% (95%CI: 0.3- 1.3) in Thailand.

Overall, seroprevalence increased with age, with marked differences across pathogens and countries. Age-dependent seroprevalence slopes were steeper for flaviviruses (i.e. DENV, JEV, and ZIKA) in Cambodia and Thailand, but less so for Zika in Bangladesh; DENV seroprevalence in Cambodia reached 100% by age 30. *Leptospira* showed a unique age-dependent seroprevalence pattern in all countries, with high seroprevalence among young children, a decline to the lowest point around the age of 30, followed by a rise with advancing age (Figure 4.3). Differences in seroprevalence dynamics across the age spectrum were observed between the countries. Across pathogens, age-dependent seroprevalence patterns varied by country. For most arboviruses (e.g., dengue, Zika, chikungunya), seroprevalence increased sharply with age and was highest in Cambodia. In contrast, *P. falciparum* and *P. vivax* seroprevalence was highest in Bangladesh, followed by Cambodia and Thailand. For *Rickettsia* spp. and *Leptospira* spp., seroprevalence patterns across age were similar in the three countries but tended to be higher in Bangladesh, followed by Thailand and lowest in Cambodia. The quantitative MFI distribution by age resembled the age-dependent seroprevalence curve (Appendix D, Figure 2).

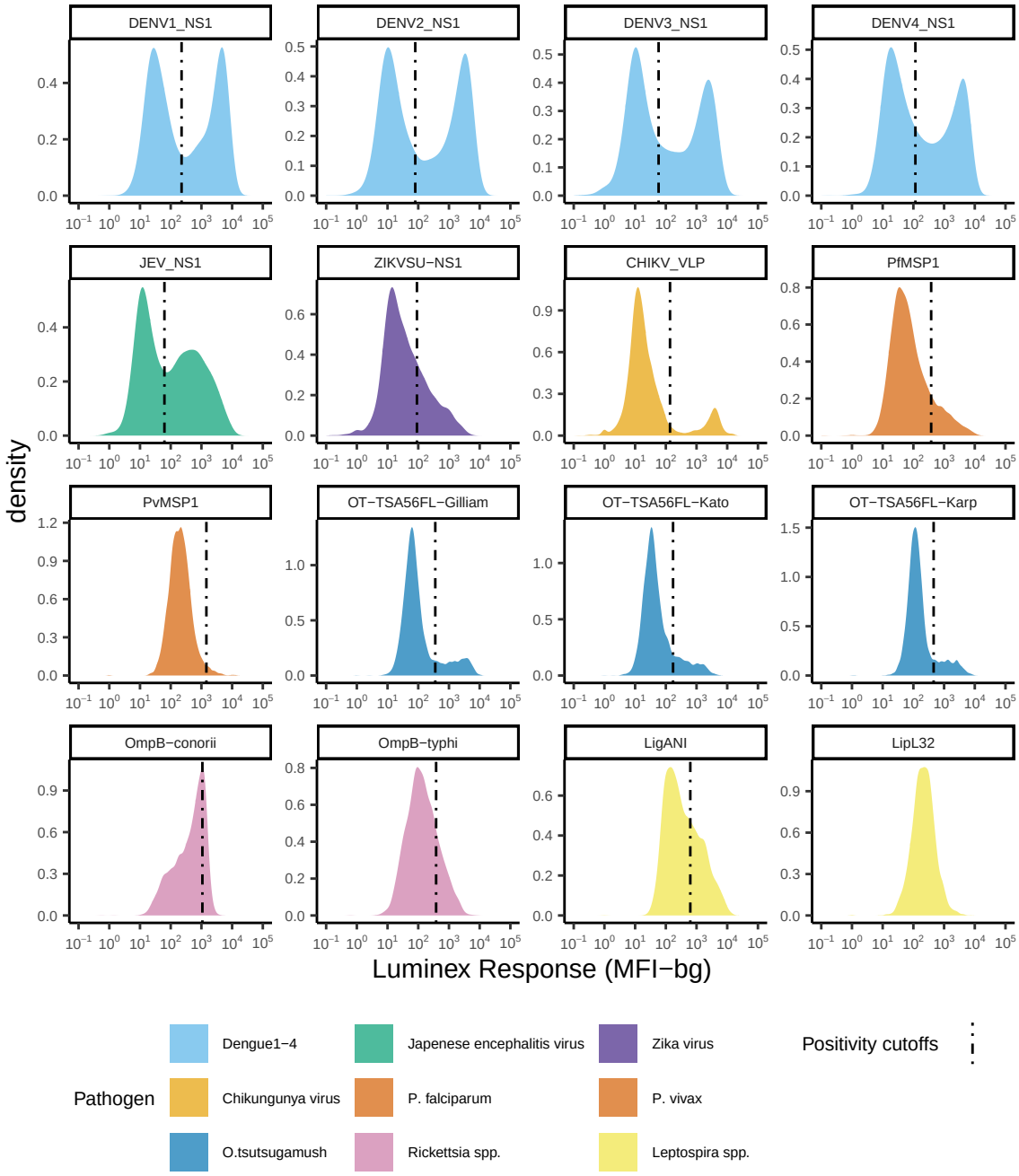


Figure 4.2: The observed MFI distribution and the cut-offs of seropositivity.
The cut-offs for seropositivity was determined by the finite mixture model (the mean plus three standard deviations of the first component).Cutoffs were established for all antigens except LipL32 for *Leptospira*, for which no clear distributional separation was observed. Cutoffs for antigens of chikungunya virus, *P. falciparum, P. vivax, O. tsutsugamushi, and Leptospira* were determined using the MFI distribution among all participants from Bangladesh, Cambodia and Thailand, and cutoffs for antigens of dengue virus 1-4, Japanese encephalitis virus, Zika virus, and *Rickettsia* were determined among children aged 0-14.

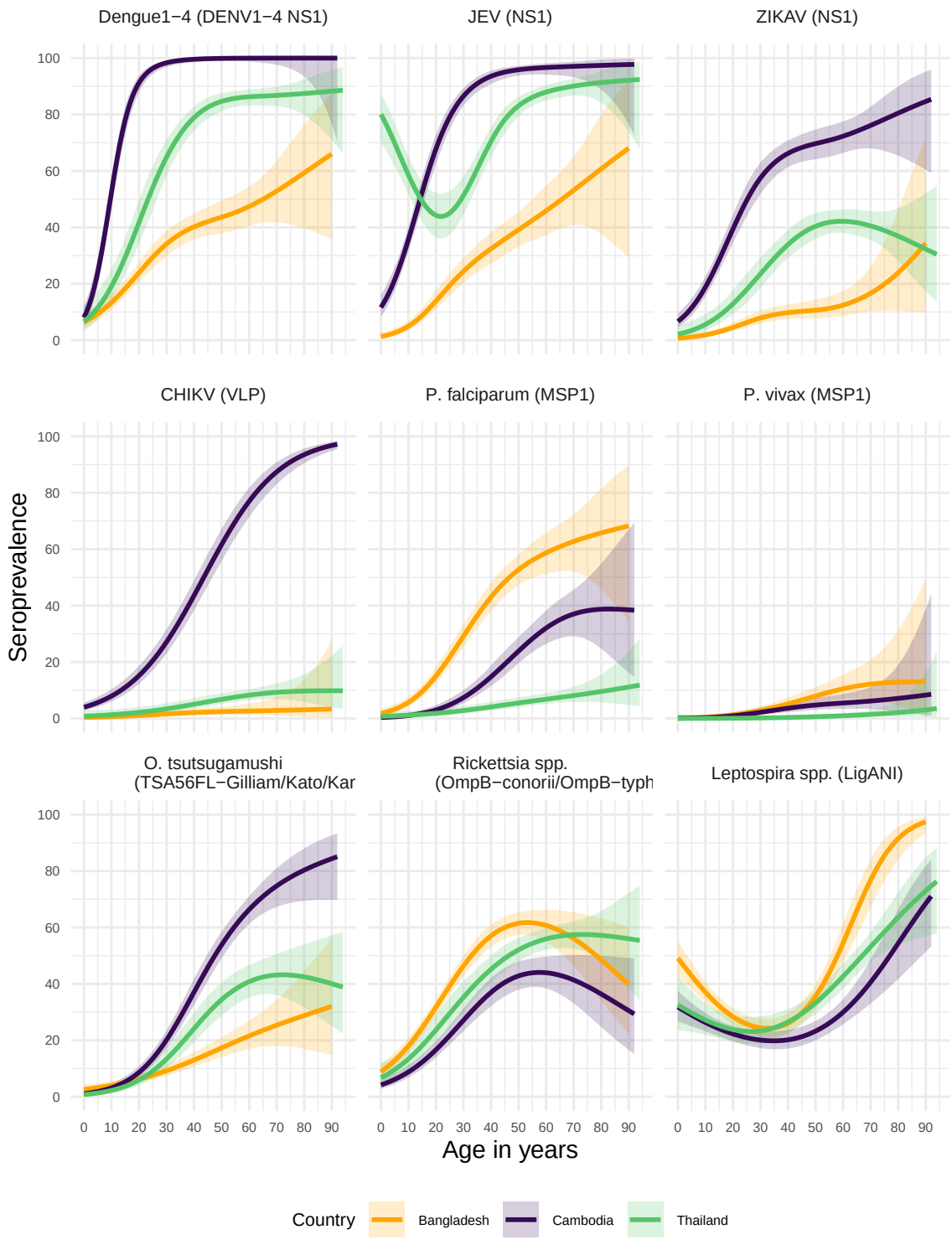


Figure 4.3: Age-dependent seroprevalence of dengue, Japanese encephalitis, Zika, chikungunya, *P. falciparum, P. vivax, O. tsutsugamushi, Rickettsia, and Leptospira* in Bangladesh, Cambodia and Thailand.

(Figure 4.3 caption continued.) Age-dependent seroprevalence curves were fitted using mixed-effect generalised additive models (GAM), with households as random intercepts and cubic splines for age. For pathogens with more than one antigen, positivity to either antigen was considered positive. IgG response measured in multiplex using median fluorescence units minus background (MFI-bg) on Luminex platform on 1709 blood samples from Bangladesh, 1456 blood samples from Cambodia and 1406 samples from Thailand.

District-level differences in seroprevalence were also observed (Figure 4.4). In Bangladesh, compared to Ukhiya district, higher odds of seropositivity for across arboviruses and bacterial infections were observed in Bandarban (JEV aOR 4.4, 95%CI 2.7-7.2; ZIKAV aOR 4.0, 95%CI 1.5-10.4; Leptospira aOR 1.8, 95%CI 1.2-2.7) and Chakaria (DENV 1.8, 95%CI 1.2- 2.6; JEV aOR 1.8, 95%CI 1.2, 2.6; ZIKAV aOR 3.1, 95%CI 1.5- 6.5; Rickettsia aOR 1.4, 95%CI 1.1-1.8; Leptospira aOR 1.6, 95%CI 1.2-2.0). In Cambodia, compared to Pailin district, lower odds of seropositivity for arboviruses were observed in Koas Krala (DENV aOR 0.3, 95%CI 0.1–0.5; CHIKV aOR 0.5, 95%CI 0.2–0.9), Rukhakiri (DENV aOR 0.2, 95%CI 0.1–0.4; CHIKV aOR 0.2, 95%CI 0.1–0.4), and Samlot (CHIKV aOR 0.3, 95%CI 0.1–0.5). Conversely, higher odds of seropositivity for bacterial infections were observed in Koas Krala (Rickettsia aOR 2.8, 95%CI 1.4-5.3; Leptospira aOR 0.5, 95%CI 0.3-0.9), Rukhakiri (Rickettsia aOR 4.4, 95%CI 2.2-8.6) and Samlot (Rickettsia aOR 4.5, 95%CI 2.5-8.2; Leptospira aOR 1.7, 95%CI 1.1–2.5). In Thailand, compared to Muang district, higher odds of seropositivity of arboviruses were found in Chiang Khong (ZIKAV aOR2.0, 95%CI 1.1-3.6), Khun Tan (DENV aOR 4.0, 95%CI 1.8-8.7; JEV aOR 2.1, 95%CI 1.1–4.3; ZIKAV aOR 2.3, 95%CI 1.2-4.1), and Wiang Kaen (DENV aOR 2.1, 95%CI 1.1–4.1), while lower odds of seropositivity for bacterial infections in Chiang Khong (O. tsutsugamushi aOR 0.4, 95%CI 0.2–0.9), and Khun Tan (Leptospira aOR 0.4, 95%CI 0.2-0.8).

Ethnic minorities in Thailand, compared to Thai, were also associated with lower odds of seropositivity for arboviruses but higher odds for bacterial infections. Among the Akha, lower odds were observed for JEV (aOR 0.5, 95%CI 0.3- 0.8) and ZIKAV (aOR 0.4, 95%CI 0.3–0.8); higher odds for *O. tsutsugamushi* (aOR 25.4,

95%CI 12.5–53.7) and *Leptospira* (aOR 1.9, 95%CI 1.1–3.1). The Lahu higher odds for *O. tsutsugamushi* (aOR 34.1, 95%CI 15.8–73.8) and *Leptospira* (aOR 2.7, 95%CI 1.6–4.5); other ethnic groups in Thailand had lower odds of seropositivity for DENV (aOR 0.4, 95%CI 0.2–0.7), JEV (aOR 0.4, 95%CI 0.2–0.7), and ZIKAV (aOR 0.5, 95%CI 0.3–1.0); and higher odds for *O. tsutsugamushi* (aOR 30.1, 95%CI 14.2–67.0). The association of seropositivity and ethnicity in Bangladesh were significant for JEV and *Leptospira*. When compared to Bengali, other ethnicities showed higher odds of seropositivity for two pathogens (JEV aOR 4.0, 95%CI 2.5-6.6; *Leptospira* aOR 4.5, 95%CI 2.9-7.1).

Household wealth status showed inconsistent associations with the odds of infection across pathogens and study sites. In Bangladesh, individuals from 'poor' households had lower odds of JEV seropositivity (aOR 0.6, 95%CI 0.4- 0.9), and higher odds for CHIKV (aOR 5.1, 95%CI 1.0-25.6), while those from 'rich' households had higher odds for CHIKV (aOR 4.5, 95%CI 1.1-17.9) and lower odds for *Leptospira* (aOR 0.7, 95%CI 0.5-0.9). In Cambodia, individuals from 'rich' households had higher odds for CHIKV (aOR 1.7, 95%CI 1.0-2.9), and lower odds for *O. tsutsugamushi* (aOR 0.7, 95% CI 0.5, 1.0). In Thailand, individuals from 'poor' households were associated with higher odds of JEV seropositivity (aOR 1.7, 95% CI 1.2, 2.5), while those from 'rich' households were associated with increased odds of *Rickettsia* (aOR 1.6, 95% CI 1.2, 2.2), and decreased odds for *Leptospira* (aOR 0.6, 95% CI 0.4, 0.8).

For *P. falciparum* in Bangladesh, higher odds of seropositivity were observed among individuals residing in Bandarban (aOR 1.7, 95% CI 1.1–2.7) compared to Ukhiya. Non-Bengali ethnic groups (aOR 2.8, 95%CI 1.7-4.6) and samples collected during the rainy season (aOR 1.5, 95%CI 1.0- 2.0) also showed increased odds of seropositivity.

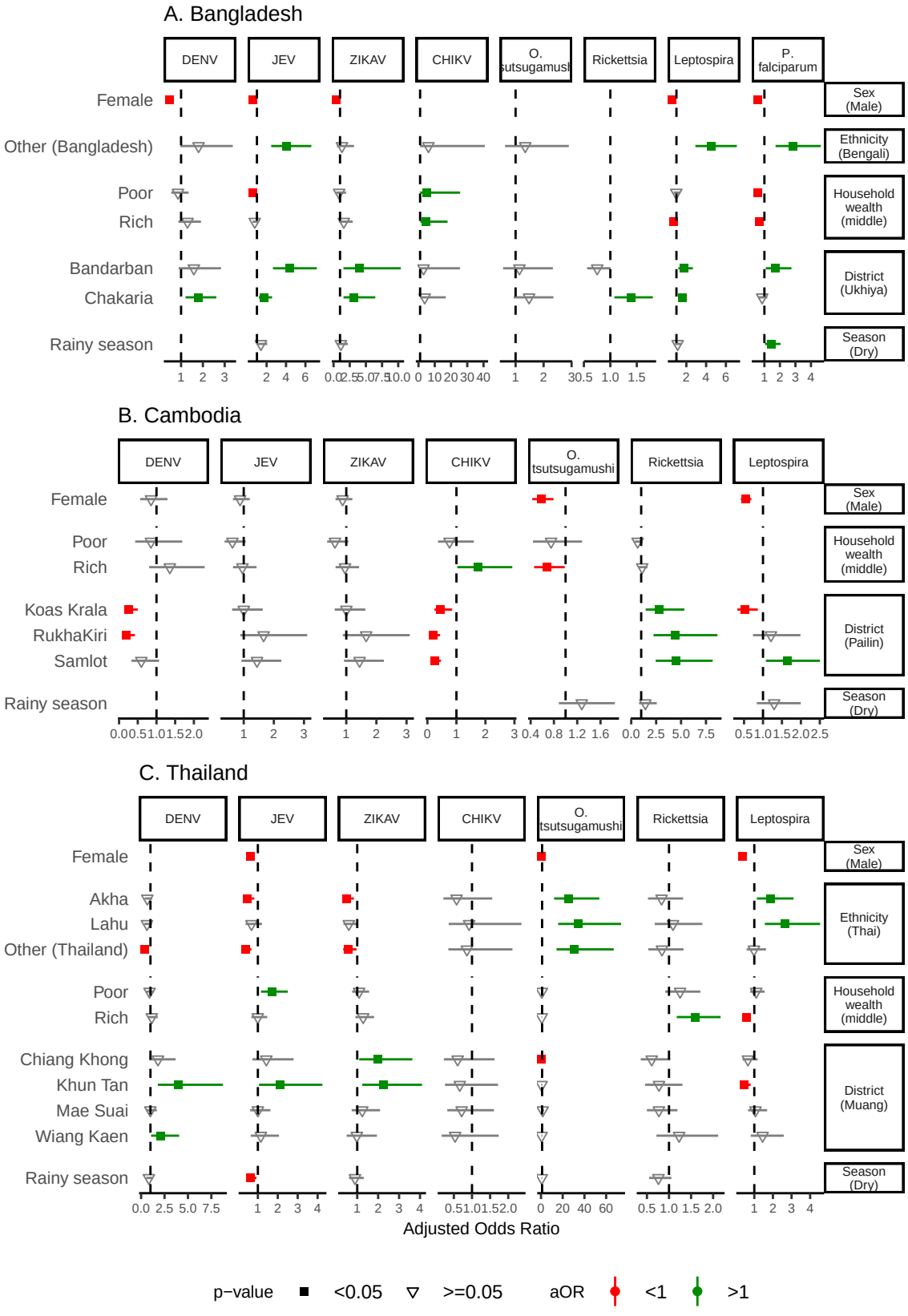


Figure 4.4: Adjusted odds ratio for risk factors for seropositivity to dengue virus, Japanese encephalitis virus, Zika virus, chikungunya virus, *O. tsutsugamushi, Rickettsia, Leptospira, and P. falciparum* in A.Bangladesh, B. Cambodia and, C. Thailand.

(Figure 4.4 caption continued.) The risk factors for seropositivity to *P. falciparum* and *P. vivax* were not tested due to low seropositivity, except *P. falciparum* among Bangladeshi participants. The variables and the reference group in parentheses are indicated on the right side of each panel, and covariate groups are on the left side. The dotted vertical line indicates unity (no difference). Age had a non-linear relationship with seropositivity that was reflected in the figure for age-dependent seropositivity, and was not included in this figure, but adjusted for in the analysis using fractional polynomials.

4.4 Discussion

By integrating serological data with self-reported fever history and healthcare utilisation, our study provides a unique population-level perspective on febrile illness dynamics. It suggested that fever was common in some rural areas, with 17.1% self-reported fever prevalence in the past 30 days in Bangladesh, 6.1% in Cambodia, and 0.9% in Thailand, reflecting regional differences in disease burden. Health-seeking behaviour also varied, with self-bought medicine the most common choice in Bangladesh, while private healthcare services were more frequently used in Cambodia. Despite the differences, an expected health-seeking pattern emerged that serious episodes or fever with concomitant symptoms led to a higher proportion of health-seeking. This is the first study in these locations to assess the seroprevalence of nine febrile pathogens- including viruses, bacteria, and *Plasmodium* - across populations of all ages, showcasing the potential of multiplex serological assays for population-level surveillance for febrile illness. This study applied integrated monitoring of the burden of febrile illnesses by collecting and analysing data on self-reported fever, health-seeking behaviour, and exposure to multiple pathogens and associated risk factors. Such an approach could be adopted by public health authorities to obtain a comprehensive understanding of the burden of febrile illness and to guide targeted interventions for disease prevention and management.

4. Self-reported fever, health-seeking behaviour, and seroprevalence of febrile pathogens

Self-reported fever was common in Bangladesh and Cambodia, especially among children yougner than five years old. This finding is consistent with existing literature, which primarily focuses on fever prevalence in children (National Institute of Statistics (NIH) Cambodia et al., 2023; Population Research et al., 2020). Very few acute conditions, including fever, were reported in Thailand. A study conducted before the COVID-19 pandemic in the same province as our study site in Thailand reported a 7% fever prevalence among adults during a two-month recall period (Haenssgen et al., 2023). Although this is higher due to longer recall periods, it aligns with the low prevalence of fever observed in our findings. The low fever prevalence in Thailand might also reflect the impact of stringent COVID-19 measures implemented in Thailand. Previous studies have reported a decline in acute respiratory infections during lockdown (Yorsaeng et al., 2022). As our data collection occurred during 2022-2023, residual effects of the pandemic and associated control measures may have continued to influence fever prevalence or reporting of fever cases. These factors highlight the need to consider the broader epidemiological and societal context when interpreting fever prevalence during this period.

The pattern of healthcare utilisation observed from our study suggested heterogeneity in healthcare accessibility across geographic locations. In Bangladesh and Cambodia, the source of care-seeking varied significantly across districts. A higher proportion of individuals in Chakaria, Bangladesh, and Palin, Cambodia, did not seek care. This suggested that access to healthcare varies substantially across neighbouring districts and remains limited in certain rural areas.

The choice of healthcare utilisation outside of public healthcare facilities suggests that existing surveillance systems likely under-capture fever cases. In Bangladesh and Cambodia, most fever cases were first managed by self-bought medicine or by seeking care at private healthcare facilities. Meanwhile, fever episodes accompanied by other symptoms, such as respiratory symptoms, were more likely to seek care at private facilities, whereas fewer cases sought care at public facilities. Conversely, more severe fever episodes were predominantly managed at public facilities. Since

national surveillance systems mainly rely on data from public healthcare facilities, incorporating alternative sources such as private clinics and pharmacies could enhance the representativeness of the population (Annear et al., 2015). An important application of healthcare utilisation data from cross-sectional surveys is adjusting facility-based case incidence to generate population-level estimates (Andrews et al., 2018). The healthcare utilisation pattern identified in our study emphasises the need to account for the type of healthcare facility involved in the facility-based study and the variations in care-seeking behaviour based on fever presentation. This can be done by expanding surveillance beyond the public sector to include common sources of care, such as pharmacies and private clinics. Incorporating data from these sources can improve surveillance coverage and yield more accurate estimates of disease burden.

There is scarce evidence on the seroprevalence of the pathogens included in our study from community-based studies in Southeast Asia (Zhang, Kozlowski, et al., 2024). Where data exists, reported seroprevalence varies within countries, influenced by analysing methods, geographic risk factors, and the year of study (Fritzell et al., 2018; Wang et al., 2016). Our findings aligned with these existing studies where direct comparisons are possible. While the transmission of malaria is low, there is an emerging epidemic of flaviviruses, scrub typhus, and *Rickettsia* infections (Bonell et al., 2017; Doum et al., 2020; Fox-Lewis et al., 2019; Gonwong et al., 2017, 2022; Laoprasopwattana et al., 2016; Limkittikul et al., 2022; Sudjaritruk et al., 2022; Tasak et al., 2023; Villarroel et al., 2024; Vongpunsawad et al., 2017).

Our study confirmed the current low transmission of malaria in Cambodia and Thailand, while higher transmission persists in Bangladesh. In Bangladesh, the seroprevalence of P. falciparum is 24%- much higher than the 6-10% seroprevalence in Cambodia and Thailand. In Cambodia and Thailand. In Cambodia and Thailand, the age-dependent seroprevalence was consistently low for *P. vivax* and *P. falciparum,* with an increase among older individuals. This finding might reflect higher malaria exposure in the past when transmission was more intense (Chhim et al., 2021). Previous studies have suggested in settings with low transmission,

repeated past exposure could result in long-lasting IgG levels (O'Flaherty et al., 2022; Wipasa et al., 2010; Yman et al., 2019). Additionally, it might also reflect the increasing risk of exposure with age due to prolonged periods of potential contact with malaria vectors. In Bangladesh, the elevated *P. falciparum* seroprevalence aligned with national data, indicating that approximately 70% of malaria cases are due to *P. falciparum* (Haldar et al., 2023). This is also consistent with the known endemicity of our study sites in Cox's Bazar and Bandarban- particularly the latter, part of the Chittagong Hill tracts, contributes to 80% of national malaria cases and showed significantly higher odds of seropositivity in our analysis. Bangladesh is currently implementing the National Malaria Elimination Program aims to eliminate malaria by 2030 in alignment with WHO goals (Ministry of Health & Family Welfare of Bangladesh, 2021) . This program prioritises high-burden districts like Bandarban and employs integrated strategies such as early diagnosis and treatment, vector control, community outreach, and strengthened surveillance. Additionally, ongoing clinical trials are also exploring other measures, such as malaria vaccination and mass drug administration (University of Oxford, 2025). Our findings are consistent with current knowledge of malaria transmission in the region, while confirming the need to tackle persistent transmission in Bangladesh.

Our findings demonstrated high seroprevalence in arboviruses, with DENV being the predominant arboviral infection, although in Cambodia seroprevalence was high for all arboviruses. In Cambodia and Thailand, DENV seroprevalence rose rapidly with age, reaching 100% by age 30 in Cambodia and above 80% by age 40 in Thailand. The WHO recommends the use of the pre-qualified dengue vaccination (Q-Dengue, Takeda) for children aged 6-16 years in high dengue transmission settings (The World Health Organization, 2024). Although the seroprevalence among nine-year-olds was around 50%, below the threshold used to define high transmission, the vaccination could still be considered as part of the strategy to control the disease (The World Health Organization, 2024). If vaccination is not introduced immediately, continued surveillance of transmission patterns remains essential. This will enable timely identification should the area reach high

transmission status, allowing for an early and informed response through targeted dengue vaccination campaigns. In Bangladesh, although dengue seroprevalence was lower than in Cambodia and Thailand, our study findings are consistent with national estimates (Salje et al., 2019). The *P. falciparum* seroprevalence observed in our study were also roughly similar to national estimates. Other evidence also suggests dengue is becoming endemic in Bangladesh, posing a new challenge to the health system (Kayesh et al., 2023). While elimination efforts are made for malaria in Bangladesh, strategies for dengue surveillance, control and prevention has increasingly drawn attention in public health priorities (Hossain et al., 2023). Notably, CHIKV seroprevalence was high in Cambodia but not in Thailand, potentially corresponding to a 2020 outbreak affecting the study areas in Cambodia (Rachmat et al., 2022).

High JEV seroprevalence among young children was observed in Thailand, while in Bangladesh and Cambodia, seroprevalence increased with age. This pattern likely reflects differences in JEV vaccination coverage. Thailand achieved 96% national coverage, but Bangladesh and Cambodia has yet to implement a consistent vaccination program covering our study areas (Sudjaritruk et al., 2022; Thigpen et al., 2022). Our findings aligned with existing evidence suggesting a routine JE vaccination program may be beneficial for the children in Bangladesh and Cambodia (K. K. Paul et al., 2020; Thigpen et al., 2022). However, our analysis showed a 66.7% JEV seroprevalence among Thai children under five, indicating lower-than-national vaccination coverage in our study areas. We also observed a dip in JEV seroprevalence among young Thai adults. Since we did not perform a 50% plaque reduction neutralisation titre test (PRNT50), we cannot determine whether this reflects an antibody titre falling below the protective level. However, the pattern may indicate suboptimal uptake of the second vaccine dose or the potential need for a booster. Future research is warranted to examine full vaccination coverage and to assess what proportion of the population remains underprotected. These findings highlight the importance of strengthening immunisation efforts and improving

surveillance to evaluate and guide vaccine strategy and coverage, particularly for arboviral diseases in endemic settings.

The seroprevalence of *O. tsutsugamushi* and *Rickettsia* was high in all three sites. While our findings align with prior knowledge of endemic areas of *O. tsutsugamushi* (Wang et al., 2024), data on seroprevalence is limited. Studies from Thailand have reported lower seroprevalence of both infections in different geographic areas (Chaisiri et al., 2022; Gonwong et al., 2022). In contrast, a recent study conducted in our study location, but only among the ethnic minority groups, reported a higher seroprevalence of *O. tsutsugamushi* (Linsuwanon et al., 2021). This suggests that while the environmental factors and lifestyle specific to ethnic minorities might contribute to an increased risk of *O. tsutsugamushi* infection, the broader population living in the study areas might also face similar risk factors and contribute to higher seroprevalence compared to the population living in other parts of Thailand (Tasak et al., 2023). Considering arthropod vectors transmit both infections, the risk of *O. tsutsugamushi* might also contribute to the high seroprevalence of *Rickettsia* (Low et al., 2020).

The differences in age-dependent seroprevalence of *O. tsutsugamushi* were also observed. In both Bangladesh and Cambodia, the seroprevalence increased consistently with age, with a more rapid increase in Cambodia. While IgG level could stay positive for 23.6 months after symptom onset (Aiemjoy et al., 2024), this pattern might suggest continuous exposure over a lifetime of the entire population. In Thailand, the slope peaked at around the age of 60 years reaching just over 40%. This indicates a different pattern of exposure, potentially reflecting a more limited proportion of the population being affected over time or a decrease in risk factors among older individuals. However, there is no recent study investigating risk factors for scrub typhus in Bangladesh or Cambodia, and the study in Thailand might not be directly applicable to our study population. These differences in age-dependent seroprevalence between the countries highlight the need for further studies to explore exposure patterns across the lifespan.

4. Self-reported fever, health-seeking behaviour, and seroprevalence of febrile pathogens

We identified a unique pattern of age-dependent seroprevalence for *Leptospira*. It was high among young children, declined to its lowest levels around the age of 30, and then increased with advancing age in all three sites. The seroprevalence observed in our study is similar to a study conducted among 18 to 30-year-old men in the north of Thailand (Gonwong et al., 2017), supporting the validity of our assay and cutoff definitions. However, this consistency in adult seroprevalence does not explain the peak among young children observed in our study. We were able to identify one seroprevalence study conducted in Malaysia, which included children and used ELISA commercial kits, and it did not report a similar pattern (Saha et al., 2019). The discrepancies might be associated with the differences in target antigens used in the tests. Our study used LigAni antigen, and commercial kits employed whole-cell antigens that might have poor sensitivity and fail to recognise local infectious strains (Maneewatchararangsri et al., 2021). Our finding might also reflect higher exposure to leptospiral at a younger age or potential cross-reactivity with other pathogens or vaccination. However, the exact mechanism underlining the antibody response to the LigAni antigen is unclear. Future studies are needed to explore these dynamics, particularly to clarify the mechanisms driving the high seroprevalence targeting the LigAni antigen among children.

We identified several risk factors for seropositivity across pathogens. Age was significantly associated with increased seroprevalence for most antigens, indicating an increased likelihood of exposure over time. Socioeconomic status has been well studied in relation to its association with exposure to febrile pathogens in Southeast Asia, with a higher wealth index as an acceptable indicator of adequate nutrition, better living conditions, clean water, and easier access to health care, thus reducing seroprevalence in higher socio-economic classes for febrile pathogens (Hotez et al., 2015). However, in our study, the association between the wealth index and seroprevalence showed varying directions of risk across pathogens. This could be partially attributable to the EquityTool used for wealth assessment, which used older references compared to the study's data collection period, making it less sensitive to the contemporary socioeconomic context (Metrics for Management, 2016; Metrics

for Management, 2022a). It could also be a more complicated dynamic between the household wealth status and pathogen-specific exposure risks associated with living conditions, occupational exposure, and access to healthcare facilities.

We observed pathogen-specific patterns associated with ethnicity in Bangladesh and Thailand, and geographic districts in all three countries. Ethnic minority groups in Thailand, districts outside of Palin in Cambodia, and Meung district compared to other districts in Thailand were associated with lower odds of seropositivity for arboviruses but higher odds for vector-borne bacterial infection. In particular, the lower odds of JEV seropositivity among ethnic minority groups in Thailand may reflect lower vaccination coverage in these populations (Apidechkul et al., 2016; Moonpanane et al., 2022). The associations in Bangladesh indicated that ethnic minorities and residents of Bandarban and Chakaria districts had higher odds of seropositivity across multiple pathogens. Notably, Bandarban- part of the mountainous Chittagong Hill Tracts and contributing to the majority of the country's malaria cases- may have higher exposure to vector-borne diseases, than flatter, less rural districts like Ukhyia (Haldar et al., 2023; Salje et al., 2019). Meanwhile, the associations with ethnicity might reflect specific cultures, farming practices, clothing, and environmental factors of ethnic minority groups, who typically reside far from the urban centre (Apidechkul et al., 2016; Tasak et al., 2023). These factors might contribute to different risks of exposure to various pathogens. Although geographic variations in the risk of infections between arboviruses and bacterial infections aligned with literature suggesting seroprevalence varies within a country (Fritzell et al., 2018; Wang et al., 2024), further geospatial analysis could be beneficial in identifying differential exposure patterns, detecting clusters with high responses to multiple pathogens, or diseases with widespread transmission. Characterising these spatial distributions could allow the development of appropriate control and surveillance for diseases with different transmission levels.

4.4.1 Limitations

Our results should be interpreted within the context of the limitations of the study design. We measured recent fever and healthcare-seeking behaviour by self-report over a 30-day recall period, which may be subject to recall bias. The household head might not accurately recall whether anyone in their household had fever or might misreport their care-seeking behaviour. In addition, the definition of fever may vary depending on individual perceptions and evaluation methods, including whether a thermometer was available and used. Healthcare-seeking behaviour can be affected by perceptions of illness, which may vary during outbreaks of diseases with overlapping manifestations (e.g., fever). It is worth noting that data collection primarily occurred in 2023, when the COVID-19 epidemic was under control, potentially reducing the influence of pandemic-related factors on health-seeking behaviour.

Seroprevalence studies remain a reliable empirical tool for assessing arboviral burden. However, the results should be interpreted with caution due to cross-reactivity among flaviviruses (i.e. DENV, JEV, ZIKAV) and alphaviruses (i.e. CHIKV) (Charrel, 2016; Fritzell et al., 2018; Haug et al., 2016). These cross-reactivity challenges are particularly pronounced in regions where multiple arboviruses cocirculate and JEV vaccination is administrated, as observed in our study areas. However, the multiplex assay used in the study targeted the NS1 protein of the flaviviruses, which has demonstrated improved specificity in serological assessment (Endale et al., 2021). We have also observed weak to moderate correlations in the MFI responses for arboviral antigens (Appendix D. Figure 2), providing support for the credibility of the seroprevalence estimate for individual pathogens. Nonetheless, we found that co-positivity for two or more arboviruses was common, particularly for DENV and JEV, where 42% of participants were positive for both (with or without being positive for other pathogens). While this could reflect high levels of transmission of both viruses, cross-reactivity cannot be entirely ruled out, especially given the JEV vaccination program in Thailand. These findings underscore the need for cautious

interpretation, especially in endemic regions with multiple arboviral exposures and overlapping vaccination coverage (Table 10, Appendix D).

Another limitation of the study was the difficulty in determining seropositivity cutoff without validation from a similar but presumed unexposed population or confirmatory tests. Despite this, we were able to determine reasonable cutoffs for all pathogens using the mixture model. Analysing quantitative antibody levels offers an alternative to seroprevalence, and potentially retains a higher resolution for the understanding of transmission patterns (Arnold et al., 2017). The similarities between the age-dependent antibody curves (Appendix D. Figure 1) and the age-dependent seroprevalence curve suggest that the cutoff derived from the mixture model was robust and provided accurate approximations of seroprevalence.

Finally, limited knowledge of antibody persistence may affect the interpretation of seroprevalence. While seroprevalence reflects cumulative exposures, without knowing the longevity, long-lasting antibodies may lead to overestimating recent transmission, whereas short-lived antibodies may underestimate the true exposure level. This uncertainty complicates efforts to distinguish between endemic and declining infections and to compare exposure levels across different age groups and regions. Since the longevity of IgG antibody varied across pathogens and is affected by factors such as exposure intensity and host genetics (Aiemjoy et al., 2024; Yman et al., 2019), future studies on longitudinal serological data to well-characterised antibody kinetics in these areas could enhance the accuracy of seroprevalence-based disease burden assessments.

4.5 Conclusion

This community-based survey, including the population of all ages, highlights the significant burden of non-malarial febrile illnesses in rural Southeast Asia, while malaria persists in Bangladesh. Our findings also indicate variations in health-seeking behaviour. The seroprevalence of nine pathogens, many of which have not been studied in similar settings, provided insights into the burden of

arboviruses and vector-borne bacterial infections at the population level. These findings emphasise the need for the integration of alternative data sources outside of the public sector to strengthen surveillance systems. They guide further research to expand knowledge on spatial variations in risk factors and antibody kinetics on specific antigens, for a better understanding of transmission dynamics and to inform targeted interventions.

5

Estimating enteric fever seroincidence in Cambodia

Chapter outline

This chapter estimated the seroincidence rate of enteric fever among children and young adults in Cambodia from the cross-sectional household survey. Using IgG and IgA responses to the hemolysin E (HlyE) antigen of *Salmonella enterica*, we employed an established antibody kinetics model. The findings demonstrated a high enteric fever seroincidence rate, suggesting a potential underestimation of enteric fever burden from previous facility-based blood culture surveillance studies. Age-specific and geographic variations were observed, with younger age groups and Koas Krala district showing higher seroincidence. We compared our findings to clinical incidence estimates from Cambodia and seroincidence estimates from other countries using the same methods. The findings were shared with policymakers to support the decision-making on introducing typhoid conjugate vaccination. The chapter also discussed the broad implications of using seroincidence in resource-limited settings for improving burden estimates of other infectious diseases.

5.1 Introduction

Enteric fever, caused by *Salmonella enterica* serovars Typhi and Paratyphi A, B, or C, remains common in low-income and middle-income countries (LMICs), especially in countries with poor water and sanitation infrastructures (Stanaway et al., 2019). Globally, there were an estimated 9 million cases in 2021 resulting in more than 100 thousand deaths, two-thirds of which were among children under 15 years (Global Burden of Disease Collaborative Network, 2022). Enteric fever incidence is most often estimated through clinical surveillance using blood culture-positive cases (Kuijpers et al., 2017; Thanh et al., 2016).

However, this approach has limitations, including the lack of diagnosis capacity in LMICs, the limited sensitivity of blood culture, and the under-capture of cases from individuals not seeking care at surveillance sites(Antillon et al., 2018). Recent advancements in measuring immune responses to Hemolysin E (HlyE) antigen of *Salmonella enterica* and the understanding of antibody kinetics have enabled the estimation of seroincidence rates from cross-sectional serosurveys (Aiemjoy et al., 2022). This novel approach yields population-level incidence estimates, offering an alternative to facility-based surveillance, particularly in settings where diseases are underdiagnosed.

Unlike the seroprevalence estimates of febrile pathogens presented in Chapter 4, which capture past exposure to infections based on cumulative IgG responses and ignore antibody decay over time, this chapter focuses on seroincidence, which estimates the rate at which new infections occur in the population. Incidence rates can provide valuable information to mathematical models and policy makers as they indicate where new infections are occurring most rapidly. To estimate the seroincidence rate, we implemented a novel approach that leverages antibody decay dynamics modeled from confirmed infections to approximate time since infection (Aiemjoy et al., 2022; P. F. M. Teunis et al., 2016; P. F. M. Teunis & Eijkeren, 2020). The approach also demonstrates how quantitative antibody response data, when integrated with antibody kinetics, can generate other robust

estimates of disease burden, a method that could be applied to other pathogens in future studies. SEACTN is contributing to this body of knowledge with a substudy aimed at modeling post-infection antibody kinetics to a variety of common pathogens in Southeast Asia by obtaining multiple sequential follow-up samples from febrile patients.

The World Health Organization (WHO) has recommended the programmatic use of typhoid conjugate vaccines (TCV) in endemic countries to prevent typhoid-related morbidity and mortality and reduce the use of antimicrobials for non-specific febrile illness (Andrews et al., 2019; World Health Organization, 2018c). Vaccination campaigns targeting children up to 15 years in LMICs have been suggested to maximise the benefit (Andrews et al., 2019). However, because of the aforementioned challenges with blood culture surveillance, many countries, including Cambodia, lack the population-level enteric fever burden data needed to justify vaccine introduction. Understanding the population-level unbiased occurrence of enteric fever, including geographic and demographic variations in burden, is important to effectively support and prioritize such immunisation programmes.

One of the thesis's core objectives was to estimate seroprevalence as a measure of cumulative exposure to infection. This chapter builds on that objective by demonstrating how cross-sectional survey data can also be used to estimate seroincidence— extending the application of serological data beyond exposure to provide insights into recent infections. Using enteric fever in Cambodia as a case study, we show how seroincidence estimation can complement traditional surveillance in settings where facility-based data are limited. Future work will aim to apply this approach to additional pathogens described in Chapter 4, further supporting the broader utility of seroincidence estimation methods in population-based studies.

5.2 Methods

With funding supported from PATH to generate evidence on typhoid epidemiology for Cambodia's national vaccination planning, this chapter focused on the study site in Cambodia and included all survey participants aged 5-25 years.

The seroincidence estimation methods were adapted from a study published previously (Aiemjoy et al., 2022), which developed a novel approach for estimating seroincidence from cross-sectional data, leveraging modelled antibody kinetics. This method includes quantifying IgA and IgG responses to HlyE of *Salmonella enterica* serovars Typhi and Paratyphi, and modelling antibody dynamics for up to two years post-infection using surveillance data across multiple endemic settings (Bangladesh, Pakistan, Nepal and Ghana). The within-host model was fit using longitudinal antibody responses measured from blood-culture-confirmed enteric fever cases aged 5–24 years, matching with our study population. The antibody kinetics parameters demonstrated high consistency across countries and clinical severity, thus allowing these parameters to be applied to different populations for the estimation of seroincidence in population-based samples.

In this study, samples were tested with the kinetic ELISA assays as described in Aiemjoy et al. (2022). Seroincidence was estimated using maximum likelihood profiles for ELISA responses of the survey participants against the fitted within-host two-phase model of antibody kinetics described by Aiemjoy et al. (2022), assuming Poisson-distributed time between incident infections. This approach allowed estimation of when infection likely occurred based on observed antibody levels. Unlike seroprevalence, which measures the proportion of individuals with positive antibody status at a single point in time, seroincidence incorporates the timing of antibody responses to estimate the rate of new infections over a defined period among the susceptible population. The seroincidence estimates were calculated using the serocalculator R package (P. Teunis et al., 2024). IgA and IgG responses to HlyE from our study participants were input into the serocalculator, stratified by age groups (5-15 years, 16- 25 years) and geographic district (Pailin, Koas

Krala, Rukhakiri, Samlot) (Chapter 2, Figure 2.1). The seroincidence estimates were reported per 1000 person-years with 95% confidence intervals, overall and by age groups and districts.

5.3 Results

A total of 529 participants were included in the analysis, of whom 71.1% (n=376) were aged 5-15 years (Table 5.1). Age distribution was consistent across districts. Quantitative ELISA response increased with age to both isotypes (Figure 5.1). Koas Krala had the highest HlyE IgG response across most of the age span compared to other districts, whereas Pailin had a higher IgA response among older individuals.

Table 5.1: Overview of the demographic characteristics of participants aged 5-24 years included in the typhoid seroincidence analysis in Cambodia

Characteristic	**Overall** N = 529	**Koas Krala** N = 136	**Pailin** N = 141	**RukhaKiri** N = 54	**Samlout** N = 198
Age	12 (8,17)	12 (8,16)	12 (8,18)	12 (9,15)	12 (8,17)
Age groups					
5-15	376 (71.1%)	99 (72.8%)	97 (68.8%)	42 (77.8%)	138 (69.7%)
16+	153 (28.9%)	37 (27.2%)	44 (31.2%)	12 (22.2%)	60 (30.3%)
Sex					
Female	241 (45.6%)	54 (39.7%)	61 (43.3%)	21 (38.9%)	105 (53.0%)
Male	288 (54.4%)	82 (60.3%)	80 (56.7%)	33 (61.1%)	93 (47.0%)

[1] Median (Q1,Q3); n (%)

The overall seroincidence rate of typhoid fever was 188.3/1000 person-years (95%CI: 172.6, 205.5) (Figure 5.2). Across districts, Koas Krala had the highest seroincidence (246.1/ 1000 person-years, 95%CI: 205.9, 294.2), followed by RukhaKiri (187.6/ 1000 person-years, 95%CI: 142.9, 246.3), Pailin (184.2/ 1000 person-years, 95%CI: 156.0, 217.4), and Samlout (162.3/ 1000 person-years, 95%CI: 140.8, 187.2).

Overall, individuals aged 16 years or older had a slightly higher seroincidence (210.6/ 1000 person-years, 95%CI: 175.8, 252.3) than children 5-15 years (181.8/

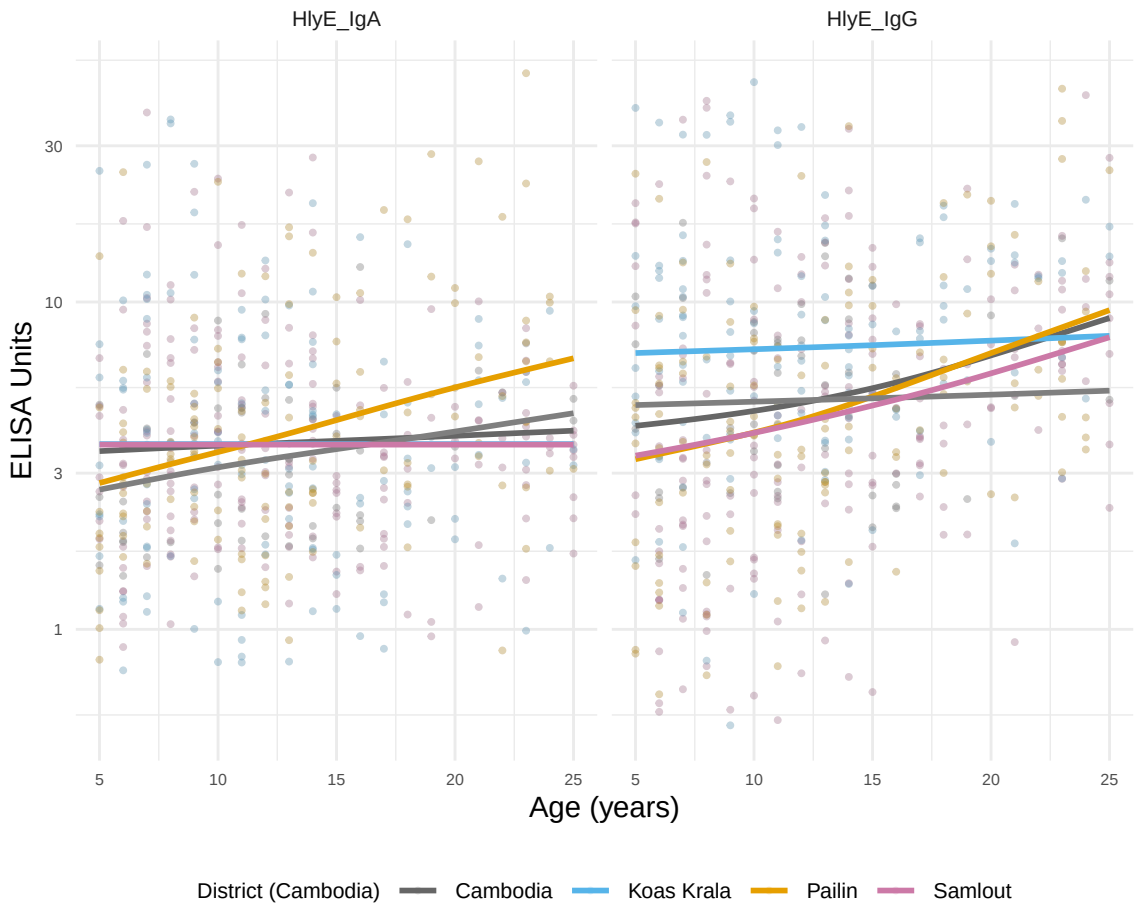


Figure 5.1: Age-dependent HlyE IgA and IgG ELISA units, overall and by districts

1000 person-years, 95%CI: 164.4, 201.1). However, this age-related pattern varied by district. In Koas Krala and Rukhakiri, children had higher seroincidence than older individuals, whereas in Pailin and Samlout, the opposite trend was observed. Among the younger age group, the highest seroincidence rate was in Koas Krala (254.4/ 1000 person-years, 95%CI: 208.1, 311.0), followed by Rukh Kiri (191.5/ 1000 person-years, 95%CI: 141.3, 259.6), Samlout (158.8/ 1000 person-years, 95%CI: 134.3, 187.7), and Pailin (184.2/ 1000 person-years, 95%CI: 156.0, 217.4).

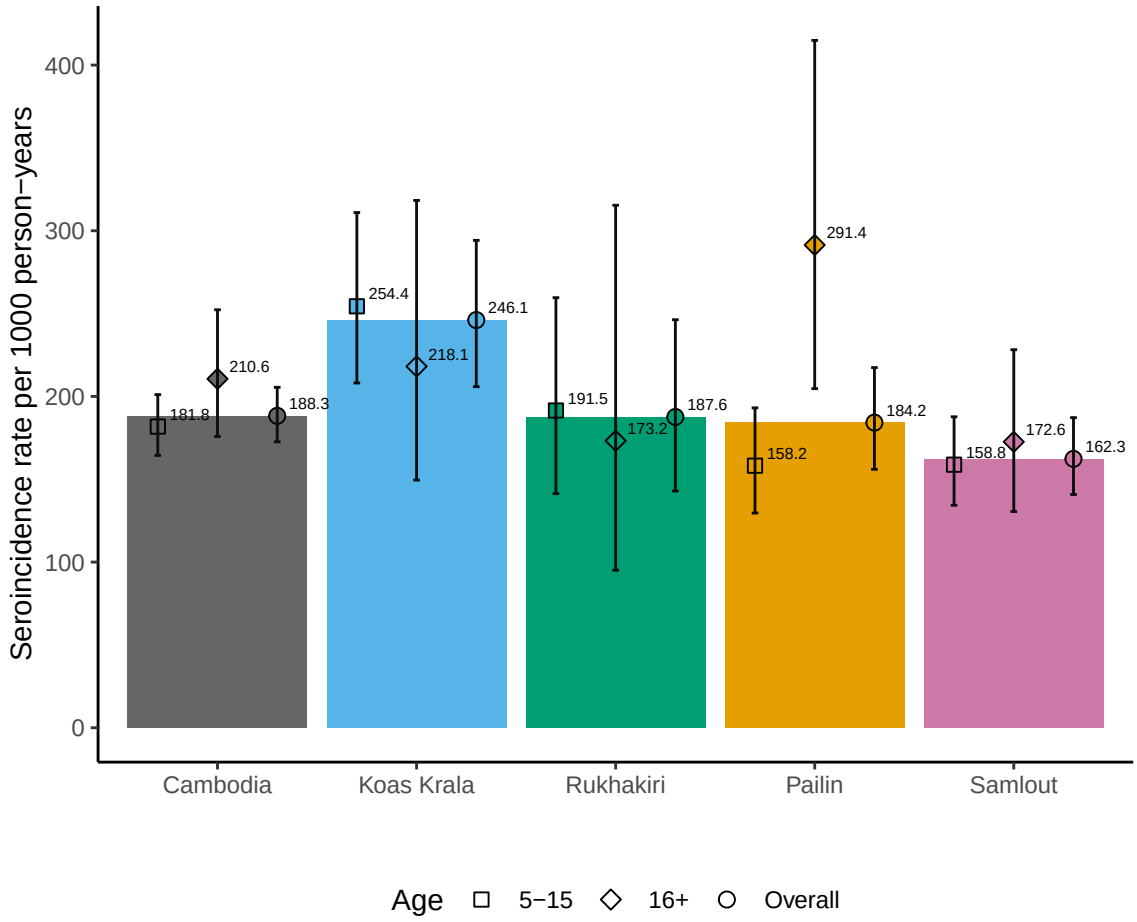


Figure 5.2: Estimated seroincidence of typhoidal Salmonella for Cambodia overall, by district and age group. Age groups are denoted by point shapes for the median, with lines indicating the 95% CI. Boxes reflect the height of the median estimate for the overall population-based serosurvey.

5.4 Discussion

To the best of our knowledge, this is the first study assessing the population-based seroepidemiology of enteric fever in Cambodia. We observed a seroincidence rate that was higher compared to findings from previous facility-based studies. The overall seroincidence rate among children and young adults was 188.3/ 1000 person-years, with the seroincidence rates among the 5-15 years ranging 184.2- 254.4/ 1000 person-years across geographic districts.

The Global Burden of Disease (GBD) study estimated a clinical incidence of enteric fever at 266/100,000 person-years among individuals under 20 in Cambodia,

meeting the definition of a high incidence setting (>100/ 100,000 person-years) (Crump et al., 2004; Global Burden of Disease Collaborative Network, 2022). Using the same seroincidence estimation methods, Aiemjoy et al. (2022) reported that the seroincidence rate was 16-32 times higher than prospective blood culture surveillance data in Bangladesh, Pakistan and Nepal. Applying this seroincidence-to-clinical incidence ratio, our findings suggest a clinical incidence rate in Cambodia may be 2-5 times higher than GBD estimates. Facility-based passive surveillance is known to underestimate clinical incidence due to variations in care-seeking behaviours, antibiotic use, and limited diagnostic sensitivity (Aiemjoy et al., 2022). It may also fail to capture mild and subclinical infections that do not require care. In addition, the accuracy of GBD estimates is limited by the lack of country-specific data (C. J. L. Murray, 2022). In the case of Cambodia, no enteric fever-specific datapoint from in-country studies was included (Institute for Health Metrics and Evaluation, 2021). Our findings highlight the value of seroincidence data in providing a more complete picture of disease burden in resource-limited settings.

Global and regional estimates highlight a high burden of enteric fever among children under 15 (Global Burden of Disease Collaborative Network, 2022; Stanaway et al., 2019). In Cambodia, this is further reflected in an estimated 356 annual deaths and 26,495 disability-adjusted life years lost due to the infection, with two-thirds occurring in this age group(Global Burden of Disease Collaborative Network, 2022). Our seroincidence estimates for children aged 5-15 years are consistent with this high burden and suggest an even higher level of transmission, corresponding to clinical incidence rates of 575- 1300/ 100,000 person-years across districts. For comparison, a prior hospital-based study in a neighbouring province reported a clinical incidence rate ranging from 62 to 1140/ 100,000 among children aged under 15 over a seven-year period (Thanh et al., 2016), while the GBD study estimated 234/ 100,000 person years among children aged 5-15 years in Cambodia (Global Burden of Disease Collaborative Network, 2022). The differences further demonstrated the potential for seroincidence estimates to better capture the true burden of new infections- often underestimated in facility-based culture surveillance- and provide

added evidence for TCV introduction decisions. These findings have been shared with PATH, a global health organisation supporting Cambodia's TCV introduction strategy and presented at the meeting with local health policymakers.

The identification of Koas Krala as a high-incidence district aligns with anecdotal reports from local health authorities regarding insufficient water, sanitation, and hygiene (WASH) infrastructure in the area during a meeting when we presented our preliminary findings, while the overall high seroincidence also corresponds to the insufficient WASH among our study population (Chapter 3). These findings highlight the utility of seroincidence studies for identifying high-risk geographic areas, informing targeted interventions on WASH improvements and vaccination prioritization.

An accurate enteric fever incidence estimate is particularly important in the context of rising antimicrobial resistance (AMR). A previous study in Cambodia found only 3.7% of febrile children had blood culture-confirmed typhoid fever, whereas combining multiple diagnostic methods (blood culture, PCR, and IgM FA and clinical assessment), more than 20% of these children were diagnosed (Wijedoru et al., 2012). This underscores the diagnostic challenge associated with enteric fever, which in return contributes to inappropriate antibiotic use and AMR development. Alarmingly, a recent study in Cambodia found that nearly 90% of Salmonella Typhi isolates from confirmed patients were multidrug-resistant(Kheng et al., 2020). In such a high-incidence, high-resistance setting, seroincidence estimation that captures underdiagnosed and asymptomatic infections could guide better evidence-based interventions, including the introduction of TCV to prevent antimicrobial misuse and resistance development.

This study highlights the applications of seroincidence estimation as a powerful surveillance tool, overcoming underreporting and diagnosis limitations in passive surveillance systems. By leveraging antibody kinetics and quantitative serological assays, this approach for seroincidence estimates could be expanded to other infectious diseases (Aiemjoy et al., 2024), offering a scalable tool for

disease surveillance in resource-limited settings, where traditional facility-based surveillance may be inadequate.

5.4.1 Limitations

This study has several limitations. First, due to compromised dried blood spot (DBS) samples, we were unable to include children aged under five, who carry a substantial burden of enteric fever. The results reported reflect combined exposure to *S. Typhi* and *S. Paratyphi*. Second, the serological assay cannot distinguish between *S. Typhi* and *Paratyphi* infections. As TCV only protects against *S. Typhi*, this limits the specificity of our findings for vaccine impact assessment. Lastly, the seroincidence model assumes a constant force of infection over time and does not account for potential seasonal variation in transmission. Given that data collection occurred over a nine-month period, seasonal variation may have influenced incidence estimates. Nonetheless, despite these limitations, our study provides population-based data on enteric fever seroepidemiolgy in a setting where such estimates are scarce.

5.5 Conclusion

Our study provides a robust community-based estimate of enteric fever seroincidence in rural areas in west Cambodia, indicating a substantially higher disease burden than previously reported. These findings underscore the urgent need for TCV introduction alongside improved WASH infrastructure and directly informed Cambodia's vaccination strategy. More broadly, this study demonstrates the power of seroincidence as a critical tool for infectious disease surveillance, particularly in understudied, high-burden settings.

6

The prevalence of chronic hepatitis B and hepatitis C

Chapter outline

This chapter explores the prevalence of and risk factors for chronic HBV and HCV infection in the study sites in Bangladesh, Cambodia and Thailand, addressing gaps in disaggregated data, particularly for rural populations and children. It begins with an overview of the WHO elimination goals, the current epidemiology landscape, and available diagnosis, prevention and treatment options for these diseases. Then it provides detailed analyses of HBV and HCV prevalence, highlighting key findings such as the lower HBsAg prevalence among individuals born after the introduction of national HBV vaccination programs and the higher HCV viraemia prevalence among older adults. It also evaluates HBV vaccination coverage among children under three, the prevalence of HBV-HCV coinfection, and awareness of infection status among those who tested positive. Furthermore, it investigates risk factors for HBV and HCV infections, identifying age and ethnicity as significant determinants. The chapter concludes by reflecting on the significance of these findings for identifying sub-national variations in disease prevalence and high-risk or vulnerable populations for infections. It emphasised the need for improved vaccination, screening, and treatment services in these rural areas to progress toward the elimination of HBV and HCV.

6.1 Introduction

In 2016, the World Health Assembly endorsed the "Global Health Sector Strategy on Viral Hepatitis 2016-2021" to eliminate viral hepatitis as a major public health threat by 2030 (World Health Organization, 2016). This strategy aimed to reduce hepatitis B and hepatitis C incidence by 90% and mortality by 65%, setting specific service targets such as increasing hepatitis B virus (HBV) vaccination coverage and improving diagnosis and treatment access for both infections (Table 6.1). Despite these goals, the World Health Organisation (WHO) estimated that in 2022, 254 million people worldwide are living with HBV and 50 million with hepatitis C virus (HCV), demonstrating the challenge in achieving these targets (World Health Organization, 2024c).

Table 6.1: Global Health Sector Strategy on Viral Hepatitis 2016-2021: Global targets for the viral hepatitis elimination goal.

Target area	2030 Target
Impact target	
Incidence: New cases of chronic viral hepatitis B and C infections	90% reduction (equivalent to 0.1% prevalence of HBsAg among children)
Mortality: Viral hepatitis B and C deaths	65% reduction
Service target	
Hepatitis B virus vaccination: childhood vaccine coverage (third-dose coverage)	90%
Prevention of hepatitis B virus mother-to-child transmission: hepatitis B virus birth-dose vaccination coverage or other approach to prevent mother-to-child transmission	90%
Blood safety	100% of donations are screened in a quality-assured manner
Safe injections: percentage of injections administered with safety-engineered devices in and out of health facilities	90%
Harm reduction: number of sterile needles and syringes provided per person who injects drugs per year	300
Viral hepatitis B and C diagnosis	90%

6. The prevalence of chronic hepatitis B and hepatitis C

Viral hepatitis B and C treatment	80% of eligible persons with chronic hepatitis B virus infection treated 80% of eligible persons with chronic hepatitis C virus infection treated

Note:
Source: World Health Organization. Global Health Sector Strategy on Viral Hepatitis 2016-2021: Towards Ending Viral Hepatitis. WHO Press; 2016.

Hepatitis B and hepatitis C are blood-borne viral infections affecting the liver, with chronic infection resulting from the body's inability to clear the virus after initial exposure. Chronic HBV and HCV infections lead to persistent viral replication and ongoing liver inflammation, which, if untreated, can progress to cirrhosis and hepatocellular carcinoma (HCC). Globally, chronic HBV and HCV infection are responsible for substantial mortality, with an estimated 1.1 million deaths attributable to HBV and 0.2 million to HCV each year (World Health Organization, 2024c). Populations at high risk of infections include individuals with a history of exposure to unsafe needles, frequent blood transfusions and improper sterilisation during procedures (Al-Mahtab, 2017; Lynch et al., 2021; World Health Organization, 2024b). Newborns and children are especially at risk through mother-to-child transmission of hepatitis B. However, effective prevention and treatment measures are available. HBV infection, particularly mother-to-child transmission can be prevented by vaccination, and antiviral treatments for HBV can effectively suppress viral replication, thus preventing the progression of cirrhosis and lowering HCC risk. For HCV, while many infections historically arose from unsafe medical practices, enhanced healthcare practices spurred by the HIV epidemic have contributed to improved awareness of blood-borne pathogens and reductions in HCV transmission in Southeast Asia (Wasitthankasem et al., 2016). More importantly, the direct-acting antiviral agent (DAA) treatments offer a cure to the infection.

In our study countries- Bangladesh, Cambodia, and Thailand, HBV and HCV infections are endemic. Bangladesh is among the top 10 countries with the highest infected populations, with about 7 million people living with chronic HBV infection,

and one million with chronic HCV (The CDA Foundation, 2024a, 2024d). In Cambodia and Thailand, approximately 0.5 million and 1.8 million people, respectively, live with chronic HBV, and 0.2 million and 0.4 million people respectively live with chronic HCV (The CDA Foundation, 2024c, 2024b, 2024f, 2024e). Annual deaths due to HBV are about 27,800 in Bangladesh, 1,300 in Cambodia, and 12,900 in Thailand (The CDA Foundation, 2024a, 2024c, 2024b). For HCV, annual deaths are approximately 3,300 in Bangladesh, 1,100 in Cambodia, and 2,000 in Thailand (The CDA Foundation, 2024d, 2024f, 2024e). Cirrhosis and other chronic liver diseases, often attributable to chronic HBV and HCV, are among the top causes of death and disability in these study countries, indicating a significant health burden (Vollset et al., 2024).

Bangladesh, Cambodia and Thailand have committed to the WHO global hepatitis elimination targets (Table 6.1). To support this goal, each country has developed national strategic plans (World Health Organization, 2024a). In addition, all three countries have implemented national HBV vaccination programs under the Expanded Program on Immunisation (EPI), with Thailand introducing the program in 1992 and Cambodia and Bangladesh following in 2005. However, at the current pace, it is estimated that these countries will not achieve all these goals by 2051 (The CDA Foundation, 2024a, 2024d, 2024c, 2024b, 2024f, 2024e). The delay is attributed to multiple barriers, including limited access to treatment, inadequate resources for population testing, and low community awareness about HBV and HCV (Heath & Hill, 2024). This situation is further complicated by a lack of disaggregated data on prevalence and disease burden, particularly in rural areas where more than half of the population resides and healthcare resource disparities are pronounced (Chongsuvivatwong et al., 2011; World Health Organization. Regional Office for South-East Asia, 2019b; World Health Organization. Regional Office for South-East Asia, 2019a; World Health Organization. Regional Office for the Western Pacific, 2018). In addition, data among children are scarce, limiting the ability to monitor vaccination progress

and establish effective strategies for the treatment of the paediatric population (Marjenberg et al., 2022; Schmelzer et al., 2020).

To address these gaps and support progress towards elimination goals, this chapter aims to provide disaggregated prevalence estimates for chronic HBV and HCV infection in rural populations, including children. It also estimated HBV vaccination coverage among children under 3 years and explored the risk factors associated with both infections.

6.2 Methods

6.2.1 Participants

All survey participants from Bangladeshi, Cambodian and Thai sites were included in the analysis. Based on the timing of the countrywide introduction of the Hepatitis B vaccine as part of the EPI, participants were categorised into two cohorts: a pre-EPI cohort (Thailand: born before 1992, >31 years; Bangladesh and Cambodia: born before 2005, >18 years), and post-EPI cohort (Thailand: born in 1992 or later, <=31 years; Bangladesh and Cambodia: born in 2005 or later, <=18 years).

6.2.2 Questionnaire interview

Household characteristics, including household wealth status and ethnicity, were obtained through the questionnaire interview with the household head. Adult participants provided additional information on their marital status, education level, and work status. In addition, adult participants were also asked to report any chronic diseases they had been previously diagnosed with, without being prompted about specific conditions. Interviewers recorded the responses based on predefined options, which included chronic HBV and HCV infections, liver cirrhosis, and liver cancer.

Guardians (e.g. parent, grandparent) of children younger than three years (aged 0-35 months) were asked about the vaccination history of their children, including

receipt of the hepatitis B vaccine. Age-appropriate vaccination receipt was assessed against country-specific EPI recommendations (Marjenberg et al., 2022). In Cambodia, the hepatitis B vaccine schedule includes doses at 0, 6, 10, and 14 weeks after birth (World Health Organization, n.d.). In Bangladesh, the schedule is similar, but it does not include the birth-dose. In Thailand, the schedule is at 0, 2, 4, and 6 months. Vaccination history was verified according to the vaccination card or other official documents presented by the guardian, and recorded by the interviewer. If documentation was unavailable, guardians were asked whether the birth-dose HBV vaccination had been given and this self-reported information was recorded.

6.2.3 Laboratory tests

For HBV infection, hepatitis B surface antigen (HBsAg) was detected by chemiluminescence microparticle immunoassay (CMIA) on the Alinity i system (Abbott, United States). HBsAg serves as a key marker for current HBV infections in endemic setting (2-5% HBsAg prevalence) (World Health Organization, 2024b). A positive HBsAg status indicates that an individual is currently infected with HBV but does not distinguish between acute and chronic infection. Serum samples were used for participants aged 5 years or older, according to the manufacturer's instructions. For children aged 6 months to 4 years old, dried-blood-spot samples (DBS) were used, using previously validated methods (Kenmoe et al., 2018).

Adult participants (15 years or older) were tested for HCV infection. Sera were tested for HCV antibody (Anti-HCV) by CMIA on the Alinity i system. Participants with positive anti-HCV were tested for HCV RNA on plasma samples using real-time PCR on Cobas 6800 (Roche Diagnostics, Switzerland). A positive anti-HCV status indicates prior exposure to the hepatitis C virus, but it does not differentiate between resolved and active infection. HCV RNA test could confirm active HCV infection when HCV RNA is detected. Anti-HCV positivity combined with detectable HCV RNA confirms ongoing viral replication and chronic infection.

6.2.4 Statistical analysis

Prevalence was estimated with 95% binomial exact confidence intervals (95%CI) for each country, and by age cohorts. For comparisons of prevalence between population groups, the chi-square test or Fisher's exact test was used.

Associations between HBV or HCV infection and demographic and socioeconomic status- including sex (man, woman), age groups (15-29, 30-39, 40-49, 50-59, and 60+), marital status (never/ not currently married, currently married/ cohabitating), education level (never attended school, primary school uncompleted, primary school completed, secondary school/ higher education), work status (agriculture, labourer, employee, unpaid work, don't know), and household wealth status (poor, middle, rich) and ethnicity in Bangladesh (Bengali, other) and Thailand (Thai, Akha, Lahu, other)- were investigated. Ethnicity was not assessed in Cambodia, as 97% of households identified as Khmer- the country's main ethnicity (see Chapter 3). These variables were selected based on published literature (Lynch et al., 2021; Posuwan et al., 2016; Upala et al., 2020; Yamada et al., 2007). Logistic regression models with household as random intercepts were used to assess the associations. Univariate analysis was conducted first, and variables with p-value<0.2 were included in the multivariable model (Mickey & Greenland, 1989). All multivariable models were controlled for age groups and sex. The events per variable (EPV) criteria, with an EPV of 10 or greater to confirm statistical power and model stability (Heinze et al., 2018). The variance inflation factor (VIF) was checked to avoid potential collinearity, ensuring VIF<5 (Fox & Monette, 1992). Crude odds ratio (cOR) and adjusted odds ratios (aOR) with 95% CI and their p-values are presented. For all analyses, p-values <0.05 were considered statistically significant.

6.3 Results

There were 1711 participants from the Bangladeshi site, 1461 participants from the Cambodian site and 1405 from the Thailand site aged six months or older who had

HbsAg test results (Figure 2.13, Table 6.2). Of these, 979 (57.2%) participants in Bangladesh, 842 (57.6%) participants in Cambodia, and 1,060 (75.4%) in Thailand belonged to the pre-EPI cohort, while 732 (42.8%) in Bangladesh, 619 (42.4%) in Cambodia and 345 (24.6%) in Thailand belonged to the post-EPI cohort. For the HCV prevalence analysis, 1138 participants in Bangladesh, 925 participants in Cambodia and 1198 in Thailand were aged 15 years or older and had anti-HCV results (Figure 2.13, Table 6.3). In Bangladesh, this included 906 (79.6%) participants aged 15–49 years and 232 (20.4%) aged 50 years or older. In Cambodia, this included 617 (36.1%) participants who were aged 15–49 years and 308 (18.0%) were aged 50 years or older. In Thailand, 448 (37.4%) participants were aged 15–49 years and 750 (62.6%) 753 were aged 50 years or older. Additionally, 127 participants from Bangladesh, 117 participants from Cambodia and 24 from Thailand who were under three years of age, had recorded vaccination histories (Table 6.4).

6.3.1 Hepatitis B prevalence

In Bangladeshi site, the overall prevalence of HBV infection was 2.6% (95%CI: 1.9-3.4), while In Cambodian site, it was 3.8% (95% CI: 2.8%, 4.9%), and in Thai site, it was 5.5% (95% CI: 4.3%, 6.8%) (Table 6.2). In all countries, the prevalence was higher in the pre-EPI cohort compared to the post-EPI cohort. In Bangladesh and Cambodia, the difference was significant (Bangladesh: pre-EPI cohort: 3.7%, post-EPI cohort: 1.1%, $p < 0.001$; Cambodia: pre-EPI cohort: 6.2%, post-EPI cohort: 0.5%, $p < 0.001$), while in Thailand it was borderline significant with a p-value equal to 0.06 (pre-EPI cohort: 6.1%, post-EPI cohort: 3.5%).

As shown in Figure 6.1 (A), the prevalence of HBV increased with age, peaking in the 40- to 49-year-old age group in all countries (40-49 years group: Bangladesh: 4.5%, 95%CI: 2.1%, 8.3%; Cambodia: 10%, 95%CI: 5.7%, 16.0%; Thailand: 12.4%, 95%CI: 8.3%, 17.7%). Among children younger than five years, four children in Bangladesh (n=4/204, prevalence in 0-4 years age group=2%, 95%CI: 0.5%, 4.9%) and one child in Cambodia tested positive (n=1/181, prevalence in 0-4 years age

group = 0.5%, 95%CI: 0, 3.0%), while no positive cases were detected in this age group in Thailand (n=0/53, prevalence=0, 95%CI: 0, 6.7%).

Table 6.2: Prevalence of HBsAg, overall and by the birth cohorts of the pre- and post-national introduction of the HBV vaccination programme. The numbers of cases are presented in brackets.

Group	N	Overall	95% CI	Pre-EPI	95% CI	Post-EPI	95% CI	p-value
Bangladesh	1,711	2.6 (44)	1.9- 3.4	3.7 (36)	2.6- 5.1	1.1 (8)	0.47- 2.1	<0.001
Cambodia	1,461	3.8 (55)	2.8- 4.9	6.2 (52)	4.6- 8.0	0.5 (3)	0.10- 1.4	<0.001
Thailand	1,405	5.5 (77)	4.3- 6.8	6.1 (65)	4.8- 7.7	3.5 (12)	1.8- 6.0	0.060

[1] % (n)

[2] Pearson's Chi-squared test

Abbreviation: CI = Confidence Interval

Note:

Bangladesh Pre-EPI: n=979, Post-EPI:n=732; Cambodia: Pre-EPI: n=842, Post-EPI: n=619; Thailand: Pre-EPI: n=1060, Post-EPI: n=345.

[*] p-value: Calculated to compare the prevalence between the pre EPI cohort and post-EPI cohort

[†] Post-EPI cohort: Participants born after HBV vaccination was introduced nationally as a part of the Expanded Programme on Immunisation (Bangladesh and Cambodia: 2005, Thailand: 1992). It includes participants who were 18 years or younger from Bangladesh and Cambodia, and those 31 years or younger from Thailand.

[‡] Pre-EPI cohort: Participants who were born before HBV vaccination was introduced nationally.

[§] EPI: Expanded Program on Immunisation

Table 6.3: Seroprevalence and viraemic prevalence of HCV among adult participants who were aged 15 years or older, overall and by age groups. The numbers of cases are presented in brackets.

Group	**Test**	**N**	**Overall**	**95% CI**	**15-49 years**	**95% CI**	**50+ years**	**95% CI**	**p-value**
Bangladesh	anti-HCV	1,138	0.7 (8)	0.30- 1.4	0.8 (7)	0.31- 1.6	0.4 (1)	0.01- 2.4	>0.9
	HCV viraemic	1,138	0.2 (2)	0.02- 0.63	0.2 (2)	0.03- 0.80	0.0 (0)	0.00- 1.6	>0.9
Cambodia	anti-HCV	925	5.4 (50)	4.0- 7.1	1.5 (9)	0.67- 2.8	13.3 (41)	9.7- 18	<0.001
	HCV viraemic	925	0.9 (8)	0.37- 1.7	0.3 (2)	0.04- 1.2	1.9 (6)	0.72- 4.2	0.019
Thailand	anti-HCV	1,198	1.2 (14)	0.64- 2.0	1.1 (5)	0.36- 2.6	1.2 (9)	0.55- 2.3	0.9
	HCV viraemic	1,198	0.2 (2)	0.02- 0.60	0.2 (1)	0.01- 1.2	0.1 (1)	0.00- 0.74	>0.9

[1] % (n)

[2] Fisher's exact test

Abbreviation: CI = Confidence Interval

Note:

Bangladesh: 15-49 years: n=906, 50+ years: n=232; Cambodia: 15-49 years: n=617, 50+ years: n=308; Thailand: 15-49 years: n=448, 50+ years: n=750.

[*] p-value: Calculated to compare the prevalence between the 1549 years and 50 years and older age groups

6.3.2 Hepatitis B vaccination history

Among children under 3 years, 44.9% (n=57) in Bangladesh, 49.6% (n=58) in Cambodia and 62.5% (n=15) in Thailand had completed age-appropriate hepatitis B vaccinations according to the vaccination cards (Table 6.4). In Bangladesh, 55.1% (n=70) did not present with a vaccination card or other document, with 48% (n=61) reporting not having received the birth dose. In Cambodia, 40.2% (n=47) did not present with a vaccination card, and 13.7% (n=16) reporting not having received the birth dose. In Thailand, 37.2% (n=9) did not present with a vaccination card, and 12.5% (n=3) reported not having received the birth-dose. In Cambodia, one child, aged 9 months, had not received any Hep B vaccinations according to the vaccination record, and the guardian confirmed that no birth dose was administered.

Table 6.4: HBsAg status and HBV vaccination status among children younger than 5 years old. HBsAg was tested among children aged 6 months to under 5 years, and the vaccination status was checked among all children under 3 years of age. Numbers are frequency (%).

Characteristic	**Bangladesh** N = 259	**Cambodia** N = 192	**Thailand** N = 55
Eligible for the test			
Had valid test results	204 (78.8)	182 (94.8)	53 (96.4)
HbsAg positive (among who had a valid result)	4 (2.0)	1 (0.5)	0 (0.0)
Eligible for checking vaccination records (age under 3 years)			
Age under 3 years	127 (100.0)	117 (100.0)	24 (100.0)
HepB vaccination status			
According to record- completed all	57 (44.9)	58 (49.6)	15 (62.5)
According to record- missing doses but had birth-dose	0 (0.0)	11 (9.4)	0 (0.0)
According to record- no vaccine recieved	0 (0.0)	1 (0.9)	0 (0.0)
Self-reported- at least birth-dose	9 (7.1)	31 (26.5)	6 (25.0)
Self-reported- no birth-dose	61 (48.0)	16 (13.7)	3 (12.5)

[1] n (%)

Table 6.4: HBsAg status and HBV vaccination status among children younger than 5 years old. HBsAg was tested among children aged 6 months to under 5 years, and the vaccination status was checked among all children under 3 years of age. Numbers are frequency (%). *(continued)*

Characteristic	Bangladesh N = 259	Cambodia N = 192	Thailand N = 55

Note:
HBsAg was tested among children 6 months to under 5 years; One child within the age range but did not have valid HBsAg results from Cambodia was excluded.
The vaccination records and history were only checked among children under 3 years.
Bangladesh: birth-dose HBV vaccine is not part of the routine vaccination for all children
* According to record: The vaccination card or other documents were checked, and the information was recorded according to the record.
† Self-reported: Among participants whose guardians did not present with a vaccination card or any documentation, guardians were asked whether the birth-dose HBV vaccination had been given and this self-reported information was recorded

6.3.3 Hepatitis C prevalence among adults

The HCV seroprevalence in the Bangladeshi site was 0.7% (95%CI: 0.3%-1.4%), and viraemia prevalence was 0.2% (95%CI: 0.02%, 0.6%) (Table 6.3). In the Cambodian site HCV seroprevalence was 5.4% (95%CI: 4.0%, 7.1%), and the viraemia prevalence was 0.9% (95%CI: 0.4%, 1.7%). In the Thai site, HCV seroprevalence was 1.2% (95%CI: 0.6%, 2.0%), and the viraemia prevalence was 0.2% (95%CI: 0, 0.6%).

In Cambodia, seroprevalence increased with age and peaked at 20.4% (95%CI: 13.1%, 29.5%) among individuals aged 60-69 years (Figure 6.1). This age-related trend was not observed in Bangladesh nor Thailand, where HCV prevalence was very low across all age groups. Among the younger age groups, one participant aged 18 years from Cambodia and one participant aged 18 years from Bangladesh tested positive for anti-HCV (prevalence of the age group 15-19 years: Bangladesh: 0.5%, 95%CI: 0, 2.9%; Cambodia:1.1%, 95%CI: 0, 5.7%) but was negative for HCV RNA test, indicating no chronic infection. No participants under 18 years old (ages 15-17) from either country tested positive for anti-HCV.

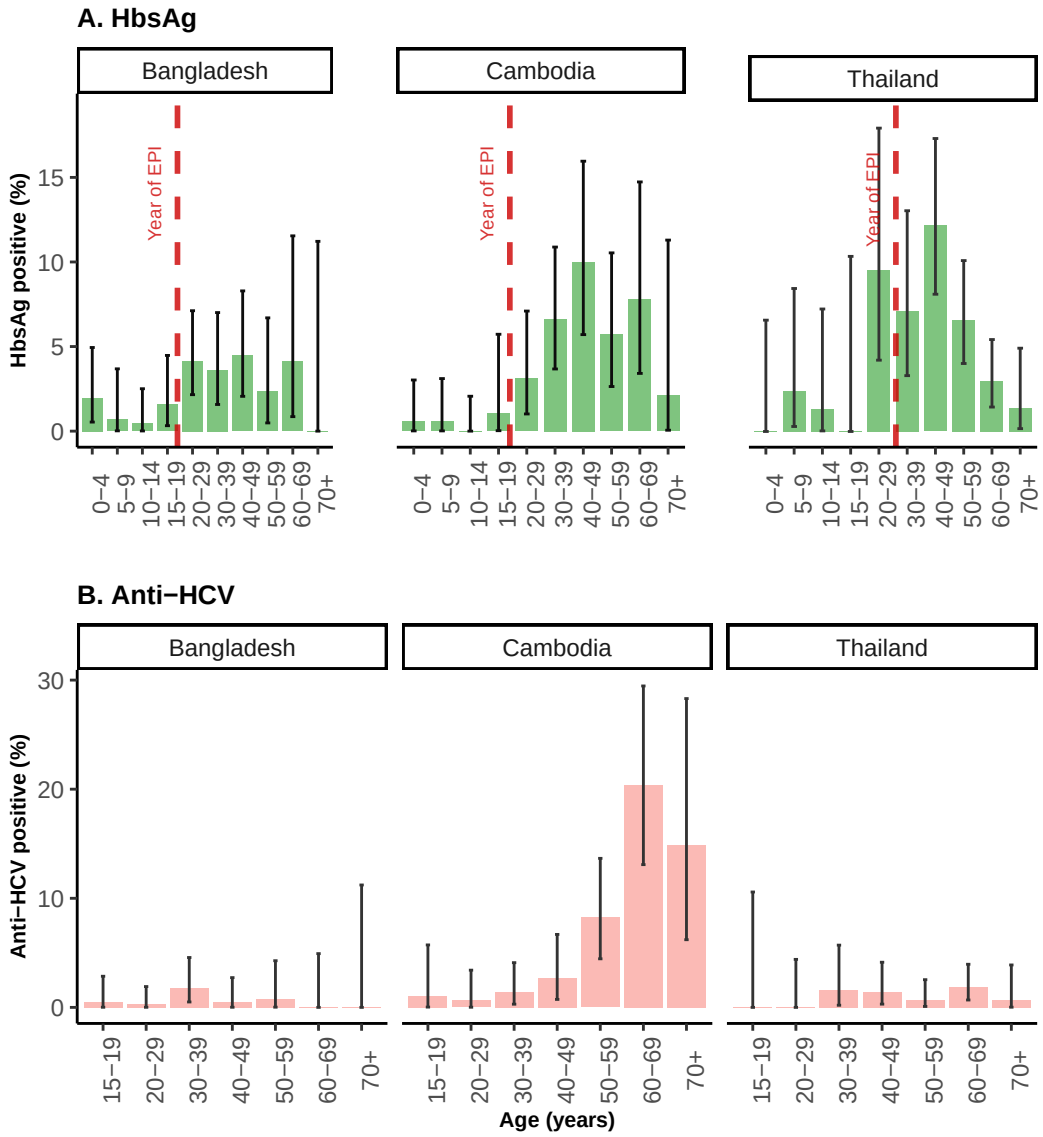


Figure 6.1: Proportion of participants with positive HBsAg (A) or anti-HCV status (B), by age group.
The bars indicate the proportion, with the black lines indicating the 95% confidence interval. In A, the red dotted lines indicate the year when HBV vaccination was introduced nationally in each country (Bangladesh and Cambodia: 2005, Thailand: 1992); and the age groups on the left side of the lines are individuals born after the introduction.(Bangladesh and Cambodia: 18 years or younger, Thailand: 31 years or younger)

6.3.4 Coinfection and self-reported disease history among adults

Among adult participants who tested for both HBV and HCV, none in Bangladesh, 0.3% (n=3) in Cambodia and 0.2% (n=2) in Thailand tested positive for both HBsAg and anti-HCV. None of the individuals were HCV viraemic. Self-reported previous diagnoses of chronic HBV infection were reported by one participant in Bangladesh who was HBsAg negative. In Cambodia, two participants, and in Thailand, six participants reported prior diagnoses of chronic HBV. Three participants from Cambodia and two from Thailand reported a prior diagnoses of chronic HCV. Among them, one participant in Cambodia and one in Thailand reported a history of both infections but tested negative for both HBsAg or anti-HCV. All other individuals with a self-reported disease history had either a positive HBsAg test or anti-HCV test corresponding with their reported condition. None of the participants with a reported history of chronic HCV infection were HCV viraemic. None of the participants in Bangladesh correctly reported prior knowledge of the infections.

Liver cirrhosis was reported by one participant from Bangladesh, and two participants each from Cambodia and Thailand. The participant from Bangladesh tested positive for HBsAg. Both participants from Cambodia and one from Thailand with a history of cirrhosis reported a prior chronic HCV status diagnosis and tested positive for anti-HCV, though none were viraemic. One participant from Bangladesh reported liver cancer. It was not reported by any participants from Cambodia and Thailand.

6.3.5 Risk factors

Associations between HBV or HCV infection and demographic and socioeconomic characteristics were examined among adult participants aged 15 years or older. In Bangladesh, adults from households with poor (aOR: 4.4, 95%CI: 1.2,16.6) or rich wealth status (aOR: 4.6, 95%CI: 1.4,15.4), compared to those from households with middle-level wealth status, had significantly higher odds of being HBsAg positive.

Conversely, coming from rich households was associated with decreased odds of anti-HCV positivity, although with borderline significance (aOR: 0.1, 95%CI: 0.0,1.1). In Cambodia, age was significantly associated with HBV and HCV infections. For HBV infection, participants aged 40-49 years had 3.8 times (95%CI: 1.2, 12.2) higher odds of being HBsAg positive compared to the reference group aged 15-29 years. For HCV, the odds of being anti-HCV positive significantly increased with age, particularly among those aged 50-59 years (aOR: 12.5, 95%CI: 2.4, 65.7) and those aged 60 years or older (aOR: 55.9, 95%CI: 9.7, 323.0). Adults who did not work had lower odds of being anti-HCV positive compared to those who worked in agriculture (aOR: 0.2, 95%CI: 0, 0.9). No other demographic or socioeconomic variables were significantly related to HBV and HCV infections in Cambodia (Table 6.6). In Thailand, being female was associated with reduced odds of being HBsAg positive (aOR: 0.4, 95%CI: 0.2, 0.8), while being Lahu ethnicity (aOR: 5.7, 95%CI: 1.3, 24.3), or belonging to other ethnic minority groups (aOR; 9.5, 95%CI: 2.7, 32.9) was associated with increased odds of HBV infection (Table 6.7). No significant risk factors for being anti-HCV positive were identified from the univariate analysis.

Table 6.5: The associations between HBV or HCV infection and the demographic and socioeconomic factors among adult participants in Bangladesh. The table includes both the crude (cOR) and the adjusted odds ratios (aOR) for HbsAg, and aOR for anti-HCV.

	HBsAg					Anti-HCV		
Variables	Freq	cOR (95%CI)	p-value	aOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Sex								
Male	19 (3.9%)	Reference				4 (0.8%)	Reference	
Female	19 (2.9%)	0.7 (0.4,1.5)	0.385	0.7 (0.4,1.4)	0.354	4 (0.6%)	0.7 (0.2,3.0)	0.671
Age group								
15-29	15 (3.1%)	Reference				2 (0.4%)	Reference	
30-39	8 (3.6%)	1.2 (0.5,3.2)	0.671	1.2 (0.5,3.1)	0.733	4 (1.8%)	4.4 (0.8,24.3)	0.087
40-49	9 (4.5%)	1.6 (0.6,4.0)	0.312	1.5 (0.6,3.8)	0.402	1 (0.5%)	1.2 (0.1,13.2)	0.885
50-59	3 (2.3%)	0.7 (0.2,2.8)	0.649	0.7 (0.2,2.6)	0.560	1 (0.8%)	1.9 (0.2,21.0)	0.604
60+	3 (2.9%)	1.0 (0.3,3.8)	0.993	0.9 (0.2,3.4)	0.847	0 (0.0%)	NA	NA
Ethnicity								
Bengali	28 (3.0%)	Reference				5 (0.5%)	Reference	
Other (Bangladesh)	10 (5.2%)	2.0 (0.8,4.9)	0.131	2.6 (1.0,6.7)	0.052	3 (1.6%)	3.0 (0.7,12.6)	0.137
Household wealth status								
Middle	4 (1.2%)	Reference				5 (1.6%)	Reference	
Poor	12 (3.8%)	3.3 (0.9,11.5)	0.064	4.4 (1.2,16.6)	0.028	2 (0.6%)	0.4 (0.1,2.1)	0.274
Rich	22 (4.4%)	4.0 (1.2,12.9)	0.022	4.6 (1.4,15.4)	0.013	1 (0.2%)	0.1 (0.0,1.1)	0.060
Marital status								
Never/not currently married	10 (3.1%)	Reference				3 (0.9%)	Reference	
Currently married/cohabitating	28 (3.4%)	1.3 (0.6,2.8)	0.586	–	–	5 (0.6%)	0.6 (0.2,2.7)	0.550
Education level								

Table 6.5: The associations between HBV or HCV infection and the demographic and socioeconomic factors among adult participants in Bangladesh. The table includes both the crude (cOR) and the adjusted odds ratios (aOR) for HbsAg, and aOR for anti-HCV. *(continued)*

Variables	HBsAg					Anti-HCV		
	Freq	cOR (95%CI)	p-value	aOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Secondary school completed/ higher	9 (3.4%)	Reference				0 (0.0%)	NA	NA
Never attended school	14 (3.7%)	1.2 (0.5,3.2)	0.691	–	–	0 (0.0%)	NA	NA
Primary school uncompleted	4 (2.3%)	0.7 (0.2,2.6)	0.613	–	–	4 (2.3%)	1.8 (0.4,7.3)	0.411
Primary school completed	11 (3.5%)	1.2 (0.4,3.2)	0.744	–	–	4 (1.3%)	Reference	
Work status								
Agriculture	5 (3.7%)	Reference				3 (2.2%)	Reference	
Labourer	7 (4.1%)	1.3 (0.3,4.6)	0.715	–	–	1 (0.6%)	0.3 (0.0,2.5)	0.242
Employee	8 (5.6%)	1.7 (0.5,6.3)	0.392	–	–	0 (0.0%)	NA	NA
Unpaid work	16 (2.5%)	0.7 (0.2,2.2)	0.552	–	–	4 (0.6%)	0.3 (0.1,1.3)	0.097
Don't work	2 (3.5%)	1.1 (0.2,6.6)	0.938	–	–	0 (0.0%)	NA	NA

Note:
This analysis included 1137 adult participants from Bangladesh. 1 participants did not complete the questionnaire excluded from this analysis.
For anti-HCV, only the univariate analysis was conducted, and the table included only the crude odds ratio. Multivariable risk analysis for HCV seroprevalence was not conducted due to the small number of cases
The reference level for the household size is 1-2 persons and for the education level is Secondary school completed/ higher for HBsAg. However, for anti-HCV, no participants from these groups had a positive status. The reference level household size was changed to 3-5 persons, and for education level was changed to Primary school uncompleted.

* Freq: n (%)

† Abbreviations: CI = Confidence Interval, aOR = Adjusted Odds Ratio, cOR = Crude Odds Ratio

Table 6.6: The associations between HBV or HCV infection and the demographic and socioeconomic factors among adult participants in Cambodia. The table includes both the crude (cOR) and the adjusted odds ratios (aOR).

	HBsAg					Anti-HCV				
Variables	Freq	cOR (95%CI)	p-value	aOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	aOR (95%CI)	p-value
Sex										
Male	31 (7.3%)	Reference				27 (6.4%)	Reference			
Female	22 (4.4%)	0.5 (0.3,1.0)	0.048	0.6 (0.3,1.2)	0.159	23 (4.6%)	0.7 (0.4,1.3)	0.218	0.7 (0.3,1.5)	0.373
Age group										
15-29	6 (2.3%)	Reference				2 (0.8%)	Reference			
30-39	14 (6.6%)	3.2 (1.1,9.0)	0.029	2.7 (0.9,8.6)	0.089	3 (1.4%)	1.8 (0.3,11.3)	0.536	1.6 (0.2,10.8)	0.654
40-49	15 (10.0%)	4.9 (1.8,13.7)	0.002	3.8 (1.2,12.2)	0.025	4 (2.7%)	3.9 (0.7,22.5)	0.134	3.8 (0.6,24.8)	0.156
50-59	9 (5.7%)	2.8 (0.9,8.4)	0.075	2.2 (0.6,7.5)	0.207	13 (8.2%)	12.9 (2.7,61.8)	0.001	12.5 (2.4,65.7)	0.003
60+	9 (6.0%)	2.8 (0.9,8.5)	0.072	2.2 (0.6,8.1)	0.225	28 (18.7%)	37.9 (8.0,180.4)	<0.001	55.9 (9.7,323.0)	<0.001
Household wealth status										
Middle	16 (6.4%)	Reference				14 (5.6%)	Reference			
Poor	8 (6.2%)	1.0 (0.4,2.7)	0.999	–	–	5 (3.9%)	0.7 (0.2,2.1)	0.486	–	–
Rich	29 (5.3%)	0.8 (0.4,1.7)	0.550	–	–	31 (5.7%)	1.0 (0.5,2.2)	0.953	–	–
Marital status										
Never/not currently married	6 (2.6%)	Reference				15 (6.4%)	Reference			
Currently married/cohabitating	47 (6.8%)	2.9 (1.2,7.0)	0.022	1.7 (0.6,4.8)	0.281	35 (5.1%)	0.8 (0.4,1.6)	0.538	–	–
Education level										

Table 6.6: The associations between HBV or HCV infection and the demographic and socioeconomic factors among adult participants in Cambodia. The table includes both the crude (cOR) and the adjusted odds ratios (aOR). *(continued)*

Variables	HBsAg					Anti-HCV				
	Freq	cOR (95%CI)	p-value	aOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	aOR (95%CI)	p-value
Secondary school completed/ higher	8 (4.0%)	Reference				9 (4.5%)	Reference			
Never attended school	14 (7.0%)	1.7 (0.7,4.5)	0.263	1.6 (0.5,4.9)	0.398	18 (9.0%)	2.3 (0.9,5.8)	0.078	0.7 (0.2,2.2)	0.562
Primary school uncompleted	17 (5.1%)	1.3 (0.5,3.2)	0.618	1.3 (0.4,3.5)	0.664	18 (5.4%)	1.2 (0.5,3.0)	0.633	0.7 (0.2,2.2)	0.581
Primary school completed	14 (7.4%)	2.0 (0.8,5.2)	0.162	2.4 (0.8,6.9)	0.102	5 (2.6%)	0.5 (0.2,1.8)	0.307	0.3 (0.1,1.3)	0.112
Work status										
Agriculture	25 (5.9%)	Reference				26 (6.2%)	Reference			
Labourer	9 (8.2%)	1.3 (0.5,3.3)	0.526	1.4 (0.5,3.6)	0.485	4 (3.6%)	0.6 (0.2,1.9)	0.360	0.6 (0.2,2.4)	0.498
Employee	9 (7.2%)	1.2 (0.5,2.8)	0.713	1.3 (0.5,3.5)	0.552	3 (2.4%)	0.4 (0.1,1.3)	0.122	0.4 (0.1,1.9)	0.253
Unpaid work	6 (2.7%)	0.4 (0.2,1.1)	0.068	0.6 (0.2,1.8)	0.405	13 (5.9%)	0.9 (0.4,2.0)	0.889	0.6 (0.2,1.6)	0.293
Don't work	4 (8.5%)	1.4 (0.4,4.6)	0.613	2.1 (0.5,8.6)	0.323	4 (8.5%)	1.4 (0.4,4.5)	0.622	0.2 (0.0,0.9)	0.040

* Freq: n (%)

† Abbreviations: CI = Confidence Interval, aOR = Adjusted Odds Ratio, cOR = Crude Odds Ratio

Table 6.7: The associations between HBV or HCV infection and the demographic and socioeconomic factors among adult participants in Thailand. The table includes both the crude (cOR) and the adjusted odds ratios (aOR) for HBsAg, and aOR for anti-HCV.

	HBsAg					Anti-HCV		
Variables	Freq	cOR (95%CI)	p-value	aOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Sex								
Male	43 (8.9%)	Reference				6 (1.2%)	Reference	
Female	31 (4.4%)	0.4 (0.2,0.8)	0.006	0.4 (0.2,0.8)	0.008	8 (1.1%)	0.9 (0.3,2.8)	0.862
Age group								
15-29	8 (7.0%)	Reference				0 (0.0%)	NA	NA
30-39	9 (7.3%)	1.6 (0.4,6.3)	0.538	1.5 (0.3,6.4)	0.589	2 (1.6%)	Reference	
40-49	26 (12.4%)	4.0 (1.2,13.6)	0.026	3.6 (0.9,13.8)	0.060	3 (1.4%)	0.9 (0.1,7.0)	0.958
50-59	19 (6.8%)	2.0 (0.6,7.0)	0.281	2.4 (0.5,10.7)	0.252	2 (0.7%)	0.4 (0.1,3.6)	0.443
60+	12 (2.6%)	0.5 (0.1,1.8)	0.302	0.8 (0.2,4.3)	0.826	7 (1.5%)	1.1 (0.2,6.2)	0.943
Ethnicity								
Thai	25 (3.5%)	Reference				7 (1.0%)	Reference	
Akha	6 (4.0%)	1.1 (0.3,4.3)	0.845	1.4 (0.3,6.7)	0.705	2 (1.3%)	1.4 (0.2,7.9)	0.706
Lahu	13 (11.1%)	4.5 (1.4,14.2)	0.010	5.7 (1.3,24.3)	0.020	3 (2.6%)	2.5 (0.5,12.2)	0.251
Other (Thailand)	30 (14.1%)	6.8 (2.7,17.5)	<0.001	9.5 (2.7,32.9)	<0.001	2 (0.9%)	0.9 (0.2,5.1)	0.930
Household wealth status								
Middle	25 (7.0%)	Reference				2 (0.6%)	Reference	
Poor	24 (6.2%)	1.0 (0.3,2.8)	0.967	–	–	7 (1.8%)	3.2 (0.6,17.4)	0.171
Rich	25 (5.6%)	0.8 (0.3,2.2)	0.623	–	–	5 (1.1%)	2.0 (0.4,11.5)	0.430
Marital status								
Never/not currently married	15 (5.2%)	Reference				3 (1.0%)	Reference	
Currently married/cohabitating	59 (6.5%)	1.5 (0.7,3.2)	0.340	–	–	11 (1.2%)	1.1 (0.3,4.4)	0.866

Table 6.7: The associations between HBV or HCV infection and the demographic and socioeconomic factors among adult participants in Thailand. The table includes both the crude (cOR) and the adjusted odds ratios (aOR) for HBsAg, and aOR for anti-HCV. *(continued)*

Variables	HBsAg					Anti-HCV		
	Freq	cOR (95%CI)	p-value	aOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Education level								
Secondary school completed/ higher	27 (6.7%)	Reference				4 (1.0%)	Reference	
Never attended school	18 (6.4%)	1.1 (0.5,2.6)	0.833	1.2 (0.4,4.3)	0.734	4 (1.4%)	1.5 (0.3,6.5)	0.619
Primary school uncompleted	6 (3.4%)	0.4 (0.1,1.2)	0.105	0.7 (0.2,2.7)	0.560	2 (1.1%)	1.1 (0.2,7.0)	0.885
Primary school completed	23 (6.8%)	1.8 (0.7,4.2)	0.206	2.5 (0.9,6.5)	0.069	4 (1.2%)	1.3 (0.3,6.0)	0.706
Work status								
Agriculture	54 (7.4%)	Reference				8 (1.1%)	Reference	
Labourer	4 (4.9%)	0.9 (0.2,3.7)	0.891	1.0 (0.2,4.4)	0.952	2 (2.5%)	2.9 (0.5,17.8)	0.251
Employee	10 (8.2%)	1.2 (0.4,3.5)	0.691	2.3 (0.7,7.1)	0.165	2 (1.6%)	1.6 (0.3,9.1)	0.588
Unpaid work	5 (2.9%)	0.3 (0.1,1.0)	0.049	0.6 (0.2,2.0)	0.391	1 (0.6%)	0.5 (0.1,4.7)	0.564
Don't work	1 (1.1%)	0.1 (0.0,1.1)	0.059	0.3 (0.0,3.2)	0.303	1 (1.1%)	1.1 (0.1,10.4)	0.935

Note:

This analysis included 1196 adult participants from Thailand. 2 participants did not complete the questionnaire, and 1 participant refused to answer marital status were excluded from this analysis.

For anti-HCV, only the univariate analysis was conducted, and the table included only the crude odds ratio. Multivariable risk analysis for HCV seroprevalence was not conducted due to the small number of cases

The reference level for the age group is 15-29 years for HBsAg. However, for anti-HCV, no participants from the 15-29 years group had a positive status. The reference level was changed to 30-39 years.

* Freq: n (%)

† Abbreviations: CI = Confidence Interval, aOR = Adjusted Odds Ratio, cOR = Crude Odds Ratio

6.4 Discussion

This study addressed a gap in disaggregated data on the prevalence of chronic HBV and HCV among rural populations and children in Bangladesh, Cambodia and Thailand. The findings showed a chronic HBV prevalence of 2.6% in Bangladesh, 3.8% in Cambodia and 5.5% in Thailand, while chronic HCV prevalence was 0.2 in Bangladesh, 0.9% in Cambodia and 0.2% in Thailand. Among children under five years, the prevalence of HBV was 2% in Bangladesh, 0.5% in Cambodia and 0% in Thailand, and no HCV cases were identified among adolescents aged 15-17 years in all countries. The study highlighted significantly higher HBV prevalence among individuals born before the introduction of national HBV vaccination programmes and higher HCV prevalence among adults aged 50 years or older. These findings emphasised the importance of subnational prevalence and targeting specific demographic groups to bridge the gaps in prevention, diagnosis and treatment.

The prevalence of HBsAg and HCV reported in this study aligned with some previous surveys, while significantly different from others. Sub-national geographic variations in HBV and HCV prevalence, as suggested by previous studies, may account for the discrepancies (Lynch et al., 2021; Posuwan et al., 2016; Wasitthankasem et al., 2016). For HBsAg prevalence, in Bangladesh, a meta-analysis estimated a prevalence of 4% in the general population (Banik et al., 2022). Although none of the individual studies were conducted in comparable rural settings, the two most recent studies in urban areas among adults workers reported 1.6% to 2.4% (Jinia Afroz et al., 2023; Jobayer et al., 2016). The differences may reflect variations in target populations and differences between urban and rural settings. In Cambodia, findings were consistent with a national survey conducted in 2017 that reported a 0.6% prevalence among children aged 5 -7 years and 4.4% among their mothers (Ork et al., 2019). A 2010-2012 study conducted in a neighbouring province found a 4.6% prevalence among adults (Yamada et al., 2007). In Thailand, HBsAg prevalence estimates differed from a national survey conducted in 2014, which reported much lower HBsAg prevalence among individuals born before (4.5%)

and after (0.6%) the national introduction of HBV vaccination (Posuwan et al., 2016). Compared to this study, our study presented about 6 times higher prevalence among the post-EPI cohort with persistent high HBsAg prevalence among those aged 20-29 years- born right after the vaccination was introduced nationally. The differences may be attributable to the inclusion of the hill tribe population in our study, who accounted for up to 40% of our participants (Chapter 3.3). Previous studies reported a 7.5% HBsAg prevalence among hill tribe adults and 1.9 % HBsAg prevalence among hill tribe youth aged 15-24 years, part of the post-EPI cohort (Apidechkul, 2019; Upala et al., 2020). Both estimates were higher than national estimates, likely due to higher risk behaviours, such as ear piercing and tattoos, combined with lower HBsAg vaccination coverage among hill tribe children.

For HCV prevalence, there is a lack of recent evidence among the rural population in Bangladesh. Our findings aligned with a study conducted in 2010 in Dhaka city, which estimated an anti-HCV prevalence of 0.9% (Mamun-Al-Mahtab et al., 2011). However, our results were lower than the modelled national HCV viraemia prevalence of 0.8% in 2022 (Ministry of Health and Family Welfare of Bangladesh, 2022). The differences may reflect variations in study populations as well as the limited availability of primary data sources, which can reduce the accuracy of modelled estimates. Nevertheless, our study helps to fill this evidence gap by providing population-based data from rural areas. Cambodia's findings aligned with one study in neighbouring villages but was different from another that reported half the seroprevalence (2.6%) in overlapping areas (Lynch et al., 2021; Yamada et al., 2007). These variations could be explained by geographic differences among health centre catchment areas. Notably, these studies estimated much higher viraemia rates (40%-72%) compared to our study (16%). This difference was likely due to some of our study participants having already been treated in the HCV screening and treatment programs introduced since the prior surveys, where all surveyed participants were linked to the program (Lynch et al., 2021; Zhang et al., 2021). In Thailand, our findings were consistent with a recent national HCV prevalence survey, which estimated a 0.9% seroprevalence in northern regions and

a national viraemia prevalence of 0.4%. These results emphasised the need for subnational and subregional data to capture variations in these burdens.

Vaccination, screening and treatment of children are vital for achieving the WHO's hepatitis elimination goals by 2030, both in their current life stage and as they progress to adulthood, where they may risk transmitting infection to peers. While modelling studies have estimated the prevalence of HBV and HCV among paediatric populations, the lack of empirical data from the general population negatively impacted the accuracy of the modelled results (Marjenberg et al., 2022; Schmelzer et al., 2020). Prevalence data on HBsAg among children under five years old is important for monitoring vaccination coverage and progress towards the elimination target of less than 0.1% HBsAg prevalence in this age group. Our study estimated an HBsAg prevalence of 2% in Bangladesh and 0.5% in Cambodia compared with 0% in Thailand, highlighting the need to reduce the incidence of HBsAg among children further in Cambodia. In addition, the vaccination coverage among children under 3 years in our study was lower than the WHO estimates for 2023 in both countries, with 50% in Cambodia and 63% in Thailand completing age-appropriate HBV vaccinations, compared with WHO estimates of 85% in Cambodia and 92% in Thailand, respectively (Global health Observatory, 2023). These findings indicate geographic variations in vaccination coverage and the need for localised efforts to address the disparities. Although HBsAg prevalence among Children in Thailand appears to have met the elimination target, both countries need to work towards achieving 90% vaccination coverage by 2030. The gap in HCV prevalence among children is concerning, especially in the context of the new WHO guidelines recommending DAA treatment for children ages 3 years or older using simplified HCV services delivery and point-of-care diagnosis tests (World Health Organization, 2022). While no HCV cases were identified among adolescents aged 15 to 17 years, our prevalence estimates provided a foundation for improving screening and treatment strategies.

Age was identified as an important risk factor for both HBV and HCV infections. HBsAg prevalence was lower among the post-EPI cohort compared to the pre-EPI cohort. Although it could be explained partially by the cohort effect, the implementation of the EPI program also led to the diminishing of HBsAg prevalence as suggested by previous studies (Ork et al., 2019; R. C. Paul et al., 2018; Posuwan et al., 2016). Among adults in all countries, the working-age group (40-49 years) had the highest prevalence, and in Cambodia, individuals from this age group had significantly higher odds of being HBsAg positive compared to those aged15-29 years. The findings corresponded to the 2014 Thai national HBV survey's findings (Posuwan et al., 2016). These individuals were born before the national vaccination programmes, and an increased risk of ongoing sexual transmission may contribute to their higher risk (Xu et al., 2023). For HCV, Cambodian adults aged 50 years or older had significantly higher odds of anti-HCV positivity, likely due to routine medical procedures, such as surgeries and blood transfusions performed before the 1990s, when awareness and practice of blood safety were less rigorous (Lynch et al., 2021; Yamada et al., 2007). These findings suggested that HBV screening could target working-age adults while HCV screening should prioritise the older population.

Socioeconomic characteristics such as education, work status, and household wealth status were not identified as significant risk factors, consistent with previous studies (Ork et al., 2019; Upala et al., 2020), except in Bangladesh, where households with either higher or lower wealth status were associated with higher odds of HBsAg positivity. No prior studies have reported such associations; commonly suggested risk factors in Bangladesh include history of vaccinations, treatment by non-qualified doctors, and shaving or haircut in barbershops, and ear piercing (Al-Mahtab, 2017). As our study did not collect information on these exposures, the observed associations with household wealth status may be confounded by these unmeasured factors. In Thailand, belonging to a hill tribe ethnic minority group was significantly associated with increased odds of HBsAg positivity. As also pointed out in the previous discussions, hill tribe populations often live in remote areas

and face barriers to healthcare access, including immunisation, due to distance, language, and stigmatisation (Apidechkul et al., 2016). These findings highlight the need for targeted strategies to improve healthcare equity for ethnic minorities.

Our study estimated that none in Bangladesh, only about 2-4% of individuals with HBV or HCV infection in Cambodia, and 7% in Thailand were aware of their infection status, reflecting the lack of adequate screening services in these areas. Consequentially, it created barriers to accessing treatment, contributing to the persistent burden of chronic hepatitis in these populations. The unmet treatment needs can be substantial. A modelling study estimated that 12% of community patients with positive HBsAg might need treatment (Tan et al., 2021). In the DAA era, the WHO recommended treatment for all individuals with chronic HCV (World Health Organization, 2018a; World Health Organization, 2022). In these rural areas, it is critical to expand screening services that identify and treat individuals with chronic infection to reduce the current burden and also to prevent the progression of liver disease and reduce the healthcare costs associated with advanced liver conditions.

6.4.1 Limitations

The number of positive HBsAg cases among children under 15 and HCV viraemic cases among adults was low, which limited our ability to conduct a robust examination of risk factors (Cohen, 1988). Nevertheless, these findings are valuable and indicate a lower burden of the diseases in these cohorts, which is consistent with the progress achieved through HBV vaccination programs and increased safety of medical practice since the 1990s. Meanwhile, it allows us to focus on adults age groups with a higher burden of HBV infection, and identify risk factors specific to these populations. The risk factors for HCV seropositivity are also informative as risk factors for infection. As spontaneous viral clearance occurred in about 25% of the individuals after the acute infection, the risk factors for anti-HCV positivity could still direct targeted screening strategy towards individuals at higher risk of infection. (Micallef et al., 2006).

While HBsAg positivity is a marker of chronic HBV infection in Southeast Asia, where HBV prevalence ranges from 2-5% (World Health Organization, 2024b), we cannot exclude the possibility that some participants experienced acute HBV infection at the time of the survey. However, given the cross-sectional nature of the study, we expect few such cases.

Lastly, the reliance on self-reported data for vaccination history and chronic disease status introduces the potential for recall bias and reporting inaccuracies. While efforts were made to verify vaccination history through documentation, a considerable proportion of participants lacked vaccination cards, which could affect the accuracy of the reported vaccination coverage. Adults with previously diagnosed chronic HBV or HCV infection might not recall or be reluctant to report their condition, especially without being prompted about specific diseases. This could lead to an underestimation of the proportion of infected individual who were aware of their status. Nevertheless, the information provided serves as a useful reference for identifying healthcare gaps and highlights areas requiring targeted intervention, while keeping these limitations in mind.

6.5 Conclusion

This study provides essential prevalence estimates of chronic HBV and HCV infection among the rural population in Bangladesh, Cambodia and Thailand and fills data gaps among children under five years for HBV prevalence and adolescents aged 15-17 years for HCV prevalence. Our study confirmed the findings on the higher prevalence of the older population, particularly the working-age who were born before HBV vaccination was introduced nationally for HBV infection, and who are 50 years or older for HCV infection. The lack of awareness among individuals with chronic HBV or HCV highlights the importance of increased screening and treatment services. Future interventions could also focus on improving healthcare access, including vaccination coverage, and ensuring equitable healthcare access in rural areas and for ethnic minority groups to achieve the 2030 elimination goals.

7

The prevalence and care cascade of non-communicable diseases

Chapter Outline

This chapter assesses the prevalence and care of non-communicable diseases (NCDs) among the adult population in the study sites in rural Cambodia and Thailand. It begins with an overview of the growing NCD burden in Southeast Asia, the current healthcare strategies, and the existing data collection system. The evaluation methods include self-reported risk behaviours and disease histories, physical examinations and laboratory tests. It first summarises self-reported risk behaviours, and the utilisation of disease screening services, followed by an age-stratified analysis of the prevalence of key NCD conditions and risk factors, including overweight and obesity, hypertension, diabetes, and raised total cholesterol. The chapter then evaluates the care cascade among participants with the diseases, assessing gaps in screening, diagnosis, treatment, and disease control. Furthermore, it assesses the prevalence of high 10-year cardiovascular disease (CVD) risk among participants aged 40-74. Finally, it investigates risk factors for NCD multimorbidity, focusing on age, BMI, and socioeconomic factors. The chapter concludes by confirming the substantial burden of NCDs in these rural populations, highlighting the age-related variations in disease burden for different diseases, the suboptimal care cascade and its impact on CVD risk, and the common risk factors that could inform screening priorities. It also emphasises the need for integrated services for lifestyle changes for NCD management.

7.1 Introduction

Non-communicable diseases (NCDs) are a major global health challenge. In 2021 NCDs were estimated to account for 60% of total disability-adjusted life years (DALY) worldwide, with the four main NCDs, cardiovascular diseases (CVD), cancers, diabetes and chronic lung diseases, making up 80% of premature NCD deaths (Global Burden of Disease Collaborative Network, 2022; Watkins et al., 2022). In Southeast Asia, NCDs have become the leading cause of mortality. In Cambodia, 60% of the total DALYs of people in the economically active age group (15-49 years), and 72% in the older population, were due to NCDs. In Thailand, the figures were 41% and 78%, respectively (Global Burden of Disease Collaborative Network, 2022).

Expanding primary healthcare to cover NCDs burden presents particular challenges to the health systems in Southeast Asia because they are geared towards addressing traditionally high-burden conditions like maternal and child health, acute infections, and tuberculosis (Allotey et al., 2014; Dans et al., 2011). The chronic nature of NCDs often requires protracted, regular contact with healthcare services, and for some conditions often lifelong treatment. The mitigation and care of NCDs requires multifaceted responses that combine health promotion, prevention, and interventions often resulting in lifestyle changes that may impact family dynamics, ability to work and household income. These responses can only be achieved by integrated service provision involving different levels of healthcare providers (O'Donnell et al., 2022).

Efforts have been made to address the NCD burden in Southeast Asian countries, but significant gaps remain along the care cascade, primarily due to limited resources. In Cambodia, the Second Health Strategic Plan (2008-2015) led to progressive interventions, including the establishment of NCD clinics in secondary hospitals, introducing the World Health Organization Package of Essential Non-Communicable Disease Interventions (WHO PEN) program at the primary healthcare level, and expanding the community-based peer educator network (Ministry

of Health of Cambodia, 2007, 2013; Olmen et al., 2016). However, these initiatives remain small-scale, covering less than 25% of secondary hospitals and less than 10% of primary healthcare centres (Chham et al., 2023). Consequently, service gaps in screening, diagnosis, and treatment adherence continue to impede effective NCD management. In Thailand, the health system is more advanced with full geographic coverage using primary healthcare units (PCU) and the provision of universal health coverage since 2002 (Tuangratananon et al., 2021). PCUs are responsible for NCD screening and surveillance with village health volunteers playing a critical role in connecting communities to PCUs. However, despite improved access, recent studies still exhibited substantial gaps in the care cascade, particularly lacking diagnoses and control of disease among patients with NCDs (Aekplakorn et al., 2018; Sakboonyarat et al., 2021; Sakboonyarat et al., 2023). The causes of these gaps can be multifaceted, but countries in Southeast Asia, including Cambodia and Thailand, face common challenges of inadequate financial resources, health workforce shortages, drug shortages, and weak health information systems, which might negatively affect the implementation and expansion of the comprehensive services for NCDs (Chham et al., 2023; Tuangratananon et al., 2021).

To effectively tackle the NCD epidemic, in addition to continuous health system strengthening, priorities should be established based on up-to-date prevalence estimates, identified service gaps, and the reported needs of populations from different geographic areas. Both Cambodia and Thailand have health information systems that capture key NCD indicators, but they are often fragmented and the reporting is inaccurate due to inconsistent data collection systems (Chham et al., 2023; Tuangratananon et al., 2021). Surveys, such as the World Health Organization's STEPwise Survey on Non-communicable Diseases (WHO STEP) and the Thai National Health Examination Survey, reporting national NCD prevalence and related factors, are conducted every four to five years (Aekplakorn et al., 2018; World Health Organization, 2017c), but more frequent updates are needed to monitor NCD care progress and to identify the next priorities. In this chapter, I aimed to assess the prevalence of NCDs and their risk factors in rural Cambodia

and Thailand, estimate healthcare coverage along the cascade and investigate risk factors for NCDs in these populations.

7.2 Methods

Adult participants (15 years or older) from all study sites with laboratory results were eligible for inclusion in the analysis of NCDs. Exclusion criteria included missing data on self-reported disease status or physical examinations and those who were 15-49 years old and self-reported being pregnant. Due to delays in sample shipment from Bangladesh, this chapter focuses only on the findings from Cambodia and Thailand for which the laboratory results were available.

7.2.1 Questionnaire interview

All adult participants were interviewed. Household wealth status and ethnicity were provided by the household head. Individual participants provided information on their socioeconomic status (age, sex, marital status, education level and work status), risk behaviours (tobacco smoking and alcohol use), and histories of NCDs and risk factors (measurements, diagnoses, and treatment for hypertension, diabetes, raised cholesterol, chronic lung disease, asthma, and cardiovascular diseases). The questions were primarily adapted from the WHO STEP Survey (World Health Organization, 2017c). Questions from widely implemented surveys, including the Demographic and Health Survey and the World Health Survey, used in the study countries or similar settings were also included (ICF, 2020; World Health Organization, 2003). Cards showing different types of alcohol and servings were used to assist in understanding and responses to the questions.

7.2.2 Physical examinations and laboratory tests

Anthropometric measures and blood samples were taken at the time of data collection by the field survey team and the local health centre nurse or village health volunteer. Weight was measured with a pre-calibrated electronic weighing scale

(SECA 872). Height was measured by using a stadiometer (SECA213). Blood pressure (BP) was measured using an automated sphygmomanometer (OMRON HEM-7121). Two cuff sizes were provided to ensure good fit and accuracy. Venous samples were collected and aliquoted at the site facilities and then sent to the central laboratory in Bangkok, Thailand. Serum samples were tested for total cholesterol (TC) by enzymatic method, and High-Density Lipoprotein (HDL) by Accelerator Selective Detergent method, and packed-red-blood-cells were tested for hemoglobin A1c (HbA1c) using the Enzymatic method. TC, HDL and Hba1c tests were performed on an Alinity c system (Abbott, United States).

7.2.3 Definitions of NCD conditions and risk factors

The definitions of NCD conditions and risk factors used in the study largely aligned with those used in the WHO STEP surveys (World Health Organization, 2017c). Current tobacco smoking was defined as someone who had smoked tobacco in the 30 days. Current alcohol use was defined as consuming any alcohol in the past 30 days, and binge drinking was defined as consuming six or more standard alcoholic drinks (e.g. one can of beer or a shot of spirit is considered as one standard drink) in a single occasion during the period. Current medication use was defined as participants taking medication prescribed by a health professional for a specific condition in the past 30 days.

Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared. BMI was classified as normal (18.5 to <25.0 kg/ m^2), overweight (25.0 to <30.0 kg/ m^2), and >30kg/m^2 as obese (World Health Organization, 2000), except for participants aged 15-17 years, where WHO's BMI-for-age criteria were used: normal weight (-2 standard deviation (SD) to +2SD), overweight (>1SD), obese (>2SD), underweight (<-2SD) (World Health Organization, 2007).

NCD status was determined using both laboratory test results and self-reported medication use to ensure a comprehensive assessment of disease prevalence. Hypertension was defined as systolic BP140 mm Hg and/or diastolic BP 90 mm Hg, or current use of antihypertensive medication (World Health Organization, 2017c).

Controlled hypertension was defined as individuals on treatment for hypertension with measured systolic BP<140mmHg and diastolic BP <90mmHg. Raised total cholesterol (TC) was defined as TC>=190mg/dL or currently using cholesterol-lowing medication (World Health Organization, 2017). Controlled TC was defined as individuals on cholesterol lowering treatment with tested TC<190mg/mL. Abnormal HDL was defined as HDL<=40mg/dL (Jellinger et al., 2017). Diabetes was defined as HbA1c>=6.5% or current use of insulin or other medications to control blood sugar (American Diabetes Association, 2013). Controlled diabetes was defined as individuals on treatment of diabetes with tested HbA1c<6.5%. Participants who had two or more NCD conditions or risk factors, among hypertension, raised TC and diabetes, were classified as having NCD multimorbidity (Academy of Medical Sciences, 2018; Asogwa et al., 2022).

7.2.4 Statistical analysis

Data were described as frequency with percentage for categorical variables, and median plus interquartile range (IQR) for continuous variables. Prevalence using total number of participants with non-missing data as denominator, with 95% binomial exact confidence intervals (95%CI), was calculated for each country and reported by age groups (<15 years, and 15 years or older). Comparisons between age groups were made using the chi-square test or Fisher's exact test.

The 10-year CVD risk was calculated for participants aged 40-74 without a self-reported history of heart disease, using both the Revised Pooled Cohort Equation (RPCE) (Yadlowsky et al., 2018) and updated WHO CVD laboratory-based risk chart for Southeast Asians (WHO CVD risk chart) (Kaptoge et al., 2019; World Health Organization, 2020a) (Table 7.1). RPCE for Caucasians was used to calculate the risk estimates for all study participants as no Asian-specific PRCE equation exists. The 10-year CVD risk indicated the likelihood of developing CVD in the next 10 years, categorised as low, intermediate, and high (Kasim et al., 2023). High risk was defined as 7.5% or higher score according to RPCE, or 20% or higher

WHO CVD risk score or blood pressure>160/100 mmHg or total cholesterol >=320 mg/dL according to the WHO CVD risk chart.

Table 7.1: Summary of the Revised Pooled Cohort Equation and the World Health Organization Cardiovascular Disease Laboratory-based Risk Chart for Southeast Asians

Tools	RPCE	WHO CVD risk chart
Endpoints	Non-fatal myocardial infarction, death from coronary heart disease, or fatal or non-fatal stroke over 10 years.	Fatal or non-fatal myocardial infarction or coronary heart disease (ICD10- codes I21-23). Fatal myocardial or coronary heart disease (ICD10- codes I24-25). Stroke (ICD10-codes 160-69).
Target age range	40 to 79	40 to 75
Target patient criteria	No history of CVD	No history of CVD
Variables	Gender, age, smoking status, systolic blood pressure, total cholesterol, HDL cholesterol, on hypertensive medication, diabetes mellitus.	Gender, age, smoking status, systolic blood pressure, total cholesterol, diabetes history
Outputs	10-year risk of atherosclerotic CVD	10-year risk of fatal and non-fatal CVD.
Risk classification	Low: <5% Intermediate: 5% to <7.5% High: >=7.5%	Low: <5% Intermediate: 5% to <20% High: >=20% or blood pressure >160/100 mmHg or total cholesterol >=320 mg/dL

Note:
RPCE: Revised Pooled Cohort Equation.
WHO CVD Risk Chart: World Health Organization Cardiovascular Disease Laboratory-based Risk Chart for Southeast Asians

Potential risk factors for NCD multimorbidity were identified in the published literature and assessed using logistic regression (Al-Zubayer et al., 2021; Somprasong et al., 2020; Upala et al., 2021). Risk factors included age groups (15-29, 30-39, 40-49, 50-59, and 60+), sex (male, female), marital status (never/ not currently married, currently married/ cohabitating), ethnicity (Thai, Akha, Lahu/Muser,

Other), education level (never attended school, primary school uncompleted, primary school completed, secondary school/ higher education), work status (agriculture, labourer, employee, unpaid work, don't know), and household wealth status (poor, middle and rich)), BMI status (Underweight, normal weight, overweight, obese), and health behaviours (tobacco smoking and alcohol use: never, current or former). Ethnicity was not assessed in Cambodia, as 97% of households identified as Khmer- the country's main ethnicity (Chapter 3). Univariate analysis was conducted first, and variables with p-value<0.2 were included in the multivariable model with adjustment for age groups and sex (Mickey & Greenland, 1989). The variance inflation factor (VIF) was checked to avoid collinearity, ensuring VIF<5 (Fox & Monette, 1992; N. Shrestha, 2020). The goodness of fit of the multivariable model was assessed using the Hosmer-Lemeshow test where the p-value was ensured to be bigger than 0.05 (Hosmer & Lemesbow, 1980). Crude Odds Ratios (OR) and adjusted odds ratios (aOR) with 95% confidence intervals (CI), and p-values were reported. A p-value<0.05 was considered significant for all tests.

The RPCE was calculated using the R package PooledCohort (Byron Jaeger, 2020).

7.3 Results

A total of 896 adult participants with laboratory results in Cambodia were included in this chapter, of whom 303 (33.8%) were aged 50 years or older, and 593 (66.2%) were between 15 and 49 years (Figure 2.13). In Thailand, 1174 adults with laboratory results were included, of whom 745 (63.5%) were aged 50 years or older and 429 (36.5%) were aged 15 to 49 years.

7.3.1 Self-reported risk behaviour, utilisation of NCD screening services, and disease history

The distribution of risk behaviours, healthcare utilisation, and self-reported disease history is detailed in Table 7.2. In Cambodia, 22% of participants reported current tobacco smoking, 35.5% reported current alcohol use, and 15.3% reported binge

drinking in the past 30 days. In Thailand, these behaviours were reported by a lower proportion of adults, with 13.7% of adults reporting current tobacco smoking, 36.2% reporting current alcohol use, and 7.3% reporting recent binge drinking. The highest prevalence of these behaviours was among middle-aged men in both countries. Among Cambodian men, those aged 50-59 reported the highest proportion of current tocacco smoking (73.3%), and those aged 30-39 years reported the highest proportion of current alcohol use (87.0%) and recent binge drinking (50%) (Figure 7.1). In Thailand, men aged 30-39 had the highest proportion of current tobacco smoking (40.4%), while those aged 50-59 years had the highest proportion of alcohol use (68.3%). However, binge drinking was most common among younger adult in Thailand (15-29 years: 24.5%).

Regarding NCD screening, only 12.7% of Cambodian adults reported ever having their cholesterol measured, but more than half (51.7%) having their blood pressure measured, and over a quarter (26.8%) reported having had blood sugar checked (Table 7.2), indicating fair utilisation of healthcare services. In Thailand, the proportion of participants who had undergone these screening services was higher, with 62.8% having their cholesterol measured previously, 93.2% having their blood pressure measured, and 83.3% having their blood sugar measured.

Self-reported chronic disease history also varied between the two countries. In Cambodia, 10.0% reported having had a diagnosis of chronic lung disease, 1.6% of asthma, and 9.4% had experienced a heart attack, chest pain, or stroke (Appendix E Table 1). In Thailand, 1.7% reported chronic lung disease, 2.5% asthma, and 4.3% a history of cardiovascular event.

Table 7.2: Self-reported risk behaviour, and history of screening for raised cholesterol, hypertension, and diabetes among adult participants, overall and by age group

	Cambodia			Thailand		
Variables/ Age group (years)	**Overall** N = 896	**15-49** N = 593	**50+** N = 303	**Overall** N = 1,174	**15-49** N = 429	**50+** N = 745
Risk behaviour						
Tobacco smoking						
Current	197 (22.0)	101 (17.0)	96 (31.7)	161 (13.7)	66 (15.4)	95 (12.8)
Former	71 (7.9)	32 (5.4)	39 (12.9)	166 (14.1)	35 (8.2)	131 (17.6)
Never	628 (70.1)	460 (77.6)	168 (55.4)	847 (72.1)	328 (76.5)	519 (69.7)
Alcohol use						
Current	318 (35.5)	248 (41.8)	70 (23.1)	425 (36.2)	168 (39.2)	257 (34.5)
Former	192 (21.4)	117 (19.7)	75 (24.8)	280 (23.9)	100 (23.3)	180 (24.2)
Never	386 (43.1)	228 (38.4)	158 (52.1)	469 (39.9)	161 (37.5)	308 (41.3)
Binge drinking in the past 30 days						
Yes	137 (15.3)	120 (20.2)	17 (5.6)	86 (7.3)	40 (9.3)	46 (6.2)
No	735 (82.0)	455 (76.7)	280 (92.4)	762 (64.9)	266 (62.0)	496 (66.6)
Don't know	24 (2.7)	18 (3.0)	6 (2.0)	326 (27.8)	123 (28.7)	203 (27.2)
History of screening						
Cholesterol ever measured	114 (12.7)	62 (10.5)	52 (17.2)	737 (62.8)	194 (45.2)	543 (72.9)
Blood pressure ever measured	463 (51.7)	245 (41.3)	218 (71.9)	1,094 (93.2)	386 (90.0)	708 (95.0)

Blood sugar level ever measured	240 (26.8)	123 (20.7)	117 (38.6)	978 (83.3)	299 (69.7)	679 (91.1)

[1] n (%)

Note:
Participants who had incomplete physical examination, laboratory test, or questionnaire interview results were excluded from the analysis (Cambodia=17, Thailand=11).

[*] Binge drinking: Had 6 or more standard alcohol drinks on any occasion in the past 30 days

[†] Currently taking medication: Had been taking medication prescribed by a health professional to treat the corresponding disease in the past 30 days

7.3.2 Prevalence of overweight, obesity, raised TC, hypertension, and diabetes

Table 7.3 summarises the prevalence of key NCDs based on physical examinations, laboratory test results, and self-reported treatment, while the breakdown is included in Appendix E (Table 1). In Cambodia site, 28.8% (95% CI: 25.8–31.9%) of adults were overweight or obese, with obesity alone affecting 5.6% (95% CI: 4.2–7.3%). The prevalence of raised TC was 45.4% (96%CI:42.1%-48.8%), hypertension was 19.4% (95%CI: 16.9%-22.2%), and diabetes was 5.6% (95%CI: 4.2%-7.3%). In Thailand site, the prevalence of overweight and obesity was higher, at 37.5% (95% CI: 34.7–40.3%), with 10.0% (95% CI: 8.3–12.0%) classified as obese. The prevalence of raised TC was 40.8% (95%CI: 38.0%-43.7%), hypertension was 44.0% (95%CI: 41.1%-46.8%), and diabetes was 12.8% (95%CI: 10.9%-14.8%). Multimorbidity was detected in 14.8% of Cambodian adults (95%CI: 12.6-17.3) and 25% (95%CI: 22.6%-27.6%) of Thai adults.

In both countries, among participants aged 50 years or older, the prevalence of hypertension, diabetes, and multimorbidity was significantly higher compared to those aged 15-49 years (Table 7.3). In addition, in Cambodia, the prevalence of raised TC was also significantly higher among older participants. In Thailand, the prevalence of overweight and obesity was significantly lower among older adults (34.9%) compared with younger adults (42.0%, p=0.016), while the prevalence of raised TC did not differ significantly by age.

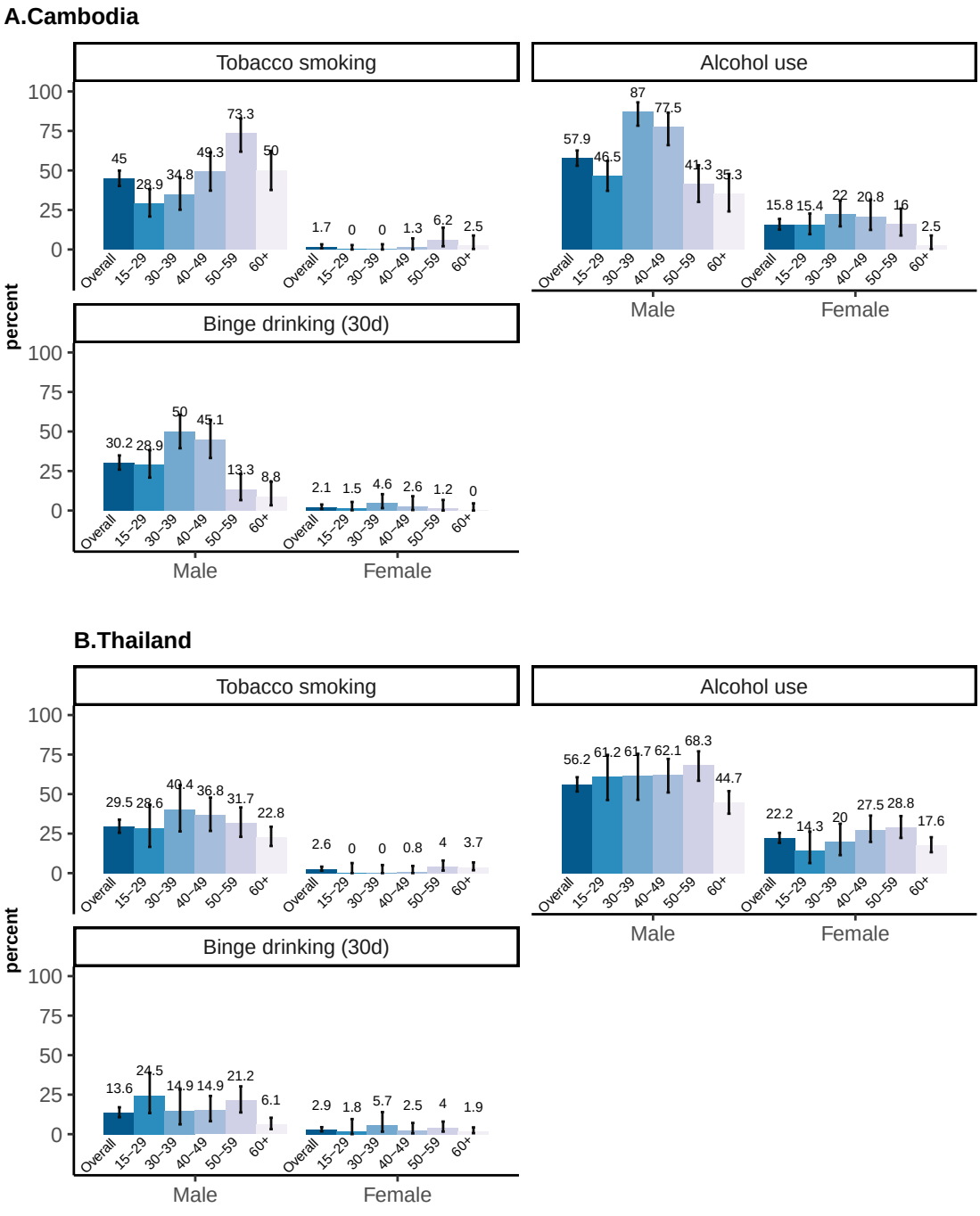


Figure 7.1: Proportion of participants reported with current tabacco smoking,alcohol use, and binge drinking in Cambodia (A) and Thailand (B), by sex and age group

Table 7.3: Prevalence of overweight and obesity, raised total cholesterol, hypertension, diabetes, and multimorbidity among adult participants, overall and by age group.

Disease	Overall	95% CI	15-49 years	95% CI	50+ years	95% CI	p-value
Cambodia							
Overweight& Obese	28.8 (258)	25.8- 31.9	29.8 (177)	26.2- 33.7	26.7 (81)	21.8- 32.1	0.3
Obese	5.6 (50)	4.17- 7.29	5.6 (33)	3.86- 7.73	5.6 (17)	3.30- 8.83	>0.9
Raised TC	45.4 (407)	42.1- 48.8	40.1 (238)	36.2- 44.2	55.8 (169)	50.0- 61.5	<0.001
Hypertension	19.4 (174)	16.9- 22.2	10.6 (63)	8.26- 13.4	36.6 (111)	31.2- 42.3	<0.001
Diabetes	5.6 (50)	4.17- 7.29	2.0 (12)	1.05- 3.51	12.5 (38)	9.03- 16.8	<0.001
Multimorbidity	14.8 (133)	12.6- 17.3	6.7 (40)	4.86- 9.07	30.7 (93)	25.5- 36.2	<0.001
Thailand							
Overweight& Obese	37.5 (440)	34.7- 40.3	42.0 (180)	37.2- 46.8	34.9 (260)	31.5- 38.4	0.016
Obese	10.0 (117)	8.31- 11.8	14.0 (60)	10.8- 17.6	7.7 (57)	5.85- 9.80	<0.001
Raised TC	40.8 (479)	38.0- 43.7	40.8 (175)	36.1- 45.6	40.8 (304)	37.3- 44.4	>0.9
Hypertension	44.0 (516)	41.1- 46.8	23.3 (100)	19.4- 27.6	55.8 (416)	52.2- 59.4	<0.001
Diabetes	12.8 (150)	10.9- 14.8	5.8 (25)	3.81- 8.48	16.8 (125)	14.2- 19.7	<0.001
Multimorbidity	25.0 (294)	22.6- 27.6	15.2 (65)	11.9- 18.9	30.7 (229)	27.4- 34.2	<0.001

[1] % (n)

[2] Pearson's Chi-squared test

Abbreviations: CI = Confidence Interval, NA

Note:

p-value: Calculated to compare the prevalence between the 1549 years and 50 years and older age groups

[*] Multimorbidity: two or more NCD conditions or risk factors among raised TC, hypertension, diabetes

[†] TC: Total cholesterol

A detailed examination of disease prevalence across age groups showed an increasing trend with age for hypertension and diabetes in both countries. The prevalence of these conditions was highest among individuals aged 60 years or older, with hypertension at 43.5% and diabetes at 13.6% in Cambodia, and hypertension at 60.1%, and diabetes at 17.7% in Thailand (Figure 7.2). In addition, in Cambodia, raised TC was also most prevalent in this age group (56.5%). In contrast, overweight and obesity peaked among individuals aged 40–49 years, with a prevalence of 41.2% in Cambodia, and 45.4% in Thailand. The highest prevalence of raised TC in Thailand was observed among individuals aged 50-59 years (48.4%).

7.3.3 Care cascade

Gaps were identified at various stages of the care cascade, particularly for raised total cholesterol. In Cambodia site, only 17.9% of individuals with raised TC (n=407) ever had their cholesterol measured, 7.4% had been diagnosed, and only 1.0% were on cholesterol-lowering medication (Figure 7.3). In Thailand site, the screening rate was higher with 61.8% of individuals with raised TC (n=479) measured, 12.3% having been diagnosed, and 9.2% currently taking medication. However, in both countries, one of the participants with TC had achieved disease control.

The care cascade for hypertension and diabetes showed higher levels of engagement. In Cambodia, 71.3% of hypertensive individuals (n=174) and 72.0% of those with diabetes (n=50) reported having their blood pressure or blood sugar measured. In Thailand, these proportions were even higher, with 95.3% of individuals with hypertension (n=516) and 97.3% with diabetes (n=150) having these measurements. Despite this, the proportion of individuals receiving services along the care cascade declined at each stage, and a substantial number remained uncontrolled. In Cambodia, 23.6% of hypertensive participants and 12.0% of those with diabetes had achieved disease control. In Thailand, these figures were 26.7% and 23.3%, respectively.

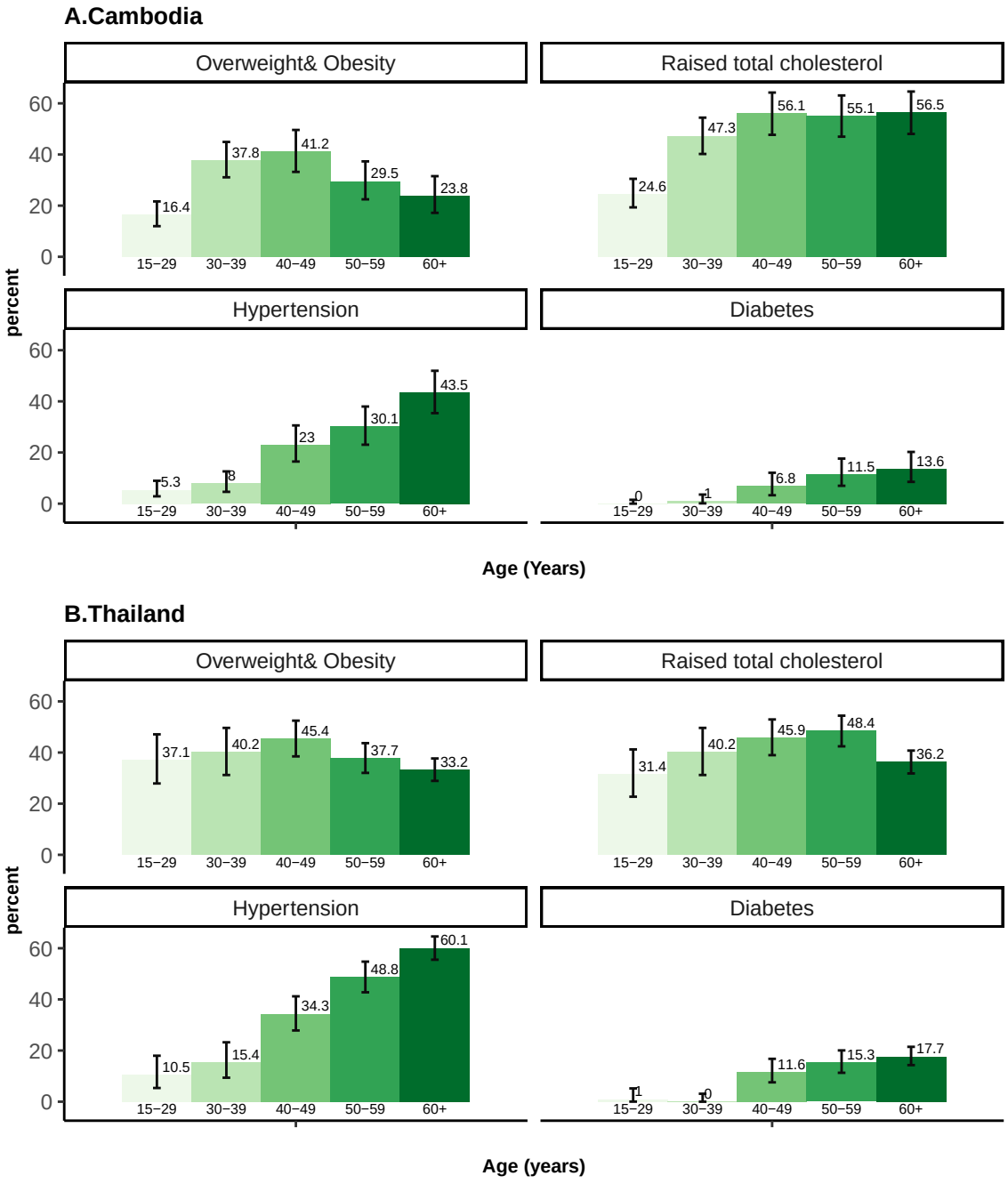


Figure 7.2: Proportion of participants who had overweight and obesity, raised total cholesterol, hypertension, or diabetes in Cambodia (A) and Thailand (B), by age group

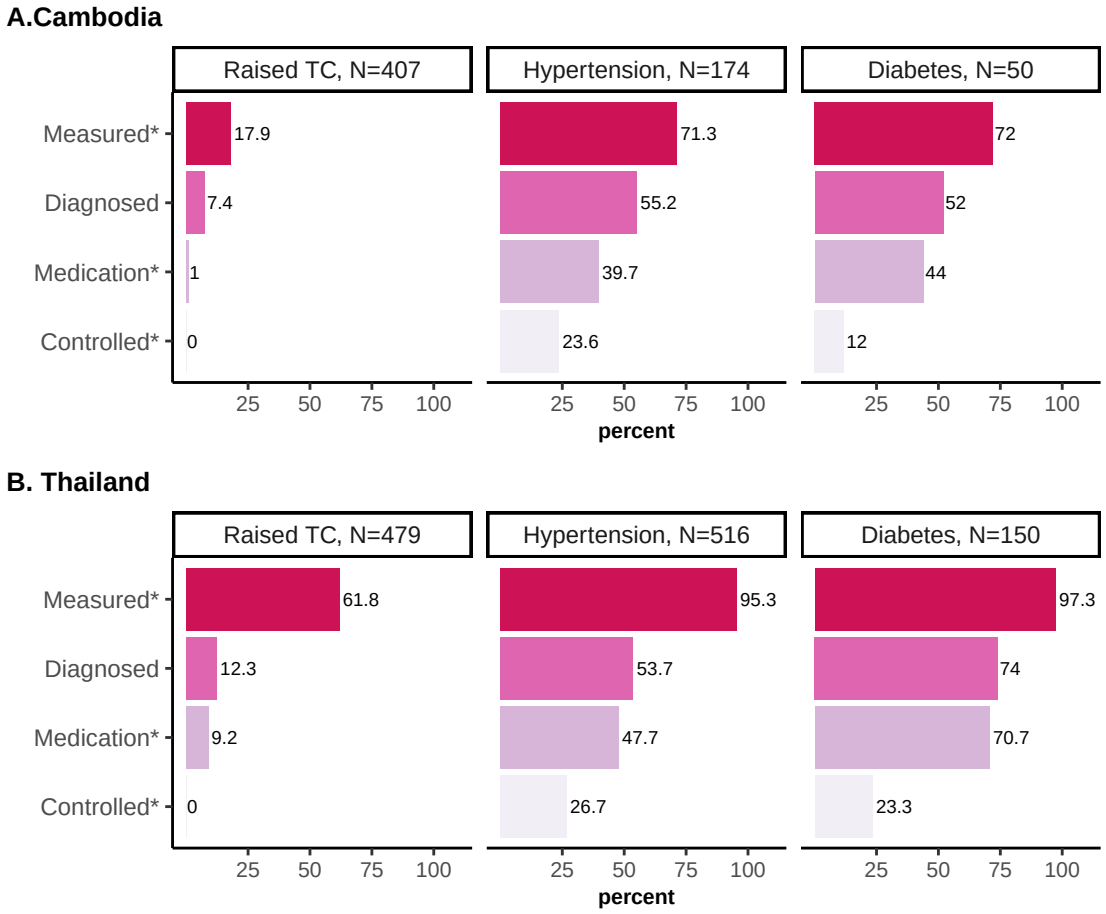


Figure 7.3: Proportion of participants who received each service along the care cascade (measured, diagnosed, treated and controlled), among those with raised total cholesterol, hypertension, or diabetes in Cambodia (A) and Thailand (B)
Measured: ever had cholesterol, blood pressure, or blood sugar measured; Medication: currently takin medication for lowering cholesterol, controlling blood pressure, or controlling blood sugar or injecting insulin that was prescribed by healthcare professionals; Controlled: Total cholesterol< 190mg/dL; hypertension- systolic blood pressure <140mmHg and diastolic blood pressure<90mmHg; diabetes- HbA1c<6.5%. TC: Total cholesterol.

7.3.4 Ten-year CVD risk

Among participants 40-74 years old (Cambodia: n=376, Thailand: n=840), 27.1% (95%CI: 22.7%-31.9%) in Cambodia and 26.8% (95%CI: 23.8%- 29.9%) in Thailand were classified as high 10-year CVD risk according to RPCE (Table 7.4, Appendix E Table 2). According to the WHO CVD risk chart, 10.1% (95%CI: 7.3%- 13.6%) of participants in Cambodia and 11.5% (95%CI: 9.5%- 13.9%) in Thailand were classified as high risk.

Table 7.4: Ten-year-CVD risks among participants who were 40-74 years, by the Revised Pooled Cohort Equation and the WHO CVD laboratory-based risk chart for Southeast Asians

Risk categories, n (%)	**Cambodia** N = 376	**Thailand** N = 840
Revised Pooled Cohort Equation		
<0.5%	39 (10.4%)	56 (6.7%)
0.5% to <7.5%	235 (62.5%)	559 (66.5%)
>=7.5%	102 (27.1%)	225 (26.8%)
WHO CVD Risk Chart		
<10%	300 (79.8%)	605 (72.0%)
10% to <20%	65 (17.3%)	208 (24.8%)
>=20%	11 (2.9%)	27 (3.2%)
Blood pressure > 160/100 mmHg	29 (7.7%)	79 (9.4%)
Total cholesterol> 320mg/dL	3 (0.8%)	4 (0.5%)
Prevalence of high 10-year-CVD risk, n (%, 95%CI)		
Revised Pooled Cohort	102 (27.1%, 22.7- 31.9)	225 (26.8%, 23.8- 29.9)
WHO CVD risk chart	38 (10.1%, 7.25- 13.6)	97 (11.5%, 9.46- 13.9)
[1] n (%)		
Abbreviations: CI = Confidence Interval, NA		

Note:
Participants aged 40-74 who reported previous heart disease were excluded from the analysis (Cambodia: n=54, Thailand: n=41)
The high 10-year-CVD risk was defined as 7.5% or higher score according to the Revised Pooled Cohort Equation, or 20% or higher WHO CVD risk score or blood pressure>160/100 mmHg or total cholesterol >=320 mg/dL according to the WHO CVD risk chart

7.3.5 Risk factors for NCD multimorbidity

multivariable analysis identified older age and BMI status as common risk factors for multimorbidity in both Cambodia and Thailand (Table 7.5). In Cambodia, compared to individuals aged 60 years or older, the aOR for multimorbidity was 0 (95%CI: 0.0- 0.0) for those aged 15-29, 0.1 (95% CI: 0.0- 0.2) for those aged 30-39 years, 0.4 (95% CI: 0.2- 0.7) for those aged 40-49 years, and 0.8 (95% CI: 0.4- 1.4) for those aged 50-59 years. In Thailand, the corresponding aORs were 0.1 (95%CI: 0.1- 0.4) for individuals aged 15-29, and 0.3 (95%CI: 0.1- 0.5) for those aged 30-39. Compared to individuals with normal weight, those who were overweight (Cambodia: aOR: 2.5, 95% CI: 1.5- 4.1; Thailand: aOR: 2.0, 95% CI: 1.4- 2.7) or obese (Cambodia: aOR: 6.7, 95% CI: 3.1-15; Thailand: aOR: 2.8, 95% CI: 1.8-4.4)

had higher odds of having two or more NCDs. In contrast, individuals who were underweight compared to normal weight had lower odds of having multimorbidity (Cambodia aOR: 0.2, 95%CI: 0- 0.5, Thailand: aOR:0.4, 95%CI: 0.2- 0.8).

Additional associations varied between countries. In Cambodia, individuals engaged in unpaid work (OR: 2.0, 95%CI: 1.1- 3.6), or do not work (OR: 2.4, 95%CI: 1.0- 5.8) had higher odds of multimorbidity compared to those working in agriculture. In contrast, current tobacco smoking had lower odds of having two or more NCDs compared to those who never smoked (OR: 0.4, 95%CI: 0.2-0.8). In Thailand, individuals who had completed primary school education had higher odds of multimorbidity compared to those who completed secondary school or higher education (OR: 1.6, 95%CI:1.1-2.3). Conversely, those who identified as Akha ethnic group (aOR: 0.4, 95%CI: 0.2, 0.7) compared to Thai had lower odds of having multimorbidity.

Table 7.5: The associations between multimorbidity and demographic, socioeconomic, risk behaviour, and BMI status, by country

Variables	Cambodia					Thailand				
	Double NCDs	**cOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**	**Double NCDs**	**cOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**
Sex										
Male	55 (13.1%)	Reference		Reference	–	115 (23.8%)	Reference		Reference	–
Female	78 (16.4%)	1.3 (0.9,1.9)	0.2	0.7 (0.3,1.3)	0.2	179 (26.0%)	1.1 (0.9,1.5)	0.4	0.9 (0.6,1.3)	0.7
Age groups										
60+	52 (35.4%)	Reference		Reference	–	139 (30.0%)	Reference		Reference	–
15-29	1 (0.4%)	0.0 (0.0,0.0)	<0.001	0.0 (0.0,0.0)	<0.001	6 (5.7%)	0.1 (0.1,0.3)	<0.001	0.1 (0.1,0.4)	<0.001
30-39	10 (5.0%)	0.1 (0.0,0.2)	<0.001	0.1 (0.0,0.2)	<0.001	10 (8.5%)	0.2 (0.1,0.4)	<0.001	0.3 (0.1,0.5)	<0.001
40-49	29 (19.6%)	0.4 (0.3,0.8)	0.003	0.4 (0.2,0.7)	0.005	49 (23.7%)	0.7 (0.5,1.1)	0.095	0.7 (0.4,1.0)	0.084
50-59	41 (26.3%)	0.7 (0.4,1.1)	0.087	0.8 (0.4,1.4)	0.4	90 (32.1%)	1.1 (0.8,1.5)	0.5	1.0 (0.7,1.4)	>0.9
Tobacco smoking										
Never	94 (15.0%)	Reference		Reference	–	219 (25.9%)	Reference		Reference	–
Current	19 (9.6%)	0.6 (0.4,1.0)	0.060	0.4 (0.2,0.8)	0.016	33 (20.5%)	0.7 (0.5,1.1)	0.15	0.8 (0.5,1.4)	0.5
Former	20 (28.2%)	2.2 (1.2,3.9)	0.005	1.2 (0.6,2.7)	0.6	42 (25.3%)	1.0 (0.7,1.4)	0.9	0.8 (0.5,1.2)	0.2
Alcohol use										
Never	69 (17.9%)	Reference		Reference	–	109 (23.2%)	Reference			–
Current	37 (11.6%)	0.6 (0.4,0.9)	0.022	0.9 (0.5,1.7)	0.8	110 (25.9%)	1.2 (0.9,1.6)	0.4		–
Former	27 (14.1%)	0.8 (0.5,1.2)	0.2	0.7 (0.4,1.2)	0.2	75 (26.9%)	1.2 (0.9,1.7)	0.3		–
BMI										
Normal	61 (10.9%)	Reference		Reference	–	137 (21.1%)	Reference		Reference	–
Underweight	3 (3.8%)	0.3 (0.1,0.9)	0.064	0.2 (0.0,0.5)	0.004	8 (9.6%)	0.4 (0.2,0.8)	0.017	0.4 (0.2,0.8)	0.012
Overweight	48 (23.1%)	2.5 (1.6,3.7)	<0.001	2.5 (1.5,4.1)	<0.001	105 (32.5%)	1.8 (1.3,2.4)	<0.001	2.0 (1.4,2.7)	<0.001
Obese	21 (42.0%)	5.9 (3.2,11)	<0.001	6.7 (3.1,15)	<0.001	44 (37.6%)	2.3 (1.5,3.4)	<0.001	2.8 (1.8,4.4)	<0.001
Marital status										

Table 7.5: The associations between multimorbidity and demographic, socioeconomic, risk behaviour, and BMI status, by country *(continued)*

Variables	Cambodia					Thailand				
	Double NCDs	**cOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**	**Double NCDs**	**cOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**
Currently married/cohabitating	107 (16.1%)	Reference		Reference	–	231 (25.9%)	Reference			–
Never/not currently married	26 (11.3%)	0.7 (0.4,1.0)	0.077	1.2 (0.6,2.1)	0.6	63 (22.4%)	0.8 (0.6,1.1)	0.2		–
Education level										
Secondary school completed/ higher	24 (12.7%)	Reference		Reference	–	68 (17.4%)	Reference		Reference	–
Never attended school	47 (23.9%)	2.2 (1.3,3.7)	0.005	1.2 (0.6,2.5)	0.7	58 (21.2%)	1.3 (0.9,1.9)	0.2	0.9 (0.5,1.6)	0.7
Primary school uncompleted	46 (14.1%)	1.1 (0.7,1.9)	0.7	1.2 (0.6,2.5)	0.6	56 (32.0%)	2.2 (1.5,3.4)	<0.001	1.4 (0.9,2.2)	0.2
Primary school completed	16 (8.7%)	0.7 (0.3,1.3)	0.2	1.0 (0.5,2.4)	>0.9	112 (33.5%)	2.4 (1.7,3.4)	<0.001	1.6 (1.1,2.3)	0.022
Work status										
Agriculture	45 (10.9%)	Reference		Reference	–	189 (26.3%)	Reference			–
Labourer	5 (4.6%)	0.4 (0.1,0.9)	0.055	0.5 (0.1,1.2)	0.2	17 (22.1%)	0.8 (0.4,1.4)	0.4		–
Employee	21 (17.5%)	1.7 (1.0,3.0)	0.058	1.6 (0.8,3.2)	0.2	24 (20.3%)	0.7 (0.4,1.1)	0.2		–
Unpaid work	44 (20.8%)	2.1 (1.4,3.4)	0.001	2.0 (1.1,3.6)	0.017	40 (23.4%)	0.9 (0.6,1.3)	0.4		–
Don't work	18 (40.0%)	5.4 (2.7,11)	<0.001	2.4 (1.0,5.8)	0.045	24 (27.6%)	1.1 (0.6,1.7)	0.8		–
Wealth status (national)										
Middle	33 (13.8%)	Reference		Reference	–	85 (24.2%)	Reference			–
Poorer	10 (8.2%)	0.6 (0.3,1.1)	0.12	0.8 (0.3,1.7)	0.5	85 (22.4%)	0.9 (0.6,1.3)	0.6		–
Richer	90 (16.8%)	1.3 (0.8,2.0)	0.3	1.1 (0.6,1.8)	0.8	124 (28.0%)	1.2 (0.9,1.7)	0.2		–

Table 7.5: The associations between multimorbidity and demographic, socioeconomic, risk behaviour, and BMI status, by country *(continued)*

Variables	Cambodia					Thailand				
	Double NCDs	**cOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**	**Double NCDs**	**cOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**
Ethnicity										
Thai					–	214 (30.2%)	Reference		Reference	–
Akha					–	13 (9.0%)	0.2 (0.1,0.4)	<0.001	0.4 (0.2,0.7)	0.007
Lahu					–	27 (23.7%)	0.7 (0.4,1.1)	0.2	1.0 (0.6,1.8)	>0.9
Other					–	40 (19.4%)	0.6 (0.4,0.8)	0.003	0.9 (0.5,1.4)	0.5
(Thailand)										

[1] n (%)

Abbreviations: CI = Confidence Interval, OR = Odds Ratio, aOR = Adjusted Odds Ratio, CI = Confidence Interval, cOR = Crude Odds Ratio

Note:

The analysis included 896 participants from Cambodia and 1173 Participants in Thailand.

Participants who refused to answer the question on marital status were excluded from the analysis (Thailand: n=1)

7.4 Discussion

In rural communities of Cambodia and Thailand, NCDs are common with insufficient screening, diagnosis, and interventions. More than 40% of adult participants had raised total cholesterol with the prevalence of other NCD conditions and risk factors ranging from 5.6% to 28.9% in Cambodia and 12.8%-37.4% in Thailand. These conditions with the highest to the lowest prevalence are overweight and obesity, hypertension, and diabetes. NCD multimorbidity was presented in 15% of Cambodian adults and 25% of Thai adults. Additionally, more than 10% of the 40- to 74-year-old population were at a high 10-year risk of CVD and required lifestyle counselling and medication. The care cascade analysis exhibited big gaps in diagnosis and control, and it was particularly poor for hypercholesterolemia care, highlighting the need to improve NCD care in these rural areas.

Our findings on NCD prevalence are consistent with recent national and subpopulation surveys. The 2023 WHO STEP survey in Cambodia reported a similar prevalence of overweight and obesity (23.7%), hypertension (16.8%) and diabetes (6.3%), though a lower prevalence of raised TC (25.5%), likely due to differences in testing methods (Ministry of Health of Cambodia, 2023). The 2022 Cambodian Demographic and Health Survey showed that 33% of women aged 20-49 years were overweight, and a rural study reported 35.2% hypertension prevalence among community members aged 40 or older (Chham et al., 2022; National Institute of Statistics (NIH) Cambodia et al., 2023). In Thailand, our prevalence of overweight and obesity aligned with the National Health and Examination Survey 2019, which reported 39.7% overweight or obese and 11.1% diabetes (Yan et al., 2020). Additionally, a 2019 study of the Chiang Rai hill tribe adults (35-year or older) reported a higher prevalence of overweight, raised TC, and hypertension but a lower prevalence of diabetes with 63% overweight (defined as BMI>=23kg/m^2), 43.8% raised TC, 24.3% hypertension, 7.3% diabetes (defined as HbA1c>6.3%). The differences

might be due to different inclusion criteria, such as age and ethnicity, or the exclusion of self-reported medication as part of the disease definitions. The variations could also reflect an increased NCD burden over time (Sakboonyarat et al., 2023).

The age-related patterns of NCD prevalence observed in this study are consistent with global trends. In our study, the prevalence of hypertension and diabetes was significantly higher among individuals aged 50 or older, while raised TC and overweight and obesity peaked among middle-aged adults. The associations between increased age and risk of NCDs are well established, often attributed to age-related metabolic changes and increased risk behaviours with age (Asogwa et al., 2022; Chia et al., 2018; Chooi et al., 2019; Pirillo et al., 2021). The higher prevalence of overweight and obesity among middle-aged adults follows a global pattern (Chooi et al., 2019), and hypercholesterolemia has been reported in rural areas of Thailand and China (Ge et al., 2015; Sakboonyarat et al., 2020; Upala et al., 2021). This suggests that the middle-aged rural population might be particularly affected by lifestyle changes, such as unhealthy dietary habits and decreased physical activity (Pu et al., 2024; Tamaoki et al., 2022).

The current care cascade for NCDs is suboptimal, with substantial gaps in disease diagnosis and control, particularly for hypercholesterolemia. While the Thai health system generally performs better than Cambodia, the issue is universal. In our study, only 20% of participants with raised TC in Cambodia and 60% in Thailand had ever had their cholesterol measured- much lower compared to the screening rate for hypertension and diabetes, which was 70% in Cambodia and more than 95% in Thailand. The unmet need for cholesterol screening is common in LMICs, where the asymptomatic nature of hypercholesterolemia may prevent patients from seeking medical attention (Marcus et al., 2021). Other researchers have also reported substantial gaps in diagnosis and disease control in the study countries (Chham et al., 2022; Sakboonyarat et al., 2021; Sakboonyarat et al., 2023; Te et al., 2023). In Cambodia, the limited service coverage could be a major barrier, with only 25% of secondary hospitals and 10% of primary healthcare centres implementing NCD care services according to the national strategic plan (Ministry

of Health of Cambodia, 2013). In Thailand, despite a stronger healthcare system and universal healthcare coverage, the gaps are likely due to service fragmentation and healthcare workforce shortage. Screening is provided at the primary care unit but the diagnosis needs to be confirmed by a physician at a district hospital (Mahipala et al., 2019; Tuangratananon et al., 2021). Patients with well-controlled NCDs are then referred back to primary care for follow-ups. Meanwhile, nurses at the primary care unit often manage high patient volumes and provide a wide range of services, making it difficult to ensure medication adherence or provide lifestyle guidance (Cheng et al., 2017; O'Donnell et al., 2022). The causes of the gaps along the cascade can be complex and require further research to identify locally relevant barriers.

Our findings showed that 10% of individuals aged 40-74 years were at high 10-year CVD risk according to the WHO CVD risk chart, and over 25% were classified as high-risk using the RPCE. Similar discrepancies between the methods have been identified by other studies, with suggestions that RPCE might be more suitable for the Southeast Asian population, whereas the WHO risk chart tends to provide more conservative estimates (Kasim et al., 2023). Regardless of the method used, individuals classified as high risk should receive consultations on healthy lifestyles, and pharmacological therapy should be considered, such as antihypertensive medication or statin (Arnett et al., 2019; World Health Organization, 2020a). This highlights a significant need for intervention among older individuals through both treatment and behavioural changes. Although the WHO suggests individuals with hypertension, diabetes, and obesity should be prioritised for CVD screening (World Health Organization, 2020a), underdiagnosis of these diseases among these rural populations might result in missed opportunities for preventive care. In this context, the use of a fixed-dose combination therapy (Polypill) offers a promising approach in low-resource settings (Huffman et al., 2017; Joseph et al., 2021; Lancet, 2017). A randomised control trial conducted in Iran demonstrated the safety and effectiveness of the polypill therapy in both primary and secondary prevention among individuals aged 50 years or older, regardless of their CVD risk status

(Roshandel et al., 2019). Given the high proportion of undiagnosed individuals in our study sites, offering Polypill therapy to all adults above a certain age threshold, without requiring prior diagnostic confirmation, may represent a feasible and impactful approach to reducing cardiovascular morbidity and mortality.

When disease diagnoses are lacking, individuals with a high risk of NCD multimorbidity should be a priority for screening and appropriate care. The interaction between multiple NCDs can exacerbate disease progression, and contribute to increased risk of CVD (Coutinho et al., 1999; Czernichow et al., 2011; The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications (DCCT/EDIC) Study Research Group, 2005; Wilson et al., 1998). Since many NCDs share common risk factors, identifying easy-to-measure factors, such as BMI and indicators for socioeconomic status, as a part of screening could facilitate the diagnosis of individuals at high-risk multimorbidity. Our multivariable logistic regression identified older age, overweight, and obesity were significantly related to increased odds of multimorbidity, which aligns with well-established evidence that was discussed in prior paragraphs. In addition, country-specific indicators for socioeconomic status showed similar associations. In Cambodia, individuals who had unpaid work (e.g. students or homemakers), or not working (e.g. retired, unemployed) had significantly higher odds of multimorbidity compared to those who worked in agriculture, potentially due to their more sedentary lifestyle (Cleven et al., 2020). In Thailand, individuals who identified themselves as Akha hill tribe had lower odds of multimorbidity compared to Thai. As suggested by studies conducted among hill tribe populations, this might be attributable to their lower socioeconomic status or differences in lifestyles and risk behaviours (Apidechkul et al., 2016; Upala et al., 2021). However, in LMICs, the relationship between socioeconomic status and behavioural risk factors for NCDs is highly context-specific, the same indicator might result in different risks (Allen et al., 2017). Investigating locally relevant socioeconomic risk factors could enhance the prioritisation of NCD and CVD risk screening, expanding beyond the commonly identified high-risk groups like older or overweight individuals.

It is important to note that, although our multivariable analysis found current smoking associated with lower odds of having multiple NCDs in Cambodia, risk behaviours such as tobacco use are well-documented contributors to the risk of NCDs and related death (Yusuf et al., 2020). Smoking cessation has been shown to significantly reduce these risks. Quitting smoking at the age of 40 could reduce 90% excess risk of death associated with smoking, and quitting by age 30 could result in a mortality risk similar to non-smokers (Pirie et al., 2013). Despite the ongoing tobacco control in both countries, including legislation, health warnings on packaging, as well as behaviour counselling for tobacco cessation, the smoking cessation rate is low (Southeast Asia Tobacco Control Alliance, 2023). In our study, only 8% of participants in Cambodia and 14% in Thailand were former smokers. Our findings are slightly different from the national estimates (Cambodia: 12.3%, Thailand: 7.6%), but they highlighted the limited success of the current efforts (Ministry of Health of Cambodia, 2023; National Statistical Office of Thailand, 2021). While a systematic review found that behaviour counselling could achieve a 40% success rate for quit attempts (Levy et al., 2010), in Thailand 3.7% of smokers who received counselling have quit (Palakai et al., 2023). In Cambodia, although data on smoking cessation counselling is lacking, there is a gap between the intention to quit (60%) and successful cessation (6% to 20%) (Ministry of Health of Cambodia, 2023). These evidences suggested insufficient smoking cessation services in both countries.

Tobacco use is one of several key behaviour risk factors contributing to NCDs. Our data also showed other lifestyle-related risk behaviours, particularly among men aged 35-59, including high rates of alcohol use and recent binge drinking. This aligns with the rising trend of alcohol consumption, heavy drinking, and tobacco use in Thailand, and Cambodia (Peltzer et al., 2016; Wakabayashi et al., 2015; Yang et al., 2019). Meanwhile, the region is experiencing lifestyle changes increased consumption of processed foods and reduced physical activity further contributing to NCDs (Chooi et al., 2019; Pirillo et al., 2021). Addressing risk behaviours is important for NCD management, and requires a comprehensive approach including

behaviour and lifestyle counselling as integrated services for NCD care suggested by WHO (World Health Organization, 2020b). However, such as smoking cessation counselling, integrated behaviour intervention is not widely implemented in Cambodia and Thailand, and pharmacotherapy remains the primary treatment due to limited health system capacity (O'Donnell et al., 2022). While strengthening the health system for NCD care, integrating lifestyle counselling should be addressed as an effective and accessible intervention (Reiter et al., 2018).

7.4.1 Limitations

The definition and criteria for controlled hypertension, diabetes, and raised TC used in this study are different from those in the clinical settings, which often require multiple visits and individual evaluation (Arnett et al., 2019; Grundy et al., 2019; Jellinger et al., 2017). This might lead to higher prevalence estimates and a lower proportion of controlled cases. However, these estimates provide valuable reference at the population level aligned with the study objectives.

Overweight and obesity were determined by BMI status. However, it is not a direct measure of adiposity and may not accurately reflect the extent to which excess body fat impacts the health of individuals (Sweatt et al., 2024). For example, BMI can overestimate adiposity among individuals with high muscle mass or underestimate the health risks in populations prone to central adiposity-such as Asians. Despite the limitations at individual level, BMI is widely used in health research due to its well-established association with NCD risks at the population level. It is also a quick and inexpensive tool for large-scale studies. While alternative BMI cut-offs for Asian populations exist, this study used cut-offs used by the WHO STEP survey to ensure cross-study comparability (Ministry of Health of Cambodia, 2023; WHO expert consultation, 2004).

Recall bias could affect reporting along the care cascade, particularly for individuals not taking medication, who may not remember previous diagnoses. Additionally, we did not collect data on lifestyle interventions or behaviour coaching, meaning people who received such interventions might be undercounted in our

"treated" category. Despite the limitations, the substantial number of uncontrolled cases suggests both medication and behavioural intervention might be insufficient for proper disease management.

When comparing prevalence between countries, caution is needed. Thailand showed a higher prevalence for most NCDs compared to Cambodia, which could be due to more older participants, reflecting its larger ageing population (Chapter 3), while greater urbanization, changes in lifestyle, living conditions, and economic development in Thailand might also contribute to the difference (Mathers & Loncar, 2006). Since the study aim to assess the disease prevalence at each site, we did not calculate age-standardized prevalence, limiting the direct cross-country comparison.

7.5 Conclusion

NCDs are common among adults in rural areas of Cambodia and Thailand, and significant gaps remain in their diagnosis and control. As the burden of NCDs grows and CVD continues to be a leading cause of mortality, the poor cascade of care suggests an urgent need for healthcare system strengthening. Prioritising populations with common risks for multiple NCDs- older individuals, those who are overweight or obese, and those with specific indicators of socioeconomic status based on local context, such as work status or ethnicity- should be key in screening efforts and management.

8
Discussion

Chapter outline

This chapter begins with an overview of the study rationale and implementation procedures, and a summary of the main findings of each chapter. It then synthesises the key findings by discussing the strengths and limitations of the study, assessing methodological rigour and potential biases. The chapter further explores the context and implications of the findings, including ethical considerations surrounding the return of individual hepatitis B and C results, and wider implications of the thesis on policy and practice. The chapter concludes with suggestions for future research directions, including pending laboratory tests and analyses, the possibility of expanding the analysis to explore associations across health conditions and personal reflections on the research.

8.1 Study overview

This survey was conducted to address gaps in population-based health data in rural Bangladesh, Cambodia, and Thailand, where limited surveillance systems and healthcare access contribute to an incomplete understanding of disease burden. National estimates can overlook subnational variations, particularly in rural areas where distinct health challenges arise due to environmental, socioeconomic, and healthcare disparities. The study aimed to generate site-representative data to improve disease burden estimation, assess healthcare utilisation, and inform future interventions. To define the study scope, a scoping review was conducted to map existing community-based health surveys, identify gaps in health conditions studied, and evaluate methods used. This process led to the inclusion of conditions with both high burden and underrepresentation in previous studies with appropriate evaluation methods.

The survey employed a two-stage cluster sampling approach, ensuring representativeness within the selected rural study sites. Data collection involved structured questionnaire-based interviews, physical examinations, and laboratory tests, enabling a comprehensive assessment of health conditions and risk factors. Recognising logistical challenges in remote areas, the study leveraged partnerships with local healthcare providers and research collaborators to enhance community engagement and operational feasibility.Rigorous quality control measures were applied throughout data collection, including standardised training for field teams, ongoing data quality checks, and interim monitoring for compliance with the study protocol and standard operating procedures. Data analysis followed a structured statistical analysis plan, incorporating methods to account for sampling design and to provide robust prevalence and association estimates. This study also integrated serosurveillance methods, generating seroprevalence and seroincidence estimates on acute febrile illness. This process—from identifying knowledge gaps to implementing the survey and analysing data—ensured that the study generated high-

quality relevant evidence to inform public health decision-making and intervention planning in these rural settings.

8.1.1 Chapter summaries

The overall aim of the study was to contribute to the understanding of the epidemiology of health among selected rural populations in Southeast Asia, thereby facilitating the design of future interventions to improve the overall health outcomes of these populations. To capture information on multiple exposures and outcomes, a cross-sectional survey was designed and implemented in three study sites in Bangladesh, Cambodia, and Thailand, with a wide range of objectives to provide data on prevalence, population characteristics, health-seeking behaviour, and subjective evaluation of health and concerns (Chapter 1).

The objectives were addressed through a number of perspectives of health or disease categories, with each chapter focus on specific areas:

1. **Chapter 3**: presented an overview of the study sites by describing health-related demographic and socioeconomic characteristics, self-perceived health status and concerns regarding health and healthcare;

2. **Chapter 4**: provided an overview of the burden of febrile diseases by estimating the period prevalence of recent fever and health-seeking, and seroprevalence of febrile pathogens;

3. **Chapter 5**: estimated the seroincidence of enteric fever among children and young adults in Cambodia;

4. **Chapter 6**: estimated the prevalence of chronic hepatitis B and C, the coverage of the HBV vaccination, and the gap in diagnosis;

5. **Chapter 7**: evaluated the prevalence of non-communicable diseases (NCD), including hypercholesterolemia, hypertension, diabetes, NCD risk factors, CVD risk, and the cascade of care of these diseases.

8.2 Strengths and limitations of the study

8.2.1 Strengths

Our study was designed to address key public health priorities while maximising resource efficiency and ensuring broad disease coverage. It builds upon findings from the scoping review (Chapter 1) by incorporating a diverse range of health conditions, a multi-method evaluation approach, and site-representative sampling across the study sites. These elements allowed for a comprehensive assessment of disease burden and healthcare access in selected areas of rural Southeast Asia.

Wide breadth of health conditions

The highlight of the study is the integration of serosurveillance into a community-based cross-sectional survey. By applying novel approaches such as multiplex serology assays, the study simultaneously measured antibody responses to nine pathogens- spanning virus, bacteria and parasites- including dengue virus, Japanese encephalitis virus, Zika virus, chikungunya virus, *Orientia Tsutsugamushi, Rickettsia spp., Leptospiral spp., Plasmodium falciparum, and Plasmodium vivax.* The study assessed age-dependent seroprevalence to capture the infection dynamic in these communities. Additionally, it employed an antibody kinetics model to estimate typhoid fever seroincidence among children and young adults in Cambodia. This study demonstrated the application of cross-sectional surveys for serosurveillance, improving the understanding of acute infection patterns.

This study also included high-burden diseases with well-established public health significance, including NCDs such as diabetes and cardiovascular disease, chronic infections like hepatitis B and C, and acute infections that present with fever. Although many of these conditions are covered by existing surveillance such as national surveys, incorporating them in our study allowed for continued monitoring of intervention progress and identification of areas requiring further health system strengthening.

Beyond well-documented conditions, the study expanded its scope to include diseases that are often overlooked among the general population, especially in rural areas, such as stroke, cancer, liver cirrhosis, and musculoskeletal pain, through self-reported disease history. Furthermore, by assessing self-perceived health status and self-reported disease history this study offered a broader perspective on health beyond clinical diagnoses, allowing for a more holistic understanding of population health.

Multi-method evaluation approach

The study integrated three complementary data collection methods—questionnaire interviews, laboratory tests, and physical examinations—to generate a comprehensive understanding of disease burden and healthcare access.

Each condition was assessed using the most suitable methods for a cross-sectional survey. For instance, for hepatitis B and C, well-established laboratory-based diagnostic methods were used. NCDs, such as diabetes and hypertension, were evaluated through a combination of self-reported treatment history and objective measurements from laboratory or physical examinations, such as HbA1c, ensuring that the impact of ongoing treatment was accounted for in disease classification. Acute infections, which are difficult to capture in cross-sectional surveys due to their short window of active infection, were assessed through serological responses, providing a long-term exposure profile rather than a real-time infection rate. Conditions that required complex diagnostics, such as cirrhosis and liver cancer, were assessed through self-reported history. While acknowledging the risk of underreporting due to limited access to diagnostic services in rural settings, this approach provided valuable indications of disease burden in regions where alternative data sources are scarce.

Inclusion of populations of all ages

Our study recruited participants of all ages, in contrast to many existing community-based cross-sectional surveys that often focus on specific age groups for different

health conditions (Zhang, Htun, et al., 2024). This approach allowed us to examine the disease burden across the full lifespan and fill the knowledge gap in population-level disease estimates for certain age groups. Additionally, it enabled the monitoring of changing disease epidemiology, particularly in age groups that were not previously considered high-risk, but are now experiencing rising burden.

The study is the first in these countries to measure exposures to nine pathogens across all age groups, offering insights into disease transmission dynamics at the population level. It provides a complete snapshot of immunity or exposure across the entire lifespan, capturing variations and trends that might be overlooked in age-restricted studies. It could also inform the role different age groups play in sustaining or mitigating transmission or the evolving epidemiology of diseases reflecting the outcome of disease prevention and control interventions. For example, in Thailand, the age-dependent seroprevalence of Japanese encephalitis virus (JEV) showed an early childhood peak, a decline to around 20 years, and then a gradual increase with age, reflecting the impact of childhood JEV vaccination (Sudjaritruk et al., 2022). Additionally, in Cambodia and Thailand, the seroprevalence of *P. falciparum* and *P. vivax* was low overall, but higher among individuals 50 years or older, reflecting historical exposure when malaria transmission was more intense (Chhim et al., 2021).

For viral hepatitis, empirical data on prevalence in the general population-particularly among paediatric age groups, have been limited, negatively impacting the accuracy of the modelled results (Marjenberg et al., 2022; Schmelzer et al., 2020). Our study provided estimates of hepatitis B prevalence among children under 5 years and hepatitis C prevalence among adolescents aged 15-17 years. The data is important for monitoring hepatitis B vaccination coverage and tracking progress towards the elimination target of $< 0.1\%$ HBsAg prevalence in children under five, a key indicator for the global hepatitis elimination goal (World Health Organization, 2016). The gap in data on HCV prevalence among children is concerning, especially with the new WHO guidelines recommending the direct-acting antiviral agents (DAA) treatment for children ages 3 years or older using

simplified HCV services delivery and point-of-care diagnosis tests (World Health Organization, 2022). While no HCV cases were identified among adolescents aged 15 to 17 years, our prevalence estimates provide a foundation for improving screening and treatment strategies.

For NCDs, most community-based surveys, including WHO's Stepwise survey for non-communicable disease surveillance (STEP), focused primarily on older adults due to their higher risks of chronic conditions (Zhang, Htun, et al., 2024). This study includes a broader age range, covering individuals 15 years and older, allowing for prevalence estimates among the younger population who are increasingly at risk of NCDs as lifestyles evolve and economies improve. For instance, diabetes was mostly studied among adults due to its associations with aging, but rising childhood obesity has led to an increasing prevalence of diabetes in younger populations (Jaruratanasirikul et al., 2017). Expanding NCD surveillance to younger age groups allows for better monitoring of the emerging trends, the early identification of at-risk individuals, and implementation of timely intervention. This approach could help to mitigate long-term impact from NCDs and reduce future burden on the healthcare system.

Site representative sample and subnational level estimates

The study was specifically designed to achieve site-representative sampling in rural areas of Bangladesh, Cambodia, and Thailand, where SEACTN operates. The overall response rate (85%), with the age and sex structure comparable to the relevant census data, confirmed the representativeness of our samples. Unlike national surveys, which often provide prevalence over broad geographic ranges, this subnational approach made it possible to identify context-specific health challenges that can be masked in national estimates (Zhang, Htun, et al., 2024). By capturing health conditions at the community-level, the study provided a more granular understanding of disease prevalence, risk factors, and healthcare access.

Variations of disease prevalence within each study site compared to national estimates or estimates of other regions within each study country were observed.

For example, in Thailand, the HBV prevalence observed in our study was much higher compared to the national estimates, and in Cambodia, the HCV prevalence was consistent with a previous study, but was only half compared with another study in neighbouring villages (Lynch et al., 2021; Posuwan et al., 2016; Yamada et al., 2007). In addition, the vaccination coverage among children under three years old in our study was lower than the WHO estimates for 2023 in both countries, with 50% in Cambodia and 63% in Thailand reporting age-appropriate HBV vaccinations, compared with WHO estimates of 85% in Cambodia and 92% in Thailand, respectively (World Health Organization, n.d.).

The variation across districts within each study site was also observed. For the seroprevalence of pathogens causing fever, districts outside of Palin in Cambodia, and Muang district compared to other districts in Thailand, were associated with lower odds of seropositivity for arboviruses but higher odds for vector-borne bacterial infection. In addition, the highest seroincidence of typhoid fever was observed in Koas Krala district in Cambodia, aligning with anecdotal reports of inadequate water, sanitation, and hygiene (WASH) facilities in the area. These findings highlight the importance of considering the influence of local environmental and socio-economic factors on disease transmission dynamics.

The study also captured demographic characteristics that differ from national distributions. For example, Chiang Rai province in Thailand is home to a high proportion of ethnic minority groups, which is not representative of Thailand's national demographic composition (Chapter 3). Our study findings indicated these ethnic minority groups were associated with varying odds of health conditions. Specifically, they had an increased risk of HBV infection and seropositivity of vector-borne bacterial infection, while being at lower risk of reporting moderate to poor self-perceived health, seropositivity of arboviruses, and multimorbidity of NCDs. Beyond disease burden, ethnic minorities were more likely to report concerns about the timeliness of healthcare services and work-related risk of chemical exposures. These findings highlight the importance of accounting for social and demographic

disparities at the district level, ensuring that health systems are responsive to the specific needs of diverse populations.

Integration with other SEACTN studies

As a core component of the Rural Febrile Illness project (RFI)- the first project under SEACTN, this survey complements other ongoing RFI initiatives in the same geographic areas. By integrating findings on fever aetiology, causes of death, and profiles of village-level access to healthcare services, the study enhances the overall assessment on disease burden beyond acute febrile illness to broader health issues. The findings also improved the understanding of health service utilisation patterns, which will support the disease incidence estimation in the aetiology study. Additionally, the survey provides contextual data, such as population structure, household wealth status, and health perceptions and concerns, which will inform other RFI studies.

8.2.2 Limitations

Limitations of the study design

One limitation of this study was the cross-sectional design, which captures exposure and health outcomes at a single time point. This restricts the ability to establish causal relationships between risk factors and health conditions. Although associations can be identified, it is not possible to determine whether specific exposures preceded the development of the observed health outcomes.

Additionally, while the study successfully achieved its target sample size and maintained a high response rate, there are inherent limitations in statistical power, particularly when analysing subgroups. The sample size calculation was designed to estimate prevalence with +/- 5% precision among the population across all ages or within broader age groups, such as those aged 15 years or older and 15–49 years (Chapter 2). However, for children under five and adults aged 50 years or above, where the sample sizes were smaller, with the estimated prevalence of childhood anaemia (30%) or hypertension among elder individuals (20%), a lower

precision of 6% to 10% was targeted. During the analysis, age groups were further stratified into smaller intervals to better capture variations in prevalence across different stages of life. While this provided more granular insights, caution is needed when interpreting findings from these narrower age bands, as smaller sample sizes further reduced statistical power, leading to wider confidence intervals. To address this, all prevalence estimates are presented with confidence intervals to provide a reference for uncertainty. The primary focus of the analysis remains on overall estimates and those stratified by broader age categories, ensuring the reliability and generalisability of key findings.

Variations in types of prevalence measured

Our study used different prevalence measures to capture various health conditions: period prevalence for self-reported fever in the past 30 days, point prevalence for chronic diseases such as hypertension and diabetes, and seroprevalence for acute infections based on IgG responses. While these measures provide valuable insights into disease burden and patterns of exposure, differences in prevalence definitions may complicate direct comparisons across conditions and populations.

Period prevalence captures fluctuating symptoms within a defined timeframe, whereas point prevalence reflects ongoing disease status at the time of measurement. Seroprevalence, on the other hand, represents cumulative exposure and does not necessarily indicate recent or active infection. This variation in prevalence measures may lead to differences in the interpretation of risk factors and disease burden.

However, these methodological choices were carefully considered and made to align with the cross-sectional design of the survey and the characteristics of each condition. Each chapter discusses the interpretation of the respective prevalence measures to enhance clarity. Although differences in prevalence definitions pose challenges in synthesising findings, they also offer a multifaceted perspective on health and disease dynamics in rural populations.

Limited generalisability to the rural population of each country

Although our study aimed to achieve a site-representative sample that captured the geographic diversity within the study network, similar age and sex distribution between our study population and national rural estimates suggest broad representativeness. Other unmeasured factors may also differ between our sample and the broader rural population, potentially limiting the generalisability of our findings to all rural areas within each country. Nevertheless, while the results may not be directly extrapolated to the entire rural population of each country, they provide a robust representation within the areas covered by the surveys, contributing meaningful evidence for target interventions within the network.

Potential sources of bias

As a cross-sectional survey, the study is at risk of several potential biases, including selection bias, measurement bias, information bias, and temporal bias. Measures were implemented to minimise the potential biases at both the design and the analytical stage. During study design, rigorous sampling methods and standardised data collection protocols were used to enhance representativeness and consistency. At the analytical stage, potential sources of bias were systematically assessed, and appropriate adjustments were made to address any identified biases, ensuring the reliability and validity of the findings. Details are provided for each potential source of bias below.

Selection bias The selection bias in this study primarily included sampling bias and non-response bias, both of which could affect the sample representativeness.

Sampling bias arises if the sample is not representative of the target population, which is affected by sampling methods. Our study was designed to achieve a site-representative sample; however, in settings where population data are outdated or unavailable, there was risk of sampling error if the sampling frame was not fully aligned with the target population. To mitigate the risk, we implemented a cost-effective approach using two-stage cluster sampling, reducing reliance on

precise population data at the first stage of cluster selection (Chapter 2) (ICF International, 2012; Milligan et al., 2004). Once clusters were selected, efforts were directed towards refining the population data within these clusters for household selection. This involved verifying household listings to achieve comprehensive coverage and avoiding duplications. Additionally, during recruitment, household heads confirmed the eligibility and accuracy of all listed household members. These system validations improved sampling accuracy and enhanced the representativeness of our study population.

Non-response bias occurs when individuals who do not participate differ systematically from those who do, leading to distortions in study findings and deviations from the intended representativeness. As demonstrated in Chapter 3, the risk of non-response bias in our study was likely minimal. A high response rate is one of the most effective ways to mitigate non-response bias, with 80% considered a recommended threshold (Sackett, 1979). Our study achieved an overall response rate of nearly 85% across all sites, with Bangladesh reaching 96%.

To assess potential non-response bias, we collected key demographic characteristics of non-responders, allowing comparison with study participants, as recommended for improving the reporting quality of observational studies (Elm et al., 2007). While this approach does not eliminate bias, it provides valuable insights into its potential impact. Our analysis indicated significant differences in age and sex, with a higher proportion of non-responders being working-age men (15–49 years), reflecting the primary reasons for non-response, being at work or school. However, despite these differences, the overall age and sex distribution of our study sample closely aligned with the target population based on recent census data, suggesting minimal bias in these demographic factors.

Although weighting adjustments were not deemed necessary due to the minimal bias in key demographic factors, statistical analysis plans were in place to adjust the study sample to reflect rural population estimates by age and sex if significant non-response bias had been detected. This would have ensured that prevalence estimates remained as representative as possible.

Information bias Information bias refers to systematic errors in collecting or recording data. It occurs when there are consistent inaccuracies in the information obtained about the study subjects. In our study, it mainly consists of recall bias, measurement bias and interview bias.

Recall bias refers to participants inaccurately recalling past events or exposures, leading to misclassification of key variables. In our study, self-reported data were collected on disease histories, health-seeking behaviours, and demographic and socioeconomic characteristics. These self-reports may be subject to recall bias, particularly when individuals were not diagnosed with a disease or were not taking medication, they may struggle to remember past disease screening experience or a disease diagnosis, potentially leading to an underestimation of healthcare utilisation or known disease history. To reduce the impact of recall bias on key prevalence estimates, objective measures, physical examinations and laboratory tests, were incorporated to supplement self-report disease history. For example, diabetes prevalence was determined using both HbA1c level and self-reported medication use (to account for controlled diabetes). Additionally, we employed validated questionnaires that had been previously implemented in the study countries, enhancing the reliability of responses. The questionnaire underwent pretesting, and adjustments were made to improve clarity, and prompts were introduced to aid participants' recall (Chapter 2). These measures helped minimise the influence of recall bias and improve the accuracy of self-reported data.

Measurement bias occurs when the tools or procedures used for data collection do not accurately capture the true values of the variables being measured. **Interviewer bias** is a specific type of measurement bias, which occurs when differences in how interviewers ask questions, probe for responses, or record answers introduce systematic distortions in the data. Measurement bias can lead to misclassification, where participants are incorrectly classified to exposure or disease status.

Measurement bias can be random, where errors occur unpredictably and dilute the true associations, or non-random where errors systematically overestimate or underestimate outcomes, leading to false associations. Given that data collection

in our study was conducted by different research teams across three study sites (Bangladesh, Cambodia, and Thailand), there was an inherent risk of measurement and interviewer bias. These biases could manifest through site-level systematic errors due to variations in how different research teams implement the study, and random error caused by inconsistent measures done by individual survey staff, during the interview, physical examination, or blood sampling and testing procedures.

To promote standardisation across sites and reduce random measurement errors, several strategies were implemented (Chapter 2):

- Standardized Protocols and Standard Operating Procedures (SOPs): All study elements, including questionnaire administration, physical measurements, and laboratory testing procedures, were clearly defined in detailed SOPs for consistency across study sites.

- Comprehensive training of research teams: All data collectors, laboratory technicians, and supervisors underwent multiple rounds of training before data collection began. These sessions covered interview techniques and other standardised procedures detailed in the SOPs.

- Pilot implementation: A one- to two-week pilot phase was conducted at each study site before the full-scale survey implementation. This allowed the research teams to implement the study under close supervision from the site coordinator and the DPhil candidate, ensuring all the procedures were consistent with the protocol and the SOPs.

- Ongoing supervision and monitoring: A structured monitoring system was established to assess the quality of data collection throughout the study. The MORU monitoring team conducted midpoint monitoring visits to evaluate adherence to protocols, and biweekly data quality checks were performed by the DPhil candidate to identify inconsistencies and correct errors in real time.

- Electronic data entry: To minimise errors in data recording, electronic data collection was used, with built-in validation checks, reducing human error in data recording.

By implementing SOPs and rigorous quality control measures, the study minimised both systematic and random errors, ensuring the reliability and comparability of data collected across sites.

Temporal bias Data collection timelines varied across sites: fieldwork was conducted in Thailand from October 3, 2022 to August 22, 2023, followed by Cambodia (April 7, 2023- December 10, 2023) and Bangladesh (April 17, 2023- December 7, 2023). Rainy and dry seasons also differ across the study sites with all districts in Thailand and Cox's Bazar, Bangladesh having the rainy season from June to October, and all districts in Cambodia and Bandarban, Bangladesh having rainy seasons from May to September (Chapter 3, Chapter 4). These seasonal variations introduce potential for temporal bias in risk of exposure, disease prevalence, and health-seeking behaviours, potentially affecting study findings and the interpretation of these findings.

To address temporal bias, several strategies were implemented. First, serological assessments focused on IgG responses to pathogens causing acute febrile illness. IgG response reflects cumulative exposure minimizing the impact of seasonal transmission fluctuations. Chronic diseases, such as hepatitis B, hepatitis C and NCD, are unlikely to be influenced by the time of data collection.

For self-reported fever, the recall period was one month, aiming to reduce the influence of seasonal peaks or dips in febrile illness on health-seeking patterns while minimising recall bias that would inevitably increase with longer periods. For chronic diseases, recall questions were framed as "ever had" to capture lifetime prevalence and healthcare utilisation patterns. Finally, to assess the consistency of our findings, results were compared with prior studies, thereby contributing to a more comprehensive understanding from which to interpret observed differences

and identify discrepancies attributable to study design, data collection methods or temporal variations. These approaches aimed to minimise the impact of temporal bias and enhance the reliability.

Multivariable model variable selection

In this thesis, the decision to apply variable selection was guided by events-per-variable criteria. Variables included in the multivariable models were selected based on both prior knowledge and univariate p-values. This approach aimed to balance empirical evidence with statistical robustness. Sole reliance on p-values for variable selection can lead to the exclusion of important explanatory variables that are not statistically significant and the inclusion of variables that are only coincidentally associated (Smith, 2018). To mitigate this, covariates with established associations in the literature were retained regardless of statistical significance, while additional variables were included if they had a p-value < 0.2 in univariable analysis (Heinze et al., 2018; Mickey & Greenland, 1989).

8.3 Returning hepatitis B and C results to individual participants - ethical considerations and public health implications

Returning the results of HBV and HCV testing to participants carries not only an ethical obligation but also important public health implications (Section 2.7.3). Ethically, providing individual test results respects participant autonomy and supports the principle of beneficence, enabling individuals to take informed steps regarding their health. At the same time, potential harms- such as distress, misunderstanding, or lack of access to follow-up care- must be considered, especially in resource-limited settings where treatment may not be readily available (Cox et al., 2011; Dixon-Woods et al., 2006; Evertsz et al., 2023; Grubbs et al., 2021; Kisiangani et al., 2022; Shalowitz & Miller, 2008). In the context of infectious diseases with long-term consequences, such as HBV and HCV, researchers have a responsibility to inform participants of clinically significant findings. As discussed

in Chapter 6, these infections, if left untreated, can lead to cirrhosis and hepatocellular carcinoma, but effective treatments exist: HCV is curable with direct-acting antivirals (DAAs), and HBV is manageable through long-term antiviral therapy. Awareness of infection was extremely low in our study population- few individuals who tested positive for HBV or HCV were aware of their status. Returning these results can therefore help close the diagnosis gap and empower individuals to seek care when it becomes available.

Guided by ethical research standards (Council for International Organizations of Medical Sciences (CIOMS), 2016), our study focused on returning only clinically actionable results- specifically, hepatitis B surface antigen (HBsAg) and HCV RNA positivity. An opt-in approach was adopted, allowing participants to decide whether they wished to receive their results, respecting their autonomy to make the decision. During the informed consent process, participants were clearly informed about the tests, the potential limitations in accessing treatment in their settings, and their right to decline result feedback (see Chapter 2). In Cambodia and Thailand, all participants opted in, while in Bangladesh, 97 participants chose not to receive their results.

Ideally, results feedback should be paired with clinical follow-up, including liver function assessments and staging of liver fibrosis to determine treatment eligibility. However, due to the cross-sectional nature of our study and limited resources, it was not possible to provide these services directly. Instead, we referred participants to local health facilities, drawing on established national care pathways for hepatitis management (Coalition for Global Hepatitis Elimination, 2025a; Coalition for Global Hepatitis Elimination, 2025b; Ministry of Health Cambodia, 2020). Meanwhile, ongoing discussion with the local partners continues, while we seek options to provide further support in linkage-to-care to the individuals that were tested positive and opted to receive the results. To ensure confidentiality and alignment with national public health protocols, the results feedback process was carefully planned. Individual results were sealed in envelopes labelled only with participant IDs; a separate, confidential list linking IDs to names was securely held by designated

distribution personnel. Depending on the local context, results were distributed by research staff, primary health centres, or village health workers. Feedback templates—reviewed by local public health experts and developed in line with national guidelines—included information on interpreting results, recommended next steps for clinical assessment, and locations where care could be accessed.

At the time of thesis writing, the results return process had been completed in Thailand. We have started the process in Bangladesh and Cambodia by actively engaging with local authorities and partners to identify the correct referral pathway and prepare for the dissemination. As the feedback process continues, we hope we can gain insights from the partners and community representatives on their opinions of this process, which may help to inform the design of future studies involving testing and screening procedures.

8.4 Implications for policy and practice

Our study highlighted the challenges and strengths of rural health systems in Bangladesh, Cambodia, and Thailand. While these systems addressed some aspects of the disease burden, rural areas such as our study sites, continue to experience disparities compared to national averages. Key gaps exist in WASH infrastructure, universal health coverage, quality of healthcare services, febrile illness diagnosis, HBV vaccination coverage, and NCD prevention and management.

Persistent socioeconomic challenges, including limited education and inadequate water, sanitation, and hygiene (WASH) infrastructure, pose key barriers to health improvements (Chapter 3). The high seroincidence of typhoid fever in Cambodia underscores the need for WASH improvements to reduce waterborne infections (Chapter 5). Additionally, low educational attainment in these communities reinforces the importance of long-term investments in education to improve health literacy and engagement with healthcare services (Chapter 3).

Financial barriers in accessing healthcare remain a major concern in Cambodia and Bangladesh, where healthcare costs were the most frequently reported

health-related concern (Chapter 3). Expanding universal health coverage in these countries may improve healthcare accessibility. As seen in Thailand, where there is better universal health coverage, the cost of care was reported far less frequently as a major health-related concern. However, access alone may be insufficient—ensuring high-quality healthcare is equally critical. In Cambodia, concerns about healthcare efficacy and safety suggest gaps in diagnostic reliability, treatment accuracy, and medication quality. Strengthening the capacity of healthcare providers, improving healthcare infrastructure and laboratory capacity, and ensuring access to quality-assured medications are needed to address these issues.

Fever is common in these rural communities, with widespread exposure to non-malarial febrile pathogens, particularly arboviruses including dengue virus, which suggests the need to equip the frontline health workers- the community health workers, malaria workers, and primary healthcare facilities, with triage or diagnostic capacity to improve case management, reduce unnecessary antibiotic use, and encourage appropriate health-seeking behaviours (Chapter 4) (Chappuis et al., 2013; Dittrich et al., 2018; Lim et al., 2015). This is particularly relevant for addressing the health-seeking patterns identified in Bangladesh and Cambodia, where individuals commonly rely on self-medication or private care. Strengthening public healthcare services, making them both accessible and trusted, could redirect patients towards effective care.

Serosurveillance can be a tool for monitoring exposure to different pathogens, especially in settings where facility-based estimates could lead to an underestimate related to health-seeking behaviour (Chapter 4 and Chapter 5). By providing population-level exposure estimates and utilising novel seroincidence estimation methods, serosurveillance can provide a better understanding of infection dynamics, strengthen disease monitoring, support vaccination programs, and guide public health interventions. For example, we identified high dengue virus (DENV) seroprevalence in Cambodia. Although it remains below the threshold recommended by WHO for routine dengue vaccination, ongoing monitoring of transmission trends could support early vaccine deployment should the area reach high transmission

levels. Similarly, the early childhood peak in Japanese encephalitis virus (JEV) seroprevalence in Thailand aligns with its national vaccination programme. However, lower-than-expected seroprevalence among young children and a notable dip among adolescents and young adults suggest suboptimal vaccine coverage in the study areas, highlighting a potential need for booster doses to improve population-level protection. Finally, the seroincidence findings for enteric fever among children and young adults in Cambodia, supported by PATH, have already been shared with national immunisation stakeholders as part of planning for typhoid conjugate vaccine (TCV) introduction. These examples illustrate how serosurveillance can directly inform and enhance national vaccination strategies and support broader public health decision-making.

Lower HBV and HCV prevalence among younger individuals suggests the success of past interventions, including HBV vaccination programs and blood safety interventions (Chapter 6). However, differences in vaccination coverage between the study areas and the national estimates, highlight the need for targeted immunisation efforts towards the rural populations. Ethnic minorities in Thailand also had a higher risk of HBV infection, suggesting that screening and prevention programs should be adapted to reach vulnerable populations that are specific to each region.

Our findings confirm a high burden of NCDs and associated risk factors among adults, with significant gaps in diagnosis and control (Chapter 7). To address the unmet screening and care needs, there could be better integration of NCD screening and management at the primary healthcare level. In addition, a targeted screening strategy could be implemented, focusing on high-risk populations, such as older adults and those who are overweight or obese, and individuals who fit certain social determinants of health linked to increased risk. In Cambodia, for example, individuals who were not working, students, or homemakers had a higher risk of NCD multimorbidity. Identifying context-specific high-risk groups in different areas would help tailor interventions to local needs. IIn addition to the targeted screening, the finding that 10-30% of middle-aged and older adults were identified as being at high risk of CVD, highlighted the potential value of using fixed-dose

combination therapy for both primary and secondary prevention for CVD (i.e. the Polypill). This therapy, which has been shown to be both safe and effective, could be given to older adults regardless of their CVD history and risk status (Roshandel et al., 2019), and would be particularly in resource-limited settings with poor diagnostic coverage. Additionally, the high prevalence of smoking and alcohol use, especially among middle-aged men, suggests the need for integrating behavioural interventions, such as smoking cessation programs and lifestyle counselling into broader NCD intervention strategies.

Our study highlights the need for a multifaceted approach to health system strengthening in rural Bangladesh, Cambodia, and Thailand. Key elements include improving healthcare access and ensuring vaccination coverage, enhancing capacity for febrile illness diagnosis and management, and better integration of NCD care into primary care services. In addition to healthcare improvement, addressing WASH infrastructure, education, and financial barriers to care will also help to improve the long-term health outcomes in these rural populations.

8.5 Future research directions

This thesis was written incorporating all laboratory results that were available at the time of completion. While laboratory test results for Cambodia and Thailand have been included in this thesis, the laboratory analysis for samples from Bangladesh is still ongoing. Additionally, enteric fever laboratory results for children under 5 years old are still in progress. Once these analyses are finalised, I will continue analysing the data to provide a complete assessment of the study objectives predefined in the Statistical Analysis Plan. Associations across health conditions and integration with other SEACTN studies.

In addition, this thesis primarily analysed each disease category separately, yet potential interactions between different health conditions remain unexplored. Future research could investigate:

- The association between self-perceived health status and objective disease status, such as assessing how NCDs or infectious diseases influence individual health perceptions and healthcare-seeking behaviour.
- The relationship between NCDs and immune responses to infections, such as how metabolic disorders affect serology responses to acute infections.
- Integrated disease burden estimation, combining survey-based prevalence data with facility-based incidence data from SEACTN fever aetiology studies.

8.5.1 Personal reflections

This research has been both challenging and deeply rewarding, reaffirming my passion for global health research. The opportunity to design, implement, and analyse data across three diverse study sites—while collaborating with dedicated teams in Bangladesh, Cambodia, and Thailand—has been an invaluable experience.

One of the most exciting aspects of this study has been working with seroprevalence and seroincidence estimates. This study allowed me to explore seroepidemiology and demonstrated the application of seroepidemiology as a powerful tool to monitor disease burden in resource-limited settings, where diagnostic infrastructure is often inadequate. Moving forward, I am interested in exploring alternative methods to determine seropositivity as described in Chapter 4, and applying the methods for seroincidence estimates of enteric fever to other infections.

The seroincidence estimates of enteric fever among children and young adults in Cambodia have been used to inform typhoid conjugate vaccine (TCV) introduction planning and vaccination campaigns. Seeing these findings contribute directly to public health action has been particularly gratifying, and I look forward to further contributing to public health by translating research into actionable interventions. Building on the lessons learned, I am eager to expand my expertise in seroepidemiology and global health research to enhance disease surveillance and inform evidence-based policy.

A

Appendix A for Chapter 1

A1. Database search terms

Database: Medline (Ovid MEDLINE® Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE® Daily and Ovid MEDLINE®) 1946 to present

Search Strategy:

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1 asia, southeastern/ or cambodia/ or laos/ or myanmar/ or thailand/ (42762)
2 asia, western/ or bangladesh/ (14281)
3 (thai* or cambodia* or kampudja or khmer or lao* or myanmar or burma or burmese or Bangladesh* or bengali or bangla or "south asia*" or "southeast asia*" or "south-east asia*").ti,ab. (91738)
4 1 or 2 or 3 (104285)
5 exp Health Surveys/ (594676)
6 ("health survey*" or (("health care" or healthcare) adj2 (surveillance or registration or "quality control")) or "population surveillance" or "public health surveillance" or "health status indicator*" or "chronic disease indicator*" or "disease activity score*" or "global disease burden" or "organ dysfunction score*" or "patient acuity" or "severity of illness index").ti,ab. (48336)
7 5 or 6 (624053)
8 Residence Characteristics/ (35970)
9 exp Population/ (132070)
10 Family Characteristics/ (27587)
11 (community-based or community or population-based or population or household).ti,ab. (1999942)
12 8 or 9 or 10 or 11 (2097339)
13 4 and 7 and 12 (2892)
14 13 (2892)
15 limit 14 to yr="2010 -Current" (1808)

Database: Medline (Ovid MEDLINE® Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE® Daily and Ovid MEDLINE®) 1946 to present

Search Strategy:

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1 asia, southeastern/ or cambodia/ or laos/ or myanmar/ or thailand/ (42762)
2 asia, western/ or bangladesh/ (14281)
3 (thai* or cambodia* or kampudja or khmer or lao* or myanmar or burma or burmese or Bangladesh* or bengali or bangla or "south asia*" or "southeast asia*" or "south-east asia*").ti,ab. (91738)
4 1 or 2 or 3 (104285)
5 exp Health Surveys/ (594676)
6 ("health survey*" or (("health care" or healthcare) adj2 (surveillance or registration or "quality control")) or "population surveillance" or "public health surveillance" or "health status indicator*" or "chronic disease indicator*" or "disease activity score*" or "global disease burden" or "organ dysfunction score*" or "patient acuity" or "severity of illness index").ti,ab. (48336)
7 5 or 6 (624053)
8 Residence Characteristics/ (35970)

9 exp Population/ (132070)
10 Family Characteristics/ (27587)
11 (community-based or community or population-based or population or household).ti,ab. (1999942)
12 8 or 9 or 10 or 11 (2097339)
13 4 and 7 and 12 (2892)
14 13 (2892)
15 limit 14 to yr="2010 -Current" (1808)

Database: Global Health <1973 to 2021 Week 34>
Search Strategy:
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2 cambodia/ (3125)
3 laos/ (1821)
4 exp bangladesh/ or south asia/ (155719)
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6 1 or 2 or 3 or 4 or 5 (258027)
7 disease surveys/ (21009)
8 ("health survey*" or (("health care" or healthcare) adj2 (surveillance or registration or "quality control")) or "population surveillance" or "public health surveillance" or "health status indicator*" or "chronic disease indicator*" or "disease activity score*" or "global disease burden" or "organ dysfunction score*" or "patient acuity" or "severity of illness index").ti,ab. (18165)
9 7 or 8 (38754)
10 communities/ (15580)
11 populations/ (2864)
12 households/ (23547)
13 (community-based or community or population-based or population or household).ti,ab. (539288)
14 10 or 11 or 12 or 13 (547167)
15 6 and 9 and 14 (2316)
16 15 (2316)
17 limit 16 to yr="2010 -Current" (1778)

CINAHL EBSCOhost

#	Query	Results
S13	S4 AND S7 AND S11	951
S12	S4 AND S7 AND S11	1,200
S11	S8 OR S9 OR S10	945,720
S10	TI (community-based or community or population-based or population or household) OR AB (community-based or community or population-based or population or household)	679,311

S9	(MH "Population+")	331,729
S8	(MH "Communities+")	52,930
S7	S5 OR S6	166,789
S6	TI ("health survey*" or (("health care" or healthcare) n2 (surveillance or registration or "quality control")) or "population surveillance" or "public health surveillance" or "health status indicator*" or "chronic disease indicator*" or "disease activity score*" or "global disease burden" or "organ dysfunction score*" or "patient acuity" or "severity of illness index") OR AB ("health survey*" or (("health care" or healthcare) n2 (surveillance or registration or "quality control")) or "population surveillance" or "public health surveillance" or "health status indicator*" or "chronic disease indicator*" or "disease activity score*" or "global disease burden" or "organ dysfunction score*" or "patient acuity" or "severity of illness index")	21,447
S5	(MH "Surveys")	151,021
S4	S1 OR S2 OR S3	26,230
S3	TI (thai* or cambodia* or kampudja or khmer or lao* or myanmar or burma or burmese or Bangladesh* or bengali or bangla or "south asia*" or "southeast asia*" or "south-east asia*") OR AB (thai* or cambodia* or kampudja or khmer or lao* or myanmar or burma or burmese or Bangladesh* or bengali or bangla or "south asia*" or "southeast asia*" or "south-east asia*")	23,025
S2	(MH "Bangladesh") OR (MH "Asia, Western")	4,762
S1	(MH "Asia, Southeastern") OR (MH "Cambodia") OR (MH "Laos") OR (MH "Myanmar") OR (MH "Thailand")	11,430

Web of Science Core Collection

thai* or cambodia* or kampudja or khmer or lao* or myanmar or burma or burmese or Bangladesh* or bengali or bangla or "south asia*" or "southeast asia*" or "south-east asia*" (Topic) and ("health survey*" or (("health care" or healthcare) Near/2 (surveillance or registration or "quality control")) or "population surveillance" or "public health surveillance" or "health status indicator*" or "chronic disease indicator*" or "disease activity score*" or "global disease burden" or "organ dysfunction score*" or "patient acuity" or "severity of illness index") (Topic) and community-based or community or population-based or population or
household (Topic) and 2021 or 2020 or 2019 or 2018 or 2017 or 2011 or 2012 or 2013 or 2014 or 2015 o r 2016 or 2010 (Publication Years)

SCOPUS

(TITLE-ABS-KEY (thai* OR cambodia* OR kampudja OR khmer OR lao* OR myanmar OR burma OR burmese OR bangladesh* OR bengali OR bangla OR "south asia*" OR "southeast asia*" OR "south-east asia*") AND TITLE-ABS-KEY (("health survey*" OR (("health care" OR healthcare) W/2 (surveillance OR registration OR "quality control")) OR "population surveillance" OR "public health surveillance" OR "health status indicator*" OR "chronic disease indicator*" OR "disease activity score*" OR "global disease burden" OR "organ dysfunction score*" OR "patient acuity" OR "severity of illness index")) AND TITLE-ABS-KEY (community-based OR community OR population-based OR population OR household)) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010))

WHO Global Index Medicus

(tw:(thai* or cambodia* or kampudja or khmer or lao* or myanmar or burma or burmese or Bangladesh* or bengali or bangla or "south asia*" or "southeast asia*" or "south-east asia*")) AND (tw:("health survey*" or (("health care" or healthcare) and (surveillance or registration or "quality control")) or "population surveillance" or "public health surveillance" or "health status indicator*" or "chronic disease indicator*" or "disease activity score*" or "global disease burden" or "organ dysfunction score*" or "patient acuity" or "severity of illness index")) AND (tw:(community-based or community or population-based or population or household))

Limited: 2010 to 2021

Google scholar

(thai*|cambodia*|kampudja|khmer|lao*|myanmar|burma|burmese|Bangladesh*|bengali|bangla)("health survey*"|"health care surveillance"|"healthcare surveillance")(community-based|community|population-based|population|household)

https://scholar.google.co.uk/scholar?hl=en&as_sdt=0%2C5&q=%28thai*%7Ccambodia*%7Ckampudja%7Ckhmer%7Clao*%7Cmyanmar%7Cburma%7Cburmese%7CBangladesh*%7Cbengali%7Cbangla%29%28%22health+survey*%22%7C%22health+care+surveillance%E2%80%9D%7C%E2%80%9Dhealthcare+surveillance%22%29%28community-based%7Ccommunity%7Cpopulation-based%7Cpopulation%7Chousehold%29&btnG=

(thai*|cambodia*|kampudja|khmer|lao*|myanmar|burma|burmese|Bangladesh*|bengali|bangla)("population surveillance"|"public health surveillance"|"health status indicator*")(community-based|community|population-based|population|household)

https://scholar.google.co.uk/scholar?hl=en&as_sdt=0%2C5&q=%28thai*%7Ccambodia*%7Ckampudja%7Ckhmer%7Clao*%7Cmyanmar%7Cburma%7Cburmese%7CBangladesh*%7Cbengali%7Cbangla%29%28%22population+surveillance%22%7C%22public+health+surveillance%22%7C%22health+status+indicator*%22%29%28community-based%7Ccommunity%7Cpopulation-based%7Cpopulation%7Chousehold%29&btnG=

(thai*|cambodia*|kampudja|khmer|lao*|myanmar|burma|burmese|Bangladesh*|bengali|bangla)("public health surveillance"|"health status indicator*"|"chronic disease indicator*")(community-based|community|population-based|population|household)

https://scholar.google.co.uk/scholar?hl=en&as_sdt=0%2C5&q=%28thai*%7Ccambodia*%7Ckampudja%7Ckhmer%7Clao*%7Cmyanmar%7Cburma%7Cburmese%7CBangladesh*%7Cbengali%7Cbangla%29%28%22public+health+surveillance%22%7C%22health+status+indicator*%22%7C%22chronic+disease+indicator*%22%29%28community-based%7Ccommunity%7Cpopulation-based%7Cpopulation%7Chousehold%29&btnG=

(thai*|cambodia*|kampudja|khmer|lao*|myanmar|burma|burmese|Bangladesh*|bengali|bangla)("disease activity score*"|"global disease burden"|"organ dysfunction score*")(community-based|community|population-based|population|household)

https://scholar.google.co.uk/scholar?hl=en&as_sdt=0%2C5&q=%28thai*%7Ccambodia*%7Ckampudja%7Ckhmer%7Clao*%7Cmyanmar%7Cburma%7Cburmese%7CBangladesh*%7Cbengali%7Cbangla%29%28%22disease+activity+score*%22%7C%22global+disease+burden%22%7C%22organ+dysfunction+score*%22%29%28community-based%7Ccommunity%7Cpopulation-based%7Cpopulation%7Chousehold%29&btnG=

A2. Publication screening and inclusion process

Screening process:

At each stage, publications were independently assessed by two reviewers. Any conflicts or discrepancies between reviewers were first attempted to be resolved through consensus discussions. Any remaining discrepancies were resolved by a third senior reviewer. The screen process and the responsible author initials are listed below (alphabetical order of initials):

1. Reviewers conducted Abstract screening:
    - Pair one: MZ, NSNH
    - Pair two: RC, MZ
2. Reviewers conducted Abstract screening of the references and citations of the inclusions from abstracts screening
    - ARS, MZ
3. Reviewers conducted Full text screening
    - Pair one: CA, MZ
    - Pair two: HK, MZ
    - Pair three: CA, HK
    - Pair four: RC, SKM

Senior reviewers who had a role for resolving discrepancies: MZ, RC, NSNH, SKM

Identification of primary data source (Survey)

The original survey from which the data was primarily collected for each publication was identified, and all publications were grouped by "survey" (e.g. multiple publications used data collected from a particular DHS survey in Bangladesh). If the publications explicitly mentioned the primary data source, searches were conducted to locate the reports or publications where the data were originally published, within already included publications and beyond. Only those published within the same inclusion period of the

review were additionally included. In cases where the name of the original study was not explicitly mentioned, publications reporting on the same population, with the same study design, and conducted during the same time period were considered part of the same original study and grouped together.

A3 Age group categorizations and health condition definitions

Table. Age group categorization and corresponding age criteria of included surveys

Age groups (years)	**Subcategories (years)**	**Age described in the study**
Lifespan	**Lifespan**	All, <60, ⩾0.5, ⩾0.7, 0.5-60, ⩾1 ⩾1.5, ⩾2, ⩾3, 5-86, ⩾5, ⩾6, ⩾10, 12-82, 13-64, 14-90,
Childhood (≤19)	**Child (**≤19)	0-18, 1-14, 2-6, 0.5-12, 0.5-6, 2-9
	Preschool child(≤5)	<0.5 month, <1 month, <1.5, <23 month, <2, ≤2, <4, <5, ≤5, 6-23.9 months 6-23 months, 0.5-2, 6-36 months, 6-47.9 months, 0.5-5, 6-59 months, 6-60 months, 6-69 months, 6-72 months, 12-35 months, 1-3, 12-47 months, 12-59 months, 1-5, 2-4, 24-59 months, 24-60 months, 3-5
	School-age child (5-19)	4-14, 5, 5-9, 5-14, 6-12, 5-17, 6-14, 9-15, 10-16, 10-19, 11-15.3, 12, 15, 15-17
Adulthood (⩾15)	**Adult (**⩾15)	⩾15, >15, 15-80, 15-99, 16-80, ⩾16, 18-69, 18-70, ⩾18, 20-70, 20-80, ⩾20, ⩾21, 25-74, ⩾25, 30-69, ⩾30, 34-77, ⩾35, 40-74, 40-80, ⩾40, >40
	Reproductive age (14-49)	**14-29**, 15-24, 15-34, 15-39, 15-45, 15-49, 16-25, 18-24, 18-30, 18-34, 18-45, 18-49, 20-45, 20-49, 35-44, 30-49
	Reproductive age and older adulthood (15-69)	15-59, 15-64, 15-65, 16-55, 18-60, 18-64, 20-59, 20-60, 20-65, 25-54, 25-64, 30-59, 30-64, 35-64, 35-65, 40-59, 40-69
	Older adulthood and retirement age (⩾50)	50-65, ⩾55, ⩾50, ⩾60, 60-75, 60-79, ⩾65, 65-74

Definition of health condition categories

Non-communicable conditions reflecting the same underlying pathophysiology but representing different degrees of severity were grouped together(e.g. elevated blood glucose level, prediabetes, and diabetes were grouped as one type of health condition and referred to as “diabetes”).

Infectious conditions were categorized based on direct microbiologic identification of a pathogen (e.g., through culture or molecular tests) or indirect measures (e.g., serologic tests). Infective syndromes without a reported microbiologic cause, such as acute respiratory infection (ARI), were also categorized as infectious conditions. Distinctions were not made between present and past infections or between the species of the pathogens (e.g. infection with *Plasmodium falciparum and P. vivax* were both grouped as “malaria”). "Intestinal parasites" was used to categorize conditions that reported the presence of any parasites in fecal samples. When specific intestinal parasites were reported, the names of the parasites were included, such as "Intestinal parasite- Trematodes (*Opisthorchis viverrini*)." Infectious conditions were further subcategorized into bacterial, viral, parasitic, and non-specified based on the microbiological results or lack thereof.

Symptoms and abnormal findings that could not be determined as infectious or non-infectious causes (e.g., fever, diarrhea, abnormal pulse rate, raised serum creatine) were categorized as "Symptoms."

Conditions categorized as disability were either specified by the study or categorized by the review authors when a condition fit the WHO definition of disability, which includes impairments, activity limitations, and participation restrictions referring to the negative aspects of the interaction between an individual and the individual's contextual factors(1). Based on the aspects of disability, conditions were grouped into body structure, body function, and activities and participation related disability, according to the International Classification of Functioning, Disability and Health (2). Subcategorization of activity of daily living defined as fundamental skills required to independently care for oneself (3,4). It was applied, when multiple body function and activity related aspects were evaluated and/or reported as ADL by the included surveys.

Self-perceived health status encompassed the assessments of an individual's own opinion on their health, which can be generic, or disease-specific. They were grouped into two subcategories: self-rated health, which was based on a single-question assessment of self-rated health, and health-related quality of life, which was evaluated by instrument-specific assessment, such as SF12, EQ-5, or multi-item health status index derived from the World Health Survey (5–7).

General health describes the data collected from the questions asked to the survey participants, soliciting self-reported presence or history without limiting the answers to specific diseases or symptoms (e.g. E.g. Have you been ill in the past 30 days? Could you tell me all the symptoms or diagnosis you had?).

References:

1. Leonardi M, Bickenbach J, Ustun TB, Kostanjsek N, Chatterji S, MHADIE Consortium. The definition of disability: what is in a name? Lancet Lond Engl. 2006 Oct 7;368(9543):1219–21.

2. International Classification of Functioning, Disability and Health (ICF) [Internet]. [cited 2022 Nov 3]. Available from: https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health

3. Katz S. Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily living. J Am Geriatr Soc. 1983 Dec;31(12):721–7.

4. Edemekong PF, Bomgaars DL, Sukumaran S, Schoo C. Activities of Daily Living. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 [cited 2022 Nov 10]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK470404/

5. A single-vs. multi-item self-rated health status measure: a 21-country study [Internet]. [cited 2023 Feb 1]. Available from: https://apps.who.int/healthinfo/systems/surveydata/index.php/citations/52427

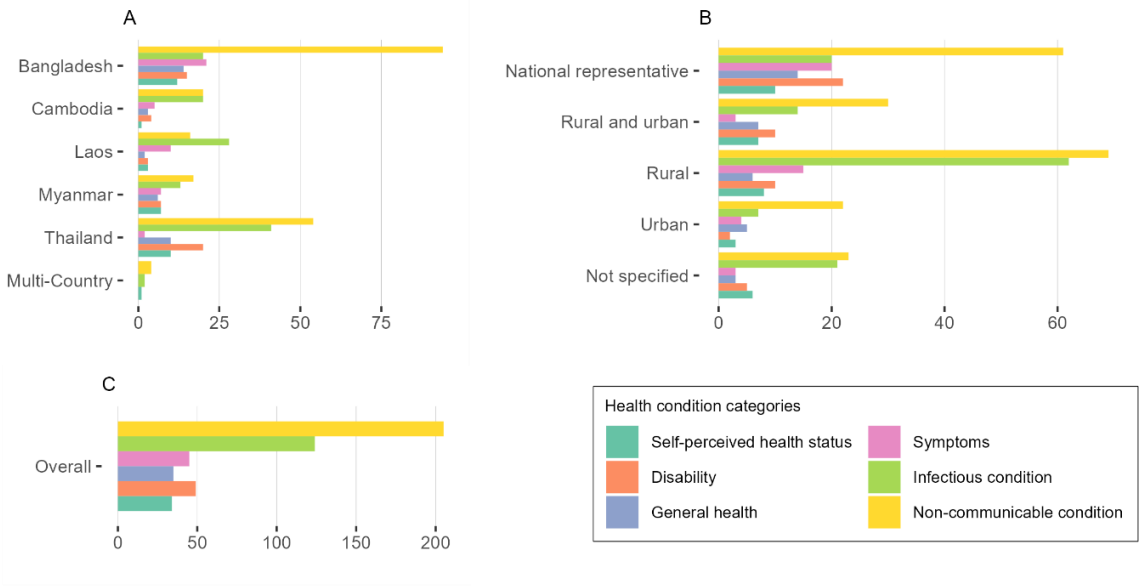
6. Gandek B, Ware JE, Aaronson NK, Apolone G, Bjorner JB, Brazier JE, et al. Cross-Validation of Item Selection and Scoring for the SF-12 Health Survey in Nine Countries: Results from the IQOLA Project. J Clin Epidemiol. 1998 Nov 1;51(11):1171–8.

7. Janssen MF, Szende A, Cabases J, Ramos-Goñi JM, Vilagut G, König HH. Population norms for the EQ-5D-3L: a cross-country analysis of population surveys for 20 countries. Eur J Health Econ. 2019;20(2):205–16.

A4. Table. Number of studies conducted in each country, by rural, urban, and nationally representative coverage.

Coverage*	Overall	Bangladesh	Thailand	Laos	Cambodia	Myanmar
n(%)	337	123	98	41	37	33
nationally representative	77 (22.8)	32 (26.0)	18 (18.4)	7 (17.1)	9 (24.3)	10 (30.3)
Rural and urban	50 (14.8)	16 (13.0)	16 (16.3)	7 (17.1)	3 (8.1)	7 (21.2)
Urban	34 (10.1)	24 (19.5)	7 (7.1)	1 (2.4)	1 (2.7)	1 (3.0)
Rural	131 (38.9)	40 (32.5)	34 (34.7)	20 (48.8)	20 (54.1)	14 (42.4)
Not specified	45 (13.4)	11 (8.9)	23 (23.5)	6 (14.6)	4 (10.8)	1 (3.0)

*Study conducted in multiple countries are not shown in the table. Including nationally representative: Laos and Thailand (n=1); Rural and urban: Laos and Thailand (n=1); Rural: Cambodia, Myanmar, and Thailand (n=1); Cambodia and Thailand (n=1): Laos and Thailand (n=1)



A5. Figure. Number of surveys by health condition category

A. Number of surveys by health condition category and study country. B. Number of surveys reported by health condition category and by urban-rural coverage. C. Overall number of surveys by health condition categories.

Studies conducted in multiple countries include: Cambodia, Myanmar, and Thailand (n=1); Cambodia and Thailand (n=1); Laos and Thailand (n=3).

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SYSTEMATIC REVIEW Open Access

The spectrum of health conditions in community-based cross-sectional surveys in Southeast Asia 2010-21: a scoping review

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Abstract

Background Southeast Asia is undergoing an epidemiological transition with non-communicable illnesses becoming increasingly important, yet infectious diseases (tuberculosis, HIV, hepatitis B, malaria) remain widely prevalent in some populations, while emerging and zoonotic diseases threaten. There are also limited population-level estimates of many important heath conditions. This restricts evidence-based decision-making for disease control and prevention priorities. Cross-sectional surveys can be efficient epidemiological tools to measure the prevalence of a wide range of diseases, but no systematic assessment of their coverage of different health conditions has been produced for the region.

Methods We conducted a systematic search in Medline, Embase, Global Health, CINAHL, Scopus, Web of Science Core Collection, and Global Index Medicus, and additionally Google Scholar. Our inclusion criteria were cross-sectional surveys conducted with community-based recruitment, in Bangladesh, Cambodia, Laos, Myanmar, and Thailand, published between January 1, 2010 and January 27, 2021, and reporting the prevalence of any health condition.

Results 542 publications from 337 surveys were included. Non-communicable conditions ($n=205$) were reported by more surveys than infectious conditions ($n=124$). Disability ($n=49$), self-report history of any disease or symptoms ($n=35$), and self-perceived health status ($n=34$), which reflect a holistic picture of health, were studied by many fewer surveys. In addition, 45 surveys studied symptomatic conditions which overlap between non-communicable and infectious conditions. The most surveyed conditions were undernutrition, obesity, hypertension, diabetes, intestinal parasites, malaria, anemia, diarrhea, fever, and acute respiratory infections. These conditions overlap with the most important causes of death and disability in the Global Burden of Disease study. However, other high-burden conditions (e.g. hearing loss, headache disorder, low back pain, chronic liver and kidney diseases, and cancers) were rarely studied.

Conclusion There were relatively few recent surveys from which to estimate representative prevalences and trends of health conditions beyond those known to be high burden. Expanding the spectrum of health conditions in cross-sectional surveys could improve understanding of evolving disease patterns in the region.

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Keywords Southeast Asia, Cross-sectional surveys, Community-based survey, Epidemiology

Background

South and Southeast Asia encompass a geographical area comprising 15 countries with diverse geography, unique history, and distinct social and economic features. These factors have contributed to variations and similarities in health status and healthcare systems across these countries [1]. Bangladesh, Cambodia, Myanmar, Laos, and Thailand, located centrally within the region, represent a mix of Lower-Middle-Income Countries and an Upper-Middle-Income Country. The demographic and economic makeup of these countries is changing rapidly, and the current disease epidemiological data do not reflect these changes. As the traditional leading causes of mortality, communicable diseases (e.g. malaria, tuberculosis, and diarrheal diseases) and maternal and child health, have been successfully addressed by vertical programs in many parts of the region [1–8]. The increasing burden of non-communicable diseases (e.g. diabetes, cardiovascular disease, cancer), and emerging infectious diseases (e.g., chikungunya, or dengue) have put new parts of the population at risk, while historically at-risk parts of the population remain vulnerable to other neglected tropical diseases [9–13].

Although the existing data collection mechanism capture some of the changes, there are major gaps for certain diseases and populations. The data on traditionally high-burden diseases are updated by monitoring and evaluation systems within the corresponding vertical programs [2–6]. Prevalence of non-communicable disease, such as cardiovascular disease and diabetes, are reported by regularly conducted population-based national surveys (e.g., Demographic and Health Survey (DHS), WHO's STEPwise approach to NCD risk factor surveillance) [14, 15]. However, there is scattered data on other diseases. Information on a wide range of diseases and populations can be obtained from existing surveillance or registration systems (e.g. health information systems, disease-specific registration systems, and death registration systems), but the coverage of these systems is limited [16, 17]. Regularly updated population-level disease burden estimates, such as the Global Burden of Disease Study (GBD) also exist, but the lack of primary data sources impedes the accuracy of the modeling results [18, 19]. The incomplete knowledge of current epidemiology in the region constrains decision makers' ability to make evidence-based decisions- to identify health priorities, allocate resources, set targets, and monitor progress at a health system level.

In this context, cross-sectional surveys are an effective research method to provide population-level prevalence estimates. These surveys can capture a wide range of health-related factors within a relatively short implementation period and at a relatively low cost compared to other population-based data sources. No systematic assessment of the coverage of different health conditions by cross-sectional surveys has been produced for the region. To inform the design of future prevalence surveys, we conducted a scoping review with three key aims. Firstly, to understand where and when community based cross-sectional surveys have recently been conducted within the region. Secondly, to identify the health conditions studied in these surveys including variations across geographies and populations. Thirdly, to identify knowledge gaps that may serve as areas of focus in future surveys.

Methods

This study was conducted according to the Preferred Reporting Items for Systematic Review and Meta-analysis Extension for Scoping Review (PRISMA-ScR) and the JBI Manual for Evidence Synthesis [20, 21]. The study protocol is registered with the Open Science Framework (OSF registration https://doi.org/10.17605/OSF.IO/9GBNK).

Literature search strategy

A systematic search was conducted in seven databases: Medline, Embase, Global Health, CINAHL, Scopus, Web of Science Core Collection, and Global Index Medicus. Additionally, we searched Google Scholar for grey literature. We employed a broad search string that consisted of Medical Subject Headings (MeSH) and free-text terms, and excluded publications published before 2010. The full search terms are included in Appendix S1.

Study selection and full-text review

The screening process followed JBI recommendations, and the details are in Appendix S2. Only publications that meet the predefined inclusion criteria: studies conducted in Bangladesh, Cambodia, Laos, Myanmar, and Thailand; published between January 1, 2010, and January 27, 2022; and cross-sectional health surveys with participants recruited from the community, irrespective of symptoms or disease status; reported the number of participants with a condition and the total number of participants assessed. The PRISMA flowchart for the review is in Fig. 1.

Data extraction and analysis

Data from publications deemed eligible for the review were extracted into an Excel sheet with predefined variables, including bibliographic metrics, study methods, and health conditions reported as prevalence, along with the age and sex of the study population.

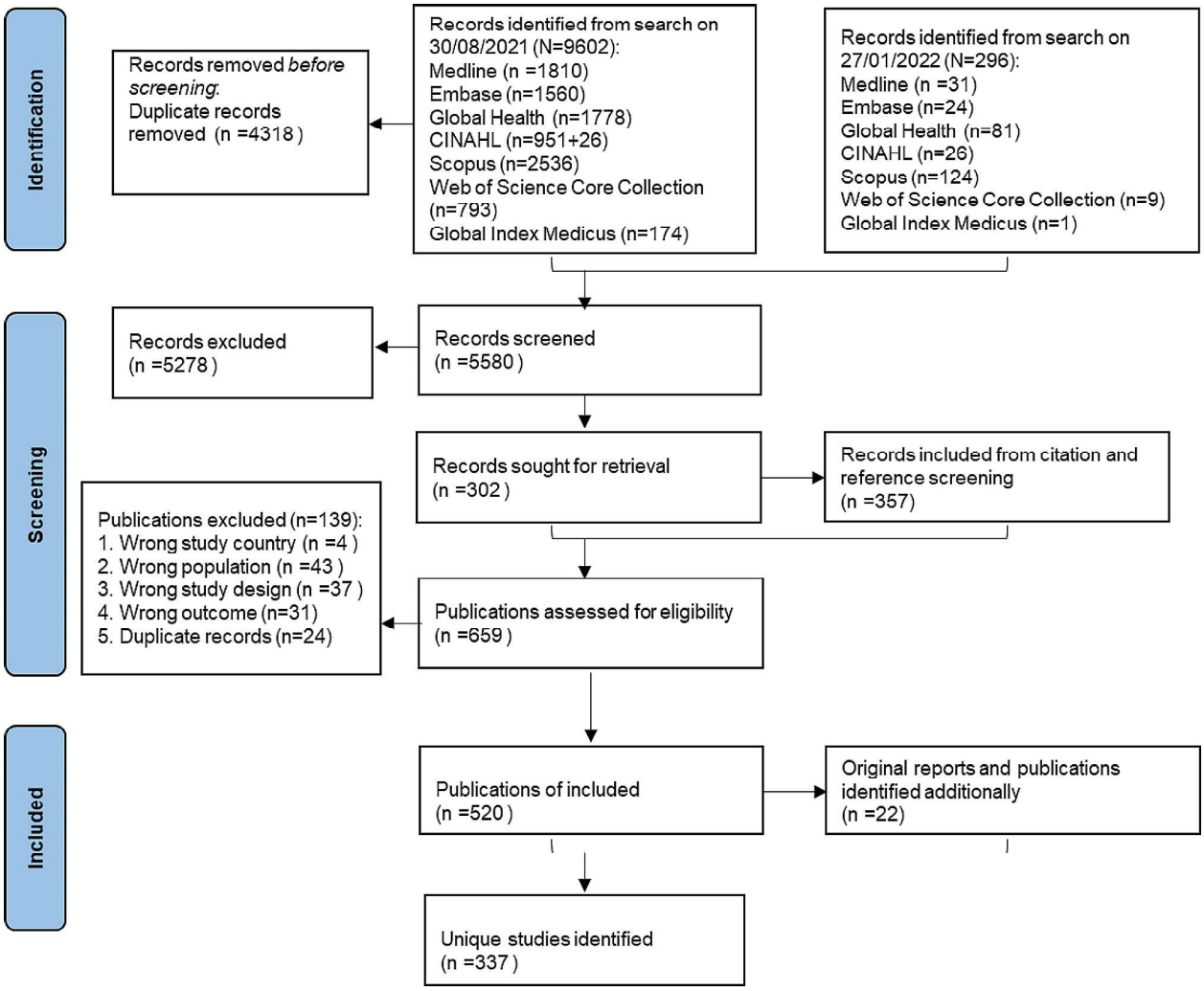


Fig. 1 PRISMA flowchart showing selection of studies

The original survey from which the data was primarily collected for each publication was identified, and all publications were grouped by "survey" (e.g. multiple publications used data collected from a particular DHS survey in Bangladesh). The identification of original data source of a publication is detailed in Appendix S2.

Definitions and categorization

The urbanicity coverage of the studies was recorded as it was described in the publications, as urban, rural, both urban and rural, or nationally representative. If a study did not describe the coverage, it was recorded as "unspecified."

The age distribution of the study population for each condition was organized into a context appropriate classification. The age groups were categorized as: Lifespan, Childhood, and Adulthood. Child and Adulthood category contains subcategories of age groups that with narrower age bands (Table 1). The exact match of inclusion of age group of a survey and the corresponding age group applied in this review is detailed in Appendix S3.

Health conditions, symptoms, laboratory or point-of-care test results, and physical examination results were recorded as reported in the publications. They were then placed into mutually exclusive categories, based primarily on the International Classification of Primary Care 3rd Edition (ICPC-3), including non-communicable conditions, infectious conditions, symptoms, disability and functional limitation (disability), self-perceived health status, general health condition inquires (general health) [22–30] (Table 1). The details of the categorization are described in Appendix S3.

Table 1 Categorizations of age groups and health conditions

Age groups (years)	Subcategories (years)
Lifespan	When a condition was studied among participants recruited without specific age criteria or across both the "Childhood" and "Adulthood" groups
Childhood (≤ 19):	– Child (≤ 19) – Preschool child(≤ 5) – School-age child (5–19)
Adulthood (≥ 15)	– Adulthood (≥ 15) – Reproductive age (15–49) – Reproductive age and older adulthood (15–64) – Older adulthood and retirement age (≥ 50)
Health condition categories	**Categorization and definition**
1. Non-communicable conditions	Non-communicable conditions reflecting the same underlying pathophysiology but representing different degrees of severity were grouped together(e.g. elevated blood glucose level, prediabetes, and diabetes were grouped as one type of health condition and referred to as "diabetes").
2. Infectious	Infectious conditions were categorized based on a. Direct microbiologic identification of a pathogen (e.g., through culture or molecular tests) or b. Indirect measures (e.g., serologic tests). c. Infective syndromes without a reported microbiologic cause, such as acute respiratory infection (ARI), were also categorized as infectious conditions. Based on the microbiologic results or lack thereof the subcategories applied: Bacterial, viral, parasitic, non-specified
3. Symptoms and abnormal findings (Symptoms)	Conditions that could not be determined as infectious or non-infectious causes (e.g., fever, diarrhea).
4. Disability and functional limitation (Disability)	Disability was defined either directly by the study that referring a condition as disability, or categorized by the review authors when a condition fit the WHO definition of disability [22]. Based on the aspects of disability, the conditions were grouped into: a. Body structure: impairments of anatomical parts of the body such as organs, limbs and their components b. Body function: impairments of physiological functions of body systems (including psychological functions) c. Activity and participation (Activity): difficulties and problems of execution of a task or action, and/ or involvement in a life situation [23]. d. Activity of daily living: Fundamental skills, related with body function and activity, required to independently care for oneself [24,25] .
1. Self-perceived health status	Self-perceived health status encompassed the questionnaire-based assessments of a. Self-rated health: a single question assessing an individual's own opinion on their health or b. health -related quality of life: the impact of health status on quality of life [26–29].
2. General health condition inquiries (General health)	It describes the data collected from the questions asked to the survey participants, soliciting self-reported presence or history without limiting the answers to specific diseases or symptoms. E.g. Have you been ill in the past 30 days? Could you tell me all the symptoms or diagnosis you had?

Comparison to global burden of disease estimates

To understand how the conditions studied by prevalence surveys compared to the highest burden conditions as determined by the Global Burden of Disease project, we:

1) Extracted the conditions that ranked the top 20 causes of death and disability (Causes) with highest disability-adjusted-life-years (DALY) rate (/100,000 population) of each country [31].
2) Summed the number of times a cause was studied in all included surveys of each country.
3) Identified country-specific leading disease burdens that were studied by a high number, a low number, or by no surveys.

To understand how well these causes were studied or described by other types of studies or data sources not included in our review, we:

1) Extracted the metadata of GDB of the top high-burden causes of each country, and summed the number of references of a cause which the data collection completed from 2010 onwards [32].
2) We assumed the number indicated the availability of a wider range of data source that consistent with the inclusion criteria of data source used in GBD (e.g. vital registration system, reports), and identify causes with high number, and low number, or no available data from data sources, beyond the surveys that are included in the review.

Statistical analysis

The unit of analysis was the "survey," which represented the original data source of multiple publications. Each study was characterized by the study country, rural or urban coverage, and whether it was a repeated survey. Each health condition was further described by the target

population's age group. All analyses were carried out using R software version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria), and graphical presentations were done using the ggplot2 library.

Results

The screening process and publication inclusion are shown in Fig. 1. A total of 542 publications were finally included, reporting results from 337 surveys (Supplementary material: Summary of publications and surveys, and conditions studied).

Most surveys were conducted in Bangladesh (n=123, 36.5%), followed by Thailand (n=98, 29.1%), Laos (n=41, 12.2%), Cambodia (n=37,11.0%), and Myanmar (n=33, 9.8%). The majority of surveys had rural coverage, including surveys conducted only in rural areas (n=131, 38.8%), nationally representative surveys (n=78, 23.1%), and surveys conducted in both rural and urban areas (n=50, 14.8%). Fewer surveys (n=34, 10.1%) had urban only coverage, and 45 (13.4%) surveys did not specify the coverage. Across countries, majority surveys (32.5 -54.1%) had rural only coverage; 17.1-30.3% surveys were national representative; and less than 10% of surveys had urban only coverage, except for Bangladesh (n=24, 19.4%)(Appendix S4).

Most surveys (n=201) studied conditions among participants in their adulthood, including adult (n=107), of reproductive age (n=29), reproductive age and older adult (n=27), and older adult and retirement age (n=48). Seventy-one surveys were done among participants in their childhood, including child (n=13), preschool-children (n=50), and school-age-children (n=13). Seventy-one surveys were conducted participants' age across the lifespan, and 25 surveys did not specify participants' age.

Non-communicable conditions were reported by 205 surveys, followed by infectious conditions (n=124), disability (n=49), symptoms (n=45), general health (n=35), and self-perceived health (n=34) .

While 70.0% (n=236) of surveys studied conditions from a single health condition category, 18.1% (n=61) studied two categories, and 11.9% (n=40) studied three to five categories. The majority of surveys studied non-communicable conditions (n=119, 58.0%) and infectious conditions (n=90, 72.6%), studied conditions from a single health conditions category. In contrast, most surveys studying symptoms (n=40, 88.9%), disability (n=42, 85.7%), self-perceived health (n=27, 79.4%) and general health (n=27, 77.1%), also studied conditions of other categories.

The most studied conditions across age groups and condition categories are: undernutrition (n=77), obesity (n=75), hypertension (n=60), diabetes (n=56), and intestinal parasites (n=38).

Non-communicable conditions

Non-communicable conditions were those most studied across countries (Bangladesh: n=94, Thailand: n=54, Cambodia: n=20, Myanmar: n=17), except Laos (n=16), and geographic coverages (rural: n=69, national representative: n=61, rural and urban: n=30, and urban: n=22). They were studied the most among participants in adults (n=76) and preschool child (n=43) age categories (Fig. 2). The most studied non-communicable conditions are described in Table 2.

Infectious diseases

Infectious conditions were those most studied in Laos (n=28) and Cambodia (n=20). They were also studied by about half of the surveys conducted in Thailand (n=41) and Myanmar (n=13), and surveys with rural only coverage (n=62), and unspecified coverage (n=21). They were studied most among participant age across the lifespan (n=49), adult (n=24) and preschool child (n=20) categories (Fig. 2). Infectious conditions were categorized into parasites (n=83), viruses (n=23), bacteria (n=14), and unspecified pathogens (n=17).

Symptoms

Symptoms were studied by relatively larger number of survey from Laos (n=10) and Myanmar (n=7), and surveys with national representative samples (n=20), compare surveys conducted in other countries, especially in Thailand (n=2), and geographic coverage. Symptoms were studied mainly among preschool children (n=26) (Fig. 2).

Disability, self-perceived health status, and general health

While general health, disability, and self-perceived status were studied by fewer surveys across countries and geographic coverage compare with other condition categories, relatively more surveys studied on these categories were identified from Myanmar (self-perceived health status (n=7), general health (n=6), and disability (n=7). Disability specifically, was studied by relatively more surveys conducted in Thailand (n=20), with nationally representative samples (n=22), or rural and urban coverage (n=10).

Older adult and retirement age were the most common study population for general health (n=13), disability (n=27), and self-perceived health (n=16) (Fig. 2). In addition, adult populations were also the common target group for surveys of general health (n=12) and self-perceived health (n=11) .

Leading causes of disability and death

From the GBD study, the top 20 causes with the highest DALY rate largely overlapped across study countries (Fig. 3). Among the 20 top burden causes of Bangladesh,

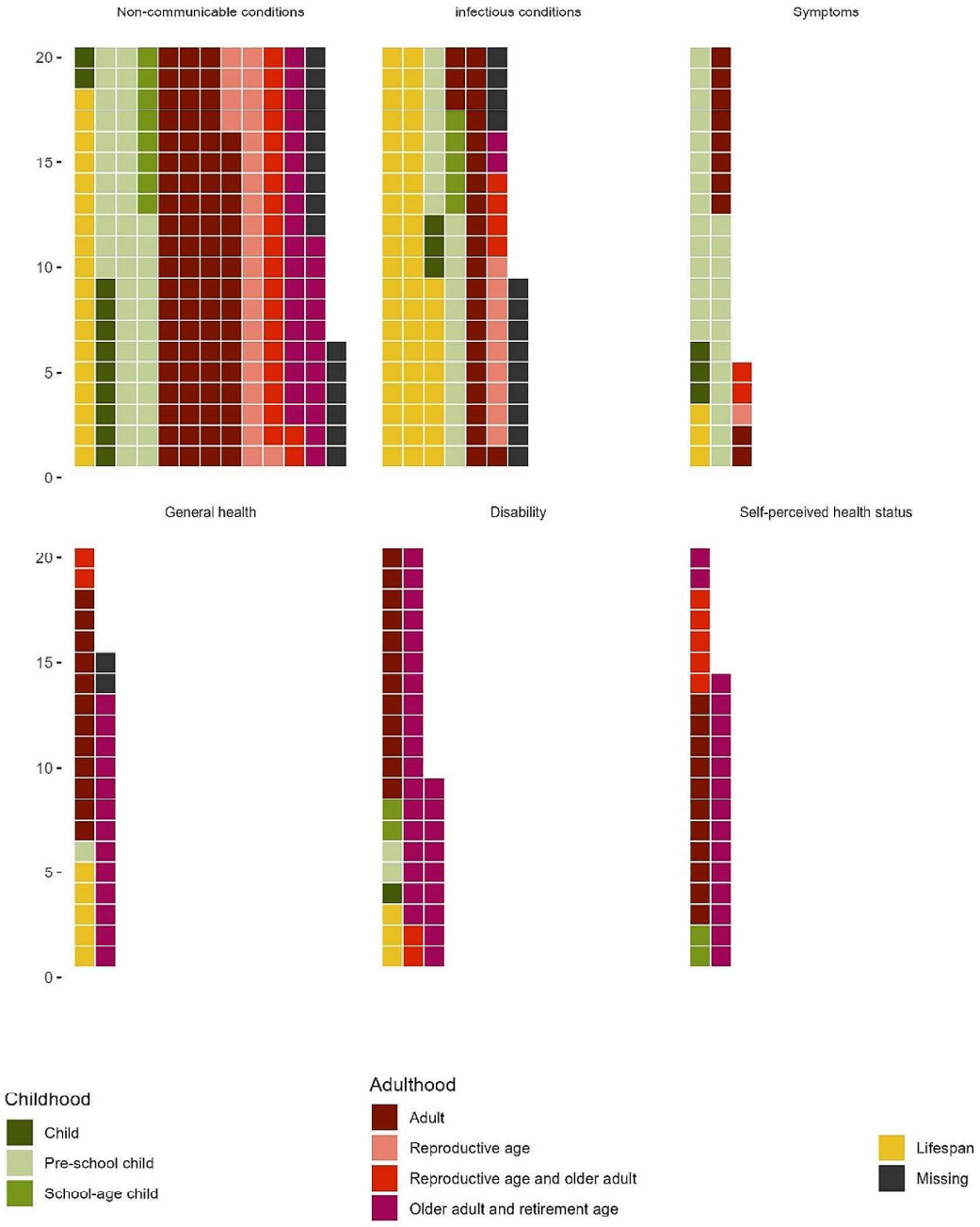


Fig. 2 Waffle plot showing the distribution of health conditions by age categories. Figure showing (from the top left to bottom right) the number of surveys studied among participants of each age group, on Non-communicable conditions, Infectious conditions, Symptoms and abnormal findings (Symptoms), General health condition inquiries (General health), Disability and functional limitation (Disability), and Self-perceived health status
Each square represents one survey. However, there are more squares than the total number of surveys, because multiple age groups can be studied by a survey. The number of squares of each condition category are: non-communicable condition ($n=236$), infectious condition ($n=129$), Symptoms ($n=45$), General health ($n=35$), disability ($n=49$), to self-perceived health status ($n=34$)

Table 2 The top 5 most studied conditions of each health condition category, by age groups

Overall across age groups	Lifespan	Childhood	Adulthood	Missing
Non-communicable conditions				
Undernutrition (*n* = 77) Obesity (*n* = 75) Hypertension (*n* = 60) Diabetes (*n* = 56) Anemia(*n* = 30)	Injury- animal cause (*n* = 3) Injury- electrocution cause (*n* = 2) Epilepsy/seizure (*n* = 2) Injury-non-specific cause (*n* = 2) Anemia (*n* = 1) Injury- eye (*n* = 1) Depression (*n* = 1) Micronutrition deficiency (*n* = 1) Obesity (*n* = 1) Periodontal conditions (*n* = 1) Psoriasis (*n* = 1) Suicidality (*n* = 1) Teeth related oral health condition (*n* = 1)	Undernutrition (*n* = 45) Obesity (*n* = 16) Anemia (*n* = 11) Micronutrition deficiency (*n* = 4) Hemoglobinopathy (*n* = 3) Aggressive behavior (*n* = 3)	Hypertension (*n* = 56) Obesity (*n* = 56) Diabetes (*n* = 54) Undernutrition (*n* = 39) Hyperlipidemia (*n* = 22)	Obesity (*n* = 3) Undernutrition (*n* = 3) Hypertension (*n* = 3) Depression (*n* = 3) Anxiety (*n* = 3)
Infectious conditions				
Intestinal parasites (*n* = 38) Malaria(*n* = 32) Acute respiratory infection (*n* = 13) Tuberculosis (*n* = 11) Hepatitis B virus (*n* = 11)	Malaria(*n* = 20) Intestinal parasites (*n* = 18) Soil-transmitted-helminth (*n* = 2) Hookworm (*n* = 2) Tapeworm (Taeniasis, Cysticercosis) (*n* = 2) Dengue (*n* = 2) Japanese encephalitis (*n* = 2) Hepatitis B virus (*n* = 2)	Acute respiratory infection (*n* = 12) Intestinal parasites (*n* = 7) Malaria(*n* = 6) Tuberculosis (*n* = 3) Hepatitis B virus (*n* = 2) Pneumonia (*n* = 2)	Intestinal parasites (*n* = 8) Tuberculosis (*n* = 7) Hepatitis C virus (*n* = 7) Malaria(*n* = 5) Hepatitis B virus (*n* = 5)	Intestinal parasites (*n* = 5) Hepatitis B virus (*n* = 2) Hepatitis C virus (*n* = 1) Malaria (*n* = 1) Dengue (*n* = 1) Acute respiratory infection (*n* = 1) Trematodes (O. viverrini, H. taichui) (*n* = 1) Trematodes (O. viverrini) (*n* = 1)
Symptoms				
Diarrhea (*n* = 25) Fever (*n* = 19) Cough(*n* = 7) Proteinuria (*n* = 2) Shortness of breath (*n* = 2) Impaired lung function (*n* = 2) Wheezing (*n* = 2)	Fever (*n* = 2) Diarrhea (*n* = 1)	Diarrhea (*n* = 24) Fever (*n* = 16) Cough (*n* = 5) Shortness of breath (*n* = 1) Multiple symptoms of digestive system (*n* = 1) Palpable spleen (*n* = 1)	Cough (*n* = 2) Impaired lung function (*n* = 2) Proteinuria (*n* = 2) Wheezing (*n* = 2) Constipation (*n* = 1) Dizziness (*n* = 1) Shortness of breath (*n* = 1) Fever (*n* = 1) Headache (*n* = 1) Presence of inflammation (*n* = 1) Raised serum creatinine (*n* = 1) Abnormal pulse rate (*n* = 1) Weakness (*n* = 1)	-
Disability				
Activity of daily living (*n* = 16) Function- &Activity- related (*n* = 10) Function-Vision (*n* = 7) Non-specified (*n* = 6) Body structure- &function-related (*n* = 5)	Function- &activity- related (*n* = 2) Body-structure (*n* = 1)	Activity- Oral health related (*n* = 2) Function- & activity- related (*n* = 2) Activity of daily living (*n* = 1) Body structure- & function related (*n* = 1)	Activity of daily living (*n* = 15) Function- Vision (*n* = 7) Function- &Activity-related (*n* = 6) Non-specified (*n* = 6) Body structure- &function- related (*n* = 4) Function-related (*n* = 4)	-
Self-perceived health status				
Quality of life (*n* = 20) Self-rated health (*n* = 19)	-	Quality of life (*n* = 2) Self-rated health (*n* = 1)	Quality of life (*n* = 18) Self-rated health (*n* = 18)	-

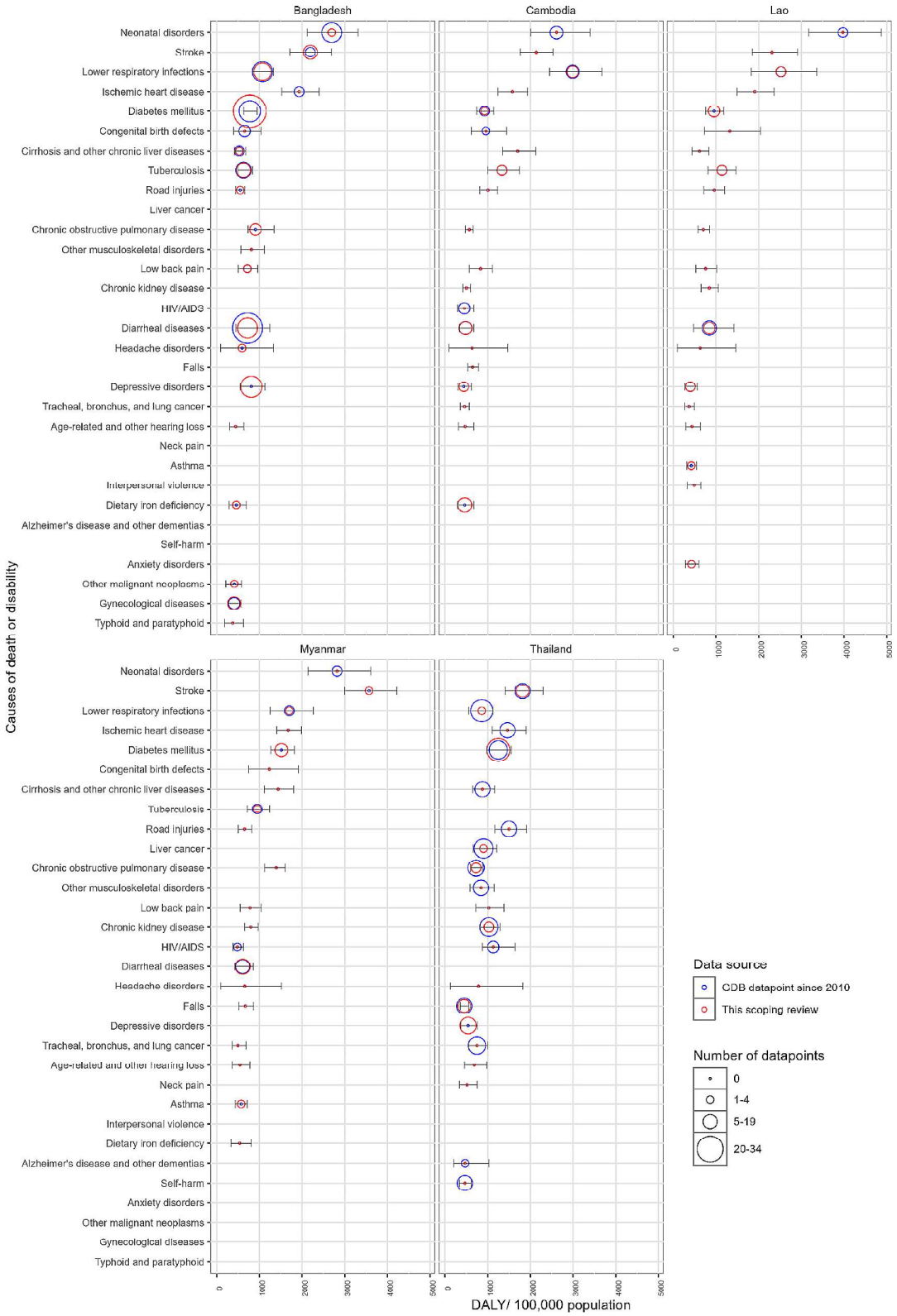


Fig. 3 (See legend on next page.)

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Fig. 3 Available datapoints and surveys covering the top 20 causes of disability and death according to disability-adjusted-life-years (DALY) rate from the Global Burden of Disease Study (GBD) 2019, by study country. The size of circle indicating number of available data source, with blue indicating data source used in the GBD study and collected since 2010, and red indicated the number of surveys included in this review. The position of the circles on x axis represents the DALY rate (100,000 population), and the bars on the circles represent the 95% confidence interval of DALY rate of each cause from the GBD study

The top 20 high-burden causes vary across countries. Common top-burden causes across all countries include: lower respiratory infections, diabetes mellitus, cirrhosis and other chronic liver diseases, ischemic heart disease, stroke, road injuries, chronic obstructive pulmonary disease, low back pain, headache disorders, age-related and other hearing loss; across 4 countries include: diarrheal diseases, tuberculosis, tracheal, bronchus, and lung cancer, congenital birth defects, chronic kidney disease, neonatal disorders, and depressive disorders. Other causes include: HIV/AIDS, falls, dietary iron deficiency, other musculoskeletal disorders, asthma, liver cancer, gynecological diseases, self-harm, Alzheimer's disease and other dementias, typhoid and paratyphoid, interpersonal violence, anxiety disorders, other malignant neoplasms, and neck pain

15 causes were studied by at least one survey included in this review, and it is 6 for Cambodia, 7 for Laos, 6 for Myanmar, and 8 for Thailand. According to the references used in GBD, 11 causes from Bangladesh had available datapoints, 7 for Cambodia, 6 for Laos, 5 for Myanmar, and 15 for Thailand.

Consistent findings were observed from both the surveys included in this review and the metadata from the GBD regarding the study coverage of common top burden causes across the countries. Diabetes, respiratory infections, tuberculosis, and diarrheal disease showed good study coverage. They have been studied by at least one survey, and identified with datapoints in GBD metadata, from all or most affected countries. In contrast, headache disorders, hearing loss, and lower back pain were rarely studied by the surveys included in the review, and had little or no data available from GBD metadata from the affected countries.

Discrepancies in study coverage were also recognized. Other common causes, including ischemic heart disease, chronic liver diseases, tracheal/ bronchus/ lung cancer, congenital birth defects, neonatal disorders, and road injuries were studied by a few or no surveys. However, GBD metadata included more datapoints for these causes, especially from Thailand and Bangladesh. Whereas depressive disorder, despite having only 2 datapoints from GBD metadata available from Laos, was among the most commonly studied conditions in the surveys ($n=24$) and in all countries.

Discussion

This scoping review included 337 community-based and population-based cross-sectional surveys conducted in Bangladesh, Cambodia, Laos, Myanmar, and Thailand published between 2010 and 22. This review highlighted firstly that the primary focus of these surveys are known high-burden causes of death and disability aligning with the recent GBD estimates, with gaps on conditions that relate to aging populations and other demographic changes in the region. Secondly, that little has been studied outside of the known regional high-burden diseases. The findings suggested while continuous monitoring well-studied high burden diseases is important for tracking the progress of the current intervention strategies, the research focus of cross-sectional surveys could expend to addressing the knowledge gaps.

Non-communicable conditions are among the leading causes of morbidity and mortality across these countries according to GBD estimates [18, 31]. They were also studied in the majority of surveys from each country. Risk factors attributable to cardiovascular disease (i.e. hypertension, underweight, and obesity) and diabetes are the most studied and are among the causes contribute to the most significant loss of DALYs. The surveys also extensively covered regionally high-burden infectious diseases, including tuberculosis, acute respiratory infection, and diarrhea. Data on these causes were also recorded from the sources beyond the prevalence surveys we reviewed (e.g. censuses, vital statistics, and other health-related data), as indicated by the rich references used in GBD study which include a wider range of data source [33]. While it is still important to continuously collect data on these conditions to monitor progress of the disease control and intervention strategies, considering the existing data sources for these conditions, the scope of community-based surveys could expand to other disease and health conditions.

The scope of future cross-sectional surveys could fill gaps in knowledge by including some of the regional high-burden causes that are predicted to increase prevalence due to the aging population and socioeconomic changes in the regions, but have not yet been widely studied [34–36]. This includes hearing loss, headache disorder, and lower back pain. Gaps in the survey, and little data used in GBDs suggest that current research and other data collection methods have potentially overlooked other emerging risk factors. Population groups with rising risks but are not considered high-risk previously for certain diseases could be included in future surveys. For example, with an evolving lifestyle and increasing prevalence of obesity among children, the prevalence of diabetes is rising in younger populations [37]. Children or adolescents could be the target population in surveys studying diabetes, whereas hitherto adults were the focus of the recent surveys. More attention could also be directed towards the elderly to understand

their health problems. Compared to the other countries there were many surveys from Thailand which studied the elderly population by evaluating their activity of daily living. This is likely attributable to Thailand's more rapid aging population [38]. However, countries with younger population structures such as Cambodia and Laos could also benefit from the health data from the elderly to better anticipate their future healthcare needs [38]. Including these conditions can fill gaps in current population-level disease estimates, and help health systems prepare for demographic change.

Some important causes of DALYs are not suitable to be studied directly by a cross-sectional survey design, albeit prevalence of known risk factors or early stage manifestation of disease can potentially be surveyed in community settings. Such conditions include ischemic heart disease, liver cirrhosis, chronic kidney disease, and tracheal, bronchus and lung cancer, have resource demanding diagnosis criteria, often rapid mortality, and were therefore studied by limited number of surveys. However, the risk factors of some of them were commonly studied. For instance, chronic viral hepatitis as a known risk factor for liver cirrhosis are with well-established point-of-care tests and procedures has surveyed [39, 40]. Depression is one of the most studied conditions in surveys, but limited data were use in GBD. It is can be explained by the questionnaire-based screening tools often used in surveys versus a strict diagnosis criteria for depressive disorder applied in GBD [41, 42]. This type of data will not only provide background information on the diseases but also support the detection of diseases at an early stage, informing optimal strategies for prevention and control, proving to be a more cost-effective public health approach [43, 44].

Other less studied high-burden causes in surveys can be explained by their low-case-number in population (e.g. neonatal disorders and congenital birth defect), which can be more efficiently studied in health facility-based studies, or using existing population data source such as vital registration, or police report (e.g. road traffic injury). It is less critical to incorporating these conditions in future cross-sectional surveys, although, collecting data on knowledge, attitudes, and behavior around such conditions may enrich the understanding and potentially improve the population-level estimations by addressing underreporting and health service utilization patterns [45, 46].

In addition to the known high-burden diseases, the scope of surveys could be broadened to include other regionally important diseases and explore potential unknown risk factors for high-burden diseases. Neglected tropical diseases (NTD), especially those related to non-malarial febrile illnesses (e.g. scrub typhus, melioidosis), still contribute significantly to morbidity and mortality in parts of the region [12, 47]. However, except for intestinal parasites, NTDs have not been well studied in the surveys identified in this review. This may be due to the challenge of capturing an acute infection within a limited data collection period through cross-sectional surveys. Despite the challenges, seroprevalence studies have proven useful in rapidly generating data on disease transmission (e.g. for COVID-19, or dengue) [48–50]. Current studies often rely on self-reported information on fever and related diseases (e.g., Acute respiratory infection), with the etiology often absent. This presents an opportunity to utilize seroprevalence surveys to detect the hidden burden of the causes of fever, and provide efficient and scalable approaches to generate population-based incidence data in resource-limited settings [51, 52].

While expanding the current research focus could pose challenges in resource limited settings, questionnaire-based evaluations which can collect data on a board range of health problems within limited time could be accessible and efficient means for surveys, compared to the resource-intense examinations and tests [53]. General health inquiries can offer direct prevalence data on the full range of existing health problems; evaluations on self-perceived health and disability can provide a comprehensive picture of health, though lacking specificity, can predict morbidity, mortality, and future healthcare needs [54–57]. In addition, analyzing the data with the results of a clinical diagnosis or objective measures (e.g. laboratory results) can aid in the identification of determinants (e.g. disease status, socioeconomic status) of self-perceived health, and thus informing public health planning for an improved self-perceived health status [58]. However, despite their utilization in surveys across countries, the inclusion of these measures remains relatively low. Most of the surveys targeting on non-communicable conditions and infectious conditions were not incorporated these measures, and is only commonly studied among the older adulthood and retirement age groups. It presents an opportunity to consistently incorporate the measures in future research and apply them to wider population.

Limitations

Our study is limited by its nature of secondary data analysis. Significant heterogeneity of definitions of health conditions were applied across studies, an exact match to a specific internal classification guidelines was not always possible. Therefore, we have primarily followed the ICPC-3 in the categorization of health conditions, while allowing for content appropriate difference that due to variances of definitions used across studies. When matching the health conditions with the causes of the death and disability from GBD similar principles applied.

Another limitation was the lack of sufficient study data to map geographically where surveys took place. We

were not able to constantly distinguish between urban and rural study locations, as about 13% of the studies did not specify the urbanicity of the study location from all related publications. Meanwhile, the names of the study area were sometimes ambiguous (e.g. the same name can refer to a city and a district). Consequentially, this limitation restricted our ability to determine the sample representativeness of each study and to establish the association between quantity and quality of studies on each health aspects. A higher number of surveys covering certain health conditions does not necessarily indicate robust surveillance of those conditions. However, the findings of this scoping review achieved its aim of depicting the health spectrum studied in these surveys and to identify knowledge gaps for future studies. As the next step, systematic reviews evaluating the sufficiency of surveillance for diseases studied by a high number of surveys could be conducted, including critical appraisal of study quality and more extensive data synthesis. Following the inclusion criteria, studies using health facilities or school-based recruitment were not included in the review. This omission partially explains the gaps in reported health conditions related to maternal and neonatal health, as well as among school-aged children. however, the inclusion criteria include only community-based studies, in which chiefly healthy participants were recruited, and avoids studies with potential selection bias such as facility-based surveys.

The inclusion criteria also restricted to quantitative studies that reported the prevalence of at least a health condition. Although community-based qualitative studies exist, their research methods and outcomes differ from those of quantitative studies. To maintain the focus of our review and to guide future prevalence surveys, we included only quantitative studies.

Implications

Cross-sectional surveys are an efficient method to obtain population-based data in Southeast Asia, where the epidemiology of many conditions is incomplete and the coverage of health reporting and surveillance systems is limited. While regionally high-burden diseases deserve continuous attention to monitor trends and progress, increased attention could be given to address population-based epidemiology gaps, particularly those associated with the aging populations and socioeconomic and environmental changes. This includes known high-burden diseases- hearing loss, headache disorder, musculoskeletal pain, and other chronic conditions, including cancer, and potentially emerging risk factors or high-burden diseases that can be anticipated based on the evolving trend of epidemiology in the region. Meanwhile, regional relevant diseases such as non-malaria febrile illness, have been understudied by prevalence surveys.

To overcome the limitations of cross-sectional surveys, and address resource constraints, some study approaches and evaluation methods could be applied. Symptoms or early onset of diseases, indications of infection (i.e. serological responses) that are suitable to be studied in the field could be surveyed; questionnaire-based evaluation, including self-reported health conditions, self-perceived health and disability, that can provide improved disease estimates cost-effectively, could also be used in surveys. This expansion of study scope may inform new areas for disease prevention and control priorities at an early stage and prepare health system readiness to meet modern needs.

Conclusion

Rich prevalence data is available for the traditionally high burden of diseases in the region, such as diabetes or tuberculosis. However, knowledge gaps were identified among conditions that with high or emerging burden related to the dynamic epidemiology of the region. The findings of this review suggest that future surveys and other data collection methods could expand their scope to new and under-studied conditions, to provide improved population-level prevalence estimates and to reflect the evolving regional epidemiology. Through better disease prevalence estimates, evidence-based resource allocation can be made to direct interventions and health system development in Southeast Asia.

Abbreviations

DALY	Disability-adjusted-life-years
DHS	Demographic and health survey
GBD	Global Burden of Disease Study
MeSH	Medical Subject Headings
NTD	Neglected tropical disease
OSF	Open Science Framework
PRISMA-ScR	Preferred Reporting Items for Systematic Review and Meta-analysis Extension for Scoping Review

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

MZ wrote the first draft of the scoping review protocol with inputs from RC, NSNH and YL. MZ, HK, RC, NSNH, SKM, CA, and ARS screened papers. MZ and HK extracted data from included publications. MZ drafted the manuscript. HK, SKM, NSNH, CR and TP provided critical reviews to the manuscript.

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Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
NA.

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NA.

Competing interests
The authors declare no competing interests.

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References

1. Chongsuvivatwong V, Phua KH, Yap MT, Pocock NS, Hashim JH, Chhem R, et al. Health and health-care systems in southeast Asia: diversity and transitions. Lancet. 2011;377(9763):429–37.
2. World Health Organization. Regional Office for South-East Asia. (2019). Health SDG profile: Thailand. World Health Organization. Regional Office for South-East Asia. https://iris.who.int/handle/10665/327767. License: CC BY-NC-SA 3.0 IGO
3. World Health Organization. Regional Office for South-East Asia. (2019). Health SDG profile: Bangladesh. World Health Organization. Regional Office for South-East Asia. https://iris.who.int/handle/10665/327747. License: CC BY-NC-SA 3.0 IGO
4. World Health Organization. Regional Office for South-East Asia. (2019). Health SDG profile: Myanmar. World Health Organization. Regional Office for South-East Asia. https://iris.who.int/handle/10665/327762. License: CC BY-NC-SA 3.0 IGO
5. World Health Organization. Regional Office for the Western Pacific. (2018). UHC and SDG country profiles : Cambodia. WHO Regional Office for the Western Pacific. https://iris.who.int/handle/10665/272307. License: CC BY-NC-SA 3.0 IGO
6. World Health Organization. Regional Office for the Western Pacific. (2018). UHC and SDG country profiles : Lao People's Democratic Republic. WHO Regional Office for the Western Pacific. https://iris.who.int/handle/10665/272312. License: CC BY-NC-SA 3.0 IGO
7. Acuin CS, Khor GL, Liabsuetrakul T, Achadi EL, Htay TT, Firestone R, et al. Maternal, neonatal, and child health in southeast Asia: towards greater regional collaboration. Lancet. 2011;377(9764):516–25.
8. Foreman KJ, Marquez N, Dolgert A, Fukutaki K, Fullman N, McGaughey M, et al. Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016–40 for 195 countries and territories. Lancet. 2018;392(10159):2052–90.
9. Angkurawaranon C, Jiraporncharoen W, Chenthanakij B, Doyle P, Nitsch D. Urbanization and non-communicable disease in Southeast Asia: a review of current evidence. Public Health. 2014;128(10):886–95.
10. Dans A, Ng N, Varghese C, Tai ES, Firestone R, Bonita R. The rise of chronic non-communicable diseases in southeast Asia: time for action. Lancet. 2011;377(9766):680–9.
11. Coker RJ, Hunter BM, Rudge JW, Liverani M, Hanvoravongchai P. Emerging infectious diseases in southeast Asia: regional challenges to control. Lancet. 2011;377(9765):599–609.
12. Hotez PJ, Bottazzi ME, Strych U, Chang LY, Lim YAL, Goodenow MM, et al. Neglected tropical diseases among the association of Southeast Asian Nations (ASEAN): overview and update. PLoS Negl Trop Dis. 2015;9(4):e0003575.
13. Bygbjerg IC. Double burden of noncommunicable and infectious diseases in developing countries. Science. 2012;337(6101):1499–501.
14. The DHS. Program - Quality information to plan, monitor and improve population, health, and nutrition programs. [cited 2024 Mar 19]. https://dhsprogram.com/
15. STEPwise approach to NCD risk factor surveillance (STEPS).. [cited 2024 Mar 19]. https://www.who.int/teams/noncommunicable-diseases/surveillance/systems-tools/steps
16. Existence of a health. surveillance system. [cited 2023 Jul 4]. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/existence-of-a-health-surveillance-system
17. World Health Organization (WHO). Improving mortality statistics as part of strengthening civil registration and vital statistics systems: guidance for country strategies and partner support. Outcome Tech Meet, 4–5.; 2014.
18. Vos T, Lim SS, Abbafati C, Abbas KM, Abbasi M, Abbasifard M, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the global burden of disease study 2019. Lancet. 2020;396(10258):1204–22.
19. Murray CJL. The global burden of disease study at 30 years. Nat Med. 2022;28(10):2019–26.
20. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467–73.
21. Chapter 11. Scoping reviews - JBI Manual for Evidence Synthesis - JBI Global Wiki. [cited 2022 Dec 26]. https://jbi-global-wiki.refined.site/space/MANUAL/4687342/Chapter+11%3A+Scoping+reviews
22. ICPC-3 Browser. [cited 2022 Dec 26]. https://browser.icpc-3.info/
23. Leonardi M, Bickenbach J, Ustun TB, Kostanjsek N, Chatterji S, MHADIE Consortium. The definition of disability: what is in a name? Lancet Lond Engl. 2006;368(9543):1219–21.
24. World Health Organization. International Classification of Functioning, Disability and Health (ICF). [cited 2024 Mar 19]. https://icd.who.int/dev11/l-icf/en
25. Katz S. Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily living. J Am Geriatr Soc. 1983;31(12):721–7.
26. Edemekong PF, Bomgaars DL, Sukumaran S, Schoo C. Activities of daily living. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2022 [cited 2022 Nov 10]. http://www.ncbi.nlm.nih.gov/books/NBK470404/
27. 1. K. Van Ginneken J, Groenewold G. A Single- . Multi-Item Self-Rated Health Status Measure: A 21-Country Study. The Open Public Health Journal [Internet]. 2012 Apr 12 [cited 2023 Oct 25];5(1). Available from: https://openpublichealthjournal.com/VOLUME/5/PAGE/1/ABSTRACT/
28. Gandek B, Ware JE, Aaronson NK, Apolone G, Bjorner JB, Brazier JE, et al. Cross-validation of item selection and scoring for the SF-12 health survey in nine countries: results from the IQOLA project. J Clin Epidemiol. 1998;51(11):1171–8.
29. Janssen MF, Szende A, Cabases J, Ramos-Goñi JM, Vilagut G, König HH. Population norms for the EQ-5D-3L: a cross-country analysis of population surveys for 20 countries. Eur J Health Econ. 2019;20(2):205–16.
30. Revicki DA, Kleinman L, Cella D. A history of health-related quality of life outcomes in psychiatry. Dialogues Clin Neurosci. 2014;16(2):127–35.
31. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019. (GBD 2019) Results.. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2020.; https://vizhub.healthdata.org/gbd-results/
32. About Dataset Records. | GHDx. [cited 2024 Mar 11]. https://ghdx.healthdata.org/about-ghdx/ghdx-records-explained
33. Global Burden of Disease Study. 2019 (GBD 2019) Data Input Sources Tool | GHDx. [cited 2023 Aug 23]. https://ghdx.healthdata.org/gbd-2019/data-input-sources
34. Li Xyu, Yang C, hao, Lv Jjie, Liu H, Zhang L, yu, Yin M et al. yi,. Global, regional, and national epidemiology of migraine and tension-type headache in youths

and young adults aged 15–39 years from 1990 to 2019: findings from the global burden of disease study 2019. J Headache Pain. 2023;24(1):126.
35. Haile LM, Kamenov K, Briant PS, Orji AU, Steinmetz JD, Abdoli A, et al. Hearing loss prevalence and years lived with disability, 1990–2019: findings from the global burden of disease study 2019. Lancet. 2021;397(10278):996–1009.
36. The Lancet Rheumatology. The global epidemic of low back pain. The Lancet Rheumatology 2023;5(6):e305.
37. Jaruratanasirikul S, Thammaratchuchai S, Sriplung H. Trends of childhood diabetes in Southern Thailand: 20-year experience in a tertiary medical center. World J Pediatr WJP. 2017;13(6):566–70.
38. World Bank Open. Data. [cited 2024 Jan 3]. World Bank Open Data. https://data.worldbank.org
39. Lynch E, Falq G, Sun C, Bunchhoeung PDT, Huerga H, Loarec A, et al. Hepatitis C viraemic and seroprevalence and risk factors for positivity in Northwest Cambodia: a household cross-sectional serosurvey. BMC Infect Dis. 2021;21(1):223.
40. Lwin AA, Aye KS, Htun MM, Kyaw YY, Zaw KK, Aung TT, et al. Sero-prevalence of hepatitis B and C viral infections in Myanmar: national and regional survey in 2015. Myanmar Health Sci Res J. 2017;29(3):167–75.
41. Cantor-Graae E, Chak T, Sunbaunat K, Jarl J, Larsson CA. Long-term psychiatric consequences of exposure to trauma in Cambodia: a regional household survey. Soc Sci Med 1982. 2014;123:133–40.
42. Wichai Ekplakom. Report of the 5th Thai National Examination Survey 2014. Nonthaburi: Institute of Health System Research; 2014.
43. Yildirim M, Gaynes BN, Keskinocak P, Pence BW, Swann J. The cost-effectiveness of depression screening for the general adult population. J Affect Disord. 2022;303:306–14.
44. Abeysekera KWM, Macpherson I, Glyn-Owen K, McPherson S, Parker R, Harris R, et al. Community pathways for the early detection and risk stratification of chronic liver disease: a narrative systematic review. Lancet Gastroenterol Hepatol. 2022;7(8):770–80.
45. Taubman – Ben-Ari O, Eherenfreund – Hager A, Prato CG. The value of self-report measures as indicators of driving behaviors among young drivers. Transp Res Part F Traffic Psychol Behav. 2016;39:33–42.
46. Boufous S, Ivers R, Senserrick T, Stevenson M, Norton R, Williamson A. Accuracy of self-report of on-road crashes and traffic offences in a cohort of young drivers: the DRIVE study. Inj Prev. 2010;16(4):275–7.
47. Shrestha P, Dahal P, Ogbonnaa-Njoku C, Das D, Stepniewska K, Thomas NV, et al. Non-malarial febrile illness: a systematic review of published aetiological studies and case reports from Southern Asia and South-eastern Asia, 1980–2015. BMC Med. 2020;18(1):299.
48. Kshatri JS, Bhattacharya D, Praharaj I, Mansingh A, Parai D, Kanungo S, et al. Seroprevalence of SARS-CoV-2 in Bhubaneswar, India: findings from three rounds of community surveys. Epidemiol Infect. 2021;149:e139.
49. Aiemjoy K, Aragie S, Wittberg DM, Tadesse Z, Callahan EK, Gwyn S, et al. Seroprevalence of antibodies against Chlamydia trachomatis and enteropathogens and distance to the nearest water source among young children in the Amhara Region of Ethiopia. PLoS Negl Trop Dis. 2020;14(9):e0008647.
50. Salje H, Cummings DAT, Rodriguez-Barraquer I, Katzelnick LC, Lessler J, Klungthong C, et al. Reconstruction of antibody dynamics and infection histories to evaluate dengue risk. Nature. 2018 May;557(7707):719–23.
51. Aiemjoy K, Seidman JC, Saha S, Munira SJ, Sajib MSI, Sium SMA, et al. Estimating typhoid incidence from community-based serosurveys: a multicohort study. Lancet Microbe. 2022;3(8):e578–87.
52. Arnold BF, Martin DL, Juma J, Mkocha H, Ochieng JB, Cooley GM et al. Enteropathogen antibody dynamics and force of infection among children in low-resource settings. eLife. 8:e45594.
53. Cleary PD. Subjective and objective measures of health: which is better when? J Health Serv Res Policy. 1997;2(1):3–4.
54. Idler EL, Benyamini Y. Self-rated health and mortality: a review of twenty-seven community studies. J Health Soc Behav. 1997;38(1):21–37.
55. Benyamini Y, Idler EL. Community studies reporting association between self-rated health and mortality: additional studies, 1995 to 1998. Res Aging. 1999;21(3):392–401.
56. Makovski TT, Schmitz S, Zeegers MP, Stranges S, van den Akker M. Multimorbidity and quality of life: systematic literature review and meta-analysis. Ageing Res Rev. 2019;53:100903.
57. Guidet B, de Lange DW, Boumendil A, Leaver S, Watson X, Boulanger C, et al. The contribution of frailty, cognition, activity of daily life and comorbidities on outcome in acutely admitted patients over 80 years in European ICUs: the VIP2 study. Intensive Care Med. 2020;46(1):57–69.
58. Mutz J, Lewis CM. Cross-classification between self-rated health and health status: longitudinal analyses of all-cause mortality and leading causes of death in the UK. Sci Rep. 2022;12(1):459.

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B

Appendix B for Chapter 2

BMJ Open

Defining the hidden burden of disease in rural communities in Bangladesh, Cambodia and Thailand: a cross-sectional household health survey protocol

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ABSTRACT

Introduction In low-income and middle-income countries in Southeast Asia, the burden of diseases among rural population remains poorly understood, posing a challenge for effective healthcare prioritisation and resource allocation. Addressing this knowledge gap, the South and Southeast Asia Community-based Trials Network (SEACTN) will undertake a survey that aims to determine the prevalence of a wide range of non-communicable and communicable diseases, as one of the key initiatives of its first project—the Rural Febrile Illness project (RFI). This survey, alongside other RFI studies that explore fever aetiology, leading causes of mortality, and establishing village and health facility maps and profiles, will provide an updated epidemiological background of the rural areas where the network is operational.

Methods and analysis During 2022–2023, a cross-sectional household survey will be conducted across three SEACTN sites in Bangladesh, Cambodia and Thailand. Using a two-stage cluster-sampling approach, we will employ a probability-proportional-to-size sample method for village, and a simple random sample for household, selection, enrolling all members from the selected households. Approximately 1500 participants will be enrolled per country. Participants will undergo questionnaire interview, physical examination and haemoglobin point-of-care testing. Blood samples will be collected and sent to central laboratories to test for chronic and acute infections, and biomarkers associated with cardiovascular disease, and diabetes. Prevalences will be presented as an overall estimate by country, and stratified and compared across sites and participants' sociodemographic characteristics. Associations between disease status, risk factors and other characteristics will be explored.

Ethics and dissemination This study protocol has been approved by the Oxford Tropical Research Ethics Committee, National Research Ethics Committee of Bangladesh Medical Research Council, the Cambodian National Ethics Committee for Health Research, the Chiang Rai Provincial Public Health Research Ethical Committee. The results will be disseminated via the local health authorities and partners, peer-reviewed journals and conference presentations.

Trial registration number NCT05389540.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study will use diverse methods (interviews, physical examinations and laboratory tests) to gather extensive data on the prevalence, risk factors, healthcare utilisation patterns of both communicable and non-communicable diseases.
⇒ The use of two-stage cluster sampling enables the sample to be representative of each study area.
⇒ As an integrated component of the Rural Febrile Illness project, the findings will be synergised with outcomes of concurrent studies in these specified regions, offering a multidimensional overview of health and healthcare provision.
⇒ The findings are specific to the selected rural areas and should be interpreted with caution when considering broader implications for rural populations in the study countries.

INTRODUCTION

Life expectancy in Southeast Asia increased from 63 to 71 years between 2000 and 2019.[1] These positive changes can be attributed, in part, to advancements in the region's health systems, which have addressed traditional high-burden diseases, such as infectious diseases, maternal and neonatal health, and

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under 5 mortality.[2] Despite these improvements, the burden of traditionally significant diseases persists, particularly in rural areas. Furthermore, there is a transition in disease epidemiology due to rapidly changing environments, growing economies and ageing populations.[3] The shift is marked by a rising burden of non-communicable diseases and injuries, along with emerging infectious diseases (eg, COVID-19 and chikungunya).[4 5]

The knowledge of current disease epidemiology in the region, however, is limited, constraining health systems' ability to identify healthcare priorities and direct future resource allocation.[6] While the Global Burden of Disease study provides insights into disease burdens across countries and diseases, the accuracy of its results is impeded by the scarcity of recent epidemiological data.[6] Given the limited coverage of disease reporting and surveillance systems in the region, research data are pivotal in bridging this information gap. Such data not only offer up-to-date information for modelling studies but are also critical for optimising resource allocation by including factors such as disease severity, the magnitude of the population affected and equity.[7]

Moreover, the marked systemic disparities in healthcare between rural and urban areas in the region highlight the need for rural-specific epidemiological data.[3] Despite 50%–85% of the region's population residing in rural areas, this large population group remains relatively understudied compared with countrywide estimates.[8–13] In this context, cross-sectional surveys are an effective research method to provide timely estimates of disease prevalence in rural communities, through cost-effective approaches combining questionnaire interviews, clinical examinations and laboratory tests.

The newly formed South and Southeast Asia Community-based Trials Network (SEACTN) aims to establish a network of community-based healthcare providers and facilities capable of implementing interventions designed to triage, diagnose and treat patients within rural communities across five South and Southeast Asian countries (Bangladesh, Cambodia, Laos, Myanmar and Thailand).[14] The first project is the Rural Febrile Illness Project (RFI), dedicated to delineating the epidemiological baseline of febrile illness in remote and underserved regions, where febrile illness and access to healthcare pose significant health challenges.[14] RFI encompasses diverse initiatives designed to gain a multifaceted understanding of the health dynamics within these communities to effectively facilitate the identification of interventions for future studies across SEACTN. Recognising the gaps in understanding of disease prevalence, a cross-sectional household health survey has been planned as one of the key initiatives of the RFI.

This survey aims to define the prevalence of a broad spectrum of communicable and non-communicable causes of health conditions in areas where the network operates. Alongside the survey, other key initiatives of RFI include a fever aetiology study to determine the incidence, causes and outcomes of febrile illness; a verbal autopsy study to identify common causes of mortality and the circumstances surrounding death; and a village and health facility mapping study creating a detailed profile of the study villages, estimating travel time to health facilities and identifying health service provision gaps. Each initiative holds significant value as an independent study, and their results will be complementary providing a thorough comprehension of healthcare needs and enabling more equitable resource allocation.

METHODS AND ANALYSIS

The SEACTN household health survey is a community-based cross-sectional survey aiming to provide an overview of the burden of disease in selected rural areas where the network is operational. The first participant was enrolled on 3 October 2022, and data collection is expected to continue until December 2023.

Primary objectives and outcomes

1. To determine the prevalences of selected diseases and exposure to locally prevalent or important pathogens, including, but not limited to:
   a. IgG against selected common pathogens causing fever.
   b. Hepatitis B and C.
      i. Hepatitis B virus (HBV) surface antigen.
      ii. IgG against Hepatitis C virus (HCV) and presence of HCV.
   c. Selected non-communicable diseases (eg, diabetes, raised blood cholesterol, hypertension, stroke) according to self-reported disease history, and/or physical examinations and/or laboratory tests.
   d. Self-reported illness or injury in the past 30 days.
      i. Any acute conditions (eg, fever, persistent cough, watery diarrhoea).
      ii. Injury or death caused by an accident.
2. To determine the point prevalence of different self-perceived health statuses.
3. To determine the prevalences of major risk factors for common non-communicable diseases (eg, smoking, alcohol consumption, overweight).

Study population and setting

All SEACTN operational areas were selected by partner organisations as they represent poor, remote and rural communities with limited access to formal healthcare.[14] This study will be conducted in three areas, consisting of 391 villages in Bangladesh, Cambodia and Thailand (figure 1). The other sites will not take part of the study due to operational constraints.

A two-stage cluster sampling will be used to obtain a representative sample from each study site. In the first stage, 75 villages will be selected using the probability-proportional-to-size sample method.[15–17] For the second stage, within each village, a simple random sample of 5–7 households (adjusted to the average household size) will

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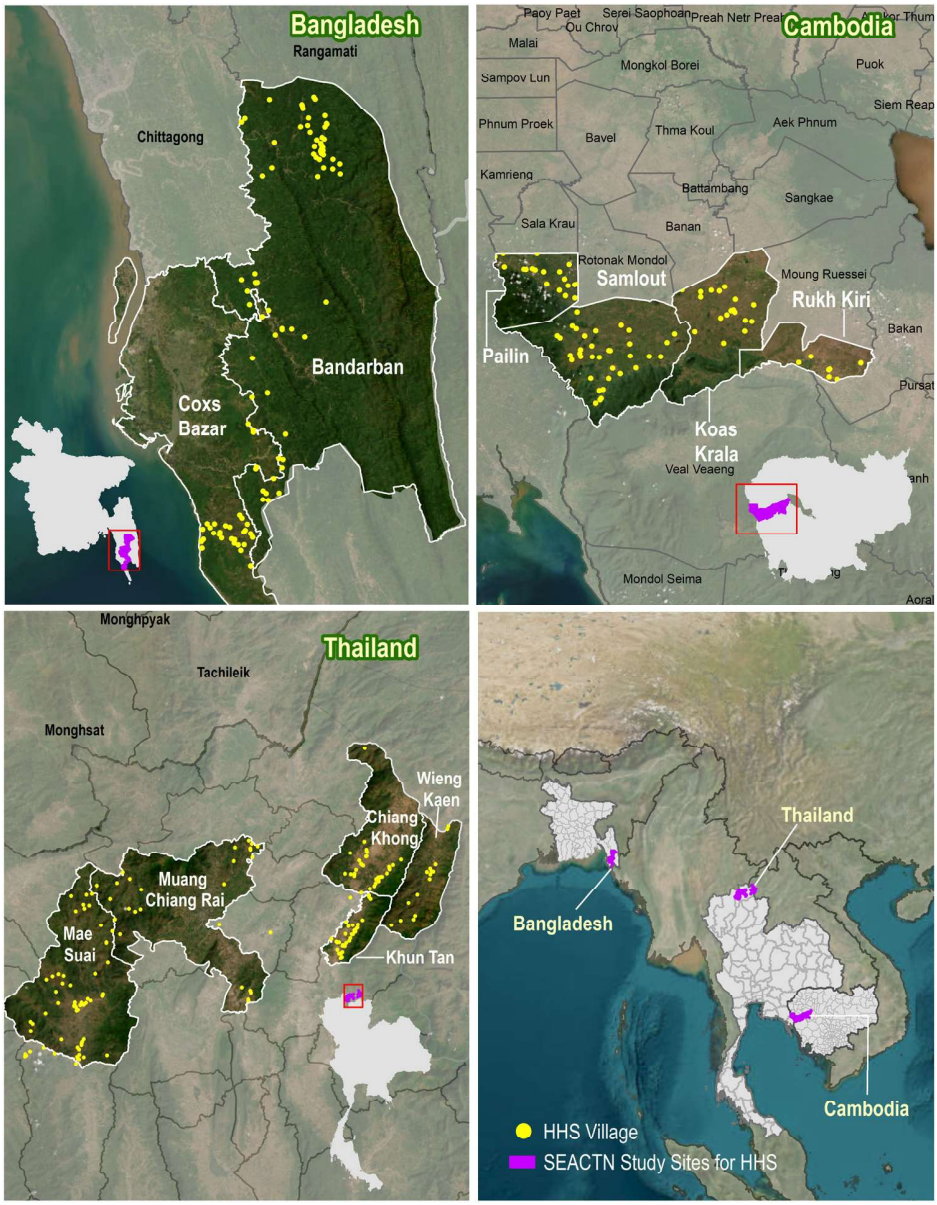


Figure 1 The study sites and population of the cross-sectional household health survey conducted by the South and Southeast Asia Community-based Trials Network (SEACTN). The Bangladesh site includes 130 villages from Cox's Bazar and Bandarban districts; the Cambodia site includes 82 villages from Battambang and Pailin provinces; and the Thailand site includes 179 villages located in Chiang Rai province. HHS, The Household Health Survey.

be selected using computer-generated random sampling from the village household list.

Inclusion and exclusion criteria

For each selected household, all usual household members or visitors who stayed overnight in the households before the survey are eligible to be enrolled.[18]

Sample size

This study is adequately powered to determine the prevalences of all key indicators within each age group, with a design effect of 1.5 and a range of 5%–10% degrees of precision, while considering a maximum of 1500 participants per study country (table 1). To account for a 10% non-response rate, assuming an average household size of 4.5 persons, and enrolling all household members, the final sample size was adjusted to 1667 participants per country.[19–21]

The minimal sample size required was calculated based on the estimated prevalences of key indicators overall and within each population age group (table 1). Prevalence estimates, population proportions within each age group and average household size were derived from previously conducted national health surveys and published studies, preferably from the study country, or from countries with a similar epidemiological context.[19–29] When the estimated prevalence of an

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Table 1 Required sample size tested against the estimated prevalence of key indicators of the highest prevalence, overall and by age groups of interests

	Expected number of participants	Indicator (estimated prevalence)	Required sample size*
Overall	1500	Overweight (20%)	369
Age groups (years)			
≥15	1050	Current drinker (55%)	570
<5	150	Anaemia (30%)	122
15–49	750	Injury or death caused by recent accident (20%)	414
≥50	300	Hypertension (20%)	257

$$n = DEFF \times \frac{Np(1-p)}{\frac{d^2}{1.96^2}(N-1)+p(1-p)}$$

n: sample size; DEFF: design effect. Design effect of 1.5 is used to account for a slightly expected increase in variance due to clustering; N: population size; p: expected prevalence of key indicators; d: degree of precision.
*The formula used for calculating sample size is shown above. Assessing the sufficiency of the sample size for the key indicators of the highest prevalences ensures sufficient statistical power for indicators with lower prevalence. A degree of precision of 5% is applied for the sample size calculation overall and across age groups, except for the under 5 years and the 50 years or older groups, for which degrees of precision of 10% and 6% are applied, respectively.

indicator varied across study country, the highest prevalence estimates were applied.

Study procedures

Standard operating procedures (SOPs) were developed for field procedures, sample collection and transportation. Training materials were developed and training sessions were delivered to all the study staff directly, or using a train-the-trainer model where field supervisors and managers will be trained first and then subsequently train other field staff. All research staff are experienced in community-based research or interventions. Experienced phlebotomists were recruited and trained in specimen collection and processing in the field. A monitoring and evaluation plan was devised to maximise the research quality.

Patient and public involvement

The potential challenges for the study include comprehensibility of the questionnaires, and willingness of selected households to participate. We have proactively addressed these concerns by involving the target population in the questionnaire validation process (section: Questionnaire interviews), and planning community mobilisation events before the survey, tailored to the local context.

Collaborators will identify contact points from local stakeholders and communities, such as village leaders, local health centre staff or community health workers, and determine the most suitable methods for establishing contact. Main events may involve community engagement meetings to explain the study purpose, organisation and procedures, and the plan for dissemination of study results. Prior to the survey day for each village, the study team will meet, or call if physical meetings are not feasible, the household head or members of the selected households. With the support of the key contact persons, this interaction will create an opportunity to address questions or concerns, enabling the survey teams to work with each community and selected household to plan an effective data collection schedule.

Survey schedule

On the scheduled survey day for each village, stations will be set up at a convenient location within or near the village. Household members will arrive at the survey location following their appointment to complete the procedures (figure 2). If household members do not attend the data collection at the appointment time, they will be contacted and encouraged to join the survey at another time during the day, while the research team is in the village.

Informed consent

Participants must sign the informed consent form before any study-specific procedures are performed. The informed consent will be available in the official local language. It will be presented to prospective participants by trained study staff detailing the study procedures and implications of study participation. It will be made explicit that participation is voluntary and participants are free to withdraw from the study at any time. If necessary, the informed consent process will be interpreted to dialect when participants do not speak the official local language.

Adequate time will be given to study participants to consider the information and ask questions. Written consent will then be obtained from the participants, or the caretakers of participants, in compliance with local legal age requirements, using the participant's dated signature or thumbprint (if unable to write) and dated signature of a person who presented and obtained the informed consent. A copy of the signed informed consent document will be given to the participant. Children aged as dictated by local legislation and regulations will be required to sign the written informed assent form in addition to their parent or guardian signing a consent form.

Questionnaire interviews

The questionnaire consists mostly of questions adapted from well-validated and widely implemented tools (online supplemental appendix A). This approach enables direct

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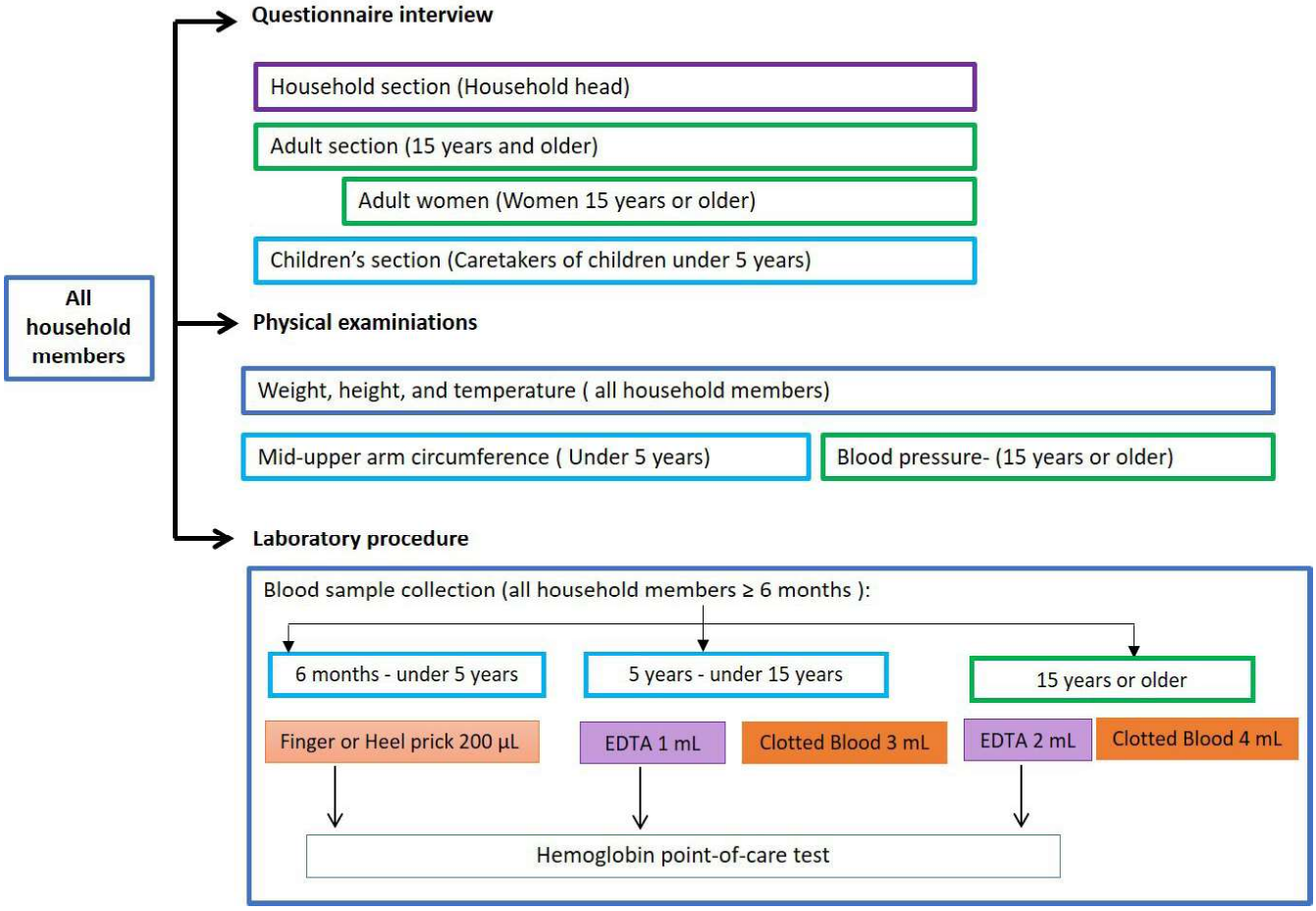


Figure 2 Questionnaire interviews, physical examinations and laboratory procedures administrated to study participants according to age and sex.

comparison of results with previously conducted surveys by incorporating questions from the Demographic and Health Surveys, WHO STEPWise surveys for Non-communicable Disease Risk Factors (STEP) and the World Health Survey.[30–32]

The questionnaire underwent adjustments and validation through pretests using behaviour coding and participant debriefing.[33 34] During mock interviews, the observer of each interview pair recorded the interaction problems for each question, such as 'major change in wording', 'question reading interrupted by the respondent' or 'additional prompt is provided'. All interviewers, interviewees and the observers participated in the debriefing. The pretest was conducted initially among peer researchers in English. Subsequently, the adjusted version was translated into Thai and tested among the target population in Thailand. This ensured the questionnaire's suitability, comprehensibility and appropriate length for administration. The final questionnaire was then translated into the official languages of each study country (Bangla, Khmer and Thai) by professional translators or dedicated staff from partner organisations, and validated by the local research teams. When necessary, during face-to-face interviews, questions will be interpreted to dialect for participants who do not speak the official local language.

The questionnaire consists of four sections answered by household members based on their sex and age (figure 2, top).

- The household section is completed by the household head, providing information on household characteristics and a list of all household members along with any illnesses in the past 4 weeks and health seeking behaviour.
- The adult section is for household members aged 15 years or older and includes questions on sociodemographic characteristics (eg, age, sex, education, marital status and occupation), disease history (eg, tuberculosis, diabetes, cardiovascular disease), self-perceived health status, health concerns, substance use (eg, tobacco and alcohol) and other disease risk factors.
- The women's health section is for female household members aged 15 years or older and includes questions on contraception use, utilisation of antenatal care and delivery services.

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- The children's health section is answered by caretakers of children under 5 years, providing information on each child's vaccination and breastfeeding history.

Physical examination

All household members will undergo weight, height and tympanic temperature measurements. Children under 5 years will also have their mid-upper arm circumference measured, and adult household members (≥15 years) will undergo blood pressure measurement (figure 2, middle). Weight will be measured with a digital scale, preferably with a taring function allowing a child's weight to be measured while being held by an adult. Height measurements will be carried out with measuring scales/boards. Children younger than 24 months will be measured lying down on the board, while standing height will be measured for older children. Tympanic temperature will be measured with infrared thermometers.

All measures will be taken by experienced and trained staff. Consistency and comparability will be ensured by using the same validated devices previously used in studies in similar settings, whenever possible, across study sites.

Blood sample collection and point-of-care haemoglobin test

Blood samples will be collected from participants aged 6 months or older (figure 2, bottom). For participants aged 6 months to under 5 years, four dried blood spots (DBS) will be collected via finger or heel prick. Participants aged 5 years or older will provide venous blood samples, with 4 mL collected from those aged 5 to under 15 years, and 6 mL from participants aged 15 years or older (figure 2, bottom). After blood sample collection, appropriate samples will be tested for haemoglobin using HemoCue Hb 301 system (HemoCueAB, Ängelholm, Sweden) to detect anaemia.

The venous blood samples will be temporarily stored in cool boxes between 4°C and 8°C, for a maximum of 24 hours before centrifugation in the field laboratories. Aliquots of whole blood, serum, plasma and packed red blood cells of these samples will be stored at a minimum of −20°C or below without freeze-thaw until analysis. DBS will be air-dried in the laboratory for at least 6 hours, after which they will be placed in a plastic zip-lock bag and stored at room temperature or at 4°C or below.

Information, consultation and referral

On completion of the field procedures, individual participants will receive the results of their haemoglobin test and physical examinations. Participants with abnormal results will be referred to a study nurse who will provide recommendations and, if the participant wishes, further referrals in accordance with local guidelines.

Non-responders

Household members who fail to attend the survey (who are absent, refuse participation or for other reasons) will have their demographic characteristics (eg, sex, age) summarised from the information obtained from the household head in the household section of the questionnaire, to determine whether systematic differences exist between responders and non-responders.

Analysis of blood samples

Sample aliquots and DBS will be shipped to the central laboratories in Bangkok, Thailand where they will be analysed. All laboratory activities will be performed by experienced and trained staff. All laboratory procedures will be performed using validated SOPs. Multiplex serology tests based on Luminex xMAP Intelliflex System will be developed and validated for measures of IgG and IgM of common pathogens causing fever; all other methods have already been published in peer-reviewed journals.

Malaria quantitative PCR (qPCR) will be performed for all participants to identify individuals with malaria parasites. The PCR methods typically have a detection level in the range of 100–1000 parasites per millilitre.[35] Genus-specific qPCR targeting Plasmodium *18S rRNA* genes will first be performed to screen for positive individuals, and then species-specific assays will be performed to differentiate the parasite species (*Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale* and *Plasmodium knowlesi*).[36–39]

Serology tests for selected common pathogens causing fever including IgG and IgM for Dengue, Chikungunya, Japanese encephalitis, Zika, SARS-CoV-2, *P. vivax*, *P. falciparum*, *Orientia tsutsugamushi*, *Rickettsia* spp and *Leptospira* spp will be performed for all participants.

Tests for hepatitis B and C: all participants will be tested for HBV surface antigen; participants 15 years or older will also be tested for IgG for HCV, and the positive samples will undergo HCV PCR.

Non-communicable disease-related markers: participants 15 years or older will be tested for Haemoglobin A1c, total cholesterol and high-density lipoprotein cholesterol.

Additionally, the remaining samples will be tested for exposure to, or presence of, pathogens associated with selected diseases that are regionally or locally prevalent or important. The final list of diseases, pathogens and sample selection will be adjusted based on findings from other SEACTN studies exploring diagnostics and prognostics in febrile patients, and other available evidence.

Results feedback

Individual-level data collected from physical examinations and haemoglobin tests will be provided on the same day once all field procedures are concluded for an individual participant (section: Study procedure—Information, consultation and referral). Additionally, participants will be thoroughly informed about the implications of the laboratory tests to be performed during the consent process. They will be presented with the option to receive the results of hepatitis B and C tests. If they wish to receive them, the results, once available, will be placed in a sealed envelope and will then be delivered by the local health providers or village leaders to the participants. It

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is anticipated that there will be a delay of approximately 6 months to 1 year from sample collection to results feedback. The time frame encompasses the completion of data collection at the entire site, transportation of samples to Bangkok, sample management, analysis and the subsequent return of results. The decision on which results to provide to individual participants is made in consultation with the site research teams and local clinicians, considering factors such as their clinical relevance, the potential harm that could result from a lack of consultation on results distribution and the accessibility of treatment.

Planned analysis

All data obtained through questionnaire interviews, physical examinations and haemoglobin point-of-care tests will be collected on tablets using an electronic data collection platform—Open Data Kit.[40] The electronic case report form has built-in validation rules to identify missing or potentially incorrect data. Stringent checks are applied to variables used to estimate the study outcomes, such as recent fever history, diabetes history and weight. Survey interviewers cannot progress to the next question if these data are missing or outside the defined ranges. Throughout the survey, data will be continuously updated and monitored for quality. Data queries and quality reports will be generated every two to 4 weeks for data verification and correction, and to identify areas needing additional training and support, ensuring data integrity.

For descriptive summaries, means and SDs or medians with IQR for continuous variables, and proportions for categorical variables will be calculated. Outcomes will be presented as an overall estimate by country, and with 95% CIs, stratified and compared across sites and participants' sociodemographic characteristics using appropriate tests, such as the Student's t-test, Mann-Whitney U tests or χ^2 tests. Associations between disease status, risk factors, self-perceived health status and other characteristics will be explored through univariate and multivariate analyses, and measures of effect will be reported with 95% CIs. Sampling weights will be accounted for, as needed, in the analysis.

DISCUSSION

This prevalence survey conducted across three rural SEACTN study sites in Bangladesh, Cambodia and Thailand aims to provide a comprehensive epidemiological description of the study areas. Employing a multifaceted approach, including questionnaire interviews, laboratory tests and physical examinations, the study will yield extensive data on the prevalence, risk factors, healthcare utilisation patterns of both communicable and non-communicable diseases. The findings will contribute to improved estimates of the burden of disease, and deepen the comprehension of findings from other RFI initiatives, offering a thorough overview of health and healthcare provision in these areas. The survey will be invaluable for setting healthcare priorities and directing resource allocation for health system development.

As a core component of RFI, this survey, alongside other initiatives, adopts an integrated approach to address health challenges more effectively, particularly in the context of the 'double burden of disease', characterised by the rising burden of non-communicable diseases, alongside ongoing challenges posed by infectious diseases and suboptimal maternal and child health.[2] This survey will encompass various dimensions of health, allowing for further exploration of associations among disease occurrence, risk factors and self-perceived health. Key data from the survey, such as household wealth status, and community members' perception of their health and health concerns, will contextualise the findings from the other three RFI studies, and provide insights into potential health disparities and inequalities. By integrating disease prevalence with fever aetiology and causes of death, a multilayered understanding of health dynamics in the study area could be attained. Additionally, knowledge from the survey will play a vital role for estimating incidence. This involves assimilating data on proportion of the population with fever who visited various healthcare providers from the survey, with the number of fever patients recruited from the village health workers or health facilities, captured from the fever aetiology studies.

The study will also bridge the gap in community-based seroprevalence estimates for common pathogens causing fever, minimising biases related to health-seeking behaviour in facility-based studies. The data can also to be used for population-based incidence estimates.[41 42] Furthermore, the updated prevalences of hepatitis B and C can be instrumental in evaluating the coverage and effectiveness of HBV vaccination programmes, and inform HCV screening and treatment strategies in the region in the era of direct-acting antiviral agents.[43 44] This study also extends its scope to gather insights into the health perspectives and concerns of community members, facilitating the alignment of future interventions with the needs and expectations of the population. Specifically, for self-perceived status, while existing studies primarily focus on the elderly population, this study encompasses a broader age range.[45–48] This can inform tailored interventions to improve the quality of life for a more extensive population.[49–51]

This study encourages regional collaboration by applying consistent research methods and seeking representative samples across study sites, allowing effective cross-country comparisons and fostering collaborative approaches to address shared health challenges.[3]

The findings of this study are limited in their generalisability and should be interpreted with caution when considering broader implications for rural populations in the study countries. However, the study was specifically designed for and conducted within the selected rural areas of Bangladesh, Cambodia and Thailand, where SEACTN is operational. This focused approach allows for insights into health challenges and opportunities within

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these areas. The cross-sectional design and observational nature of the study is at risk of, such as temporal bias, selection bias and participation bias. However, to minimise the bias as much as possible, we designed the survey with appropriate evaluation methods, and adequate training and supporting material will be well prepared for the field work.

This planned household prevalence survey will significantly contribute to disease prevention and control in the region by offering a comprehensive understanding of health conditions of the rural populations. Complementing the results from other RFI initiatives, it will serve as a foundation for evidence-based interventions, shaping future research and disease control priorities. The study findings will not only serve the next phase of SEACTN but also extend to the broader context, ultimately leading to improved health outcomes in rural communities.

ETHICS AND DISSEMINATION

This study protocol was approved by the Oxford Tropical Research Ethics Committee (OxTREC Ref: 6-22), National Research Ethics Committee of Bangladesh Medical Research Council (BMRC/NREC/2022-2025/69), the Cambodian National Ethics Committee for Health Research (23 December 2022 NECHR), the Chiang Rai Provincial Public Health Research Ethical Committee (CRPPHO 75/2565).

Safety considerations

Participants may experience slight discomfort during the blood draw, however, our experienced clinical staff performing the phlebotomy will take special attention to minimise this discomfort. While some interview questions may be personal, all data will be handled confidentially and linked only to study IDs. Participants will also be informed of their right to skip questions or end the interview if they feel uncomfortable.

Data deposition and curation

The database and all electronic data will be stored on secure servers that are backed up daily, with weekly off-site storage. Paper records, if they exist, will be kept in secure storage such as locked cabinets; if necessary, the record will be scanned and stored electronically. Study data will be archived in accordance with Mahidol Oxford Tropical Medicine Research Unit (MORU) SOPs. Electronic data will be deidentified and preserved indefinitely. Paper records will be preserved for 5 years after study completion. With participant's consent, electronic data can be shared according to the terms defined in the MORU data sharing policy with other researchers for future use.[52]

Dissemination

The results of the study will be summarised in plain language in both English and the official local language. These summaries will be disseminated via the local health authorities and partners. The findings will also be disseminated internationally through conference presentations and peer-reviewed academic journal publications, aligning with Wellcome Trust policy and guidelines.

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REFERENCES

1 Life expectancy at birth (years). Available: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/life-expectancy-at-birth-(years) [Accessed 23 Aug 2023].
2 Bygbjerg IC. Double burden of Noncommunicable and infectious diseases in developing countries. *Science* 2012;337:1499–501.
3 Chongsuvivatwong V, Phua KH, Yap MT, *et al*. Health and health-care systems in Southeast Asia: diversity and transitions. *The Lancet* 2011;377:429–37.
4 Coker RJ, Hunter BM, Rudge JW, *et al*. Emerging infectious diseases in Southeast Asia: regional challenges to control. *Lancet* 2011;377:599–609.
5 Dans A, Ng N, Varghese C, *et al*. The rise of chronic non-communicable diseases in Southeast Asia: time for action. *The Lancet* 2011;377:680–9.
6 Murray CJL. The global burden of disease study at 30 years. *Nat Med* 2022;28:2019–26.
7 Voigt K, King NB. Out of alignment? Limitations of the global burden of disease in assessing the allocation of global health aid. *Public Health Ethics* 2017;10:244–56.
8 Global Burden of Disease Study (GBD 2019). Data input sources tool | Ghdx. 2019. Available: https://ghdx.healthdata.org/gbd-2019/data-input-sources [Accessed 23 Aug 2023].
9 World Health Organization. Regional office for the Western Pacific. UHC and SDG country profiles: Cambodia. Manila: WHO Regional Office for the Western Pacific; 2018. Available: https://apps.who.int/iris/handle/10665/272307 [Accessed 6 Oct 2021].
10 UHC and SDG country profiles: Lao people's Democratic Republic. Available: https://apps.who.int/iris/handle/10665/272312 [Accessed 20 Jan 2023].
11 World Health Organization. Regional office for South-East Asia. 2019 health SDG profile: Thailand. World Health Organization. Regional Office for South-East Asia; 2019. Available: https://apps.who.int/iris/handle/10665/327767 [Accessed 6 Oct 2021].
12 World Health Organization. Regional office for South-East Asia. 2019 health SDG profile: Bangladesh. World Health Organization. Regional Office for South-East Asia; 2019. Available: https://apps.who.int/iris/handle/10665/327747 [Accessed 6 Oct 2021].
13 World Health Organization. Regional office for South-East Asia. 2019 health SDG profile: Myanmar. World Health Organization. Regional Office for South-East Asia; 2019. Available: https://apps.who.int/iris/handle/10665/327762 [Accessed 6 Oct 2021].
14 Chandna A, Chew R, Shwe Nwe Htun N, *et al*. Defining the burden of febrile illness in rural South and Southeast Asia: an open letter to announce the launch of the rural febrile illness project. *Wellcome Open Res* 2021;6:64.
15 Designing household survey samples: practical guidelines. United Nation Publication; 2008. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://unstats.un.org/unsd/publication/seriesf/seriesf_98e.pdf
16 The World Health Organization. The WHO stepwise approach to Noncommunicable disease risk factor surveillance. 2020. Available: https://www.who.int/teams/noncommunicable-diseases/surveillance/systems-tools/steps/manuals [Accessed 25 May 2023].
17 Milligan P, Njie A, Bennett S. Comparison of two cluster sampling methods for health surveys in developing countries. *Int J Epidemiol* 2004;33:469–76.
18 ICF. Demographic and health survey interviewer's manual. Maryland, USA: ICF; 2020. Available: https://dhsprogram.com/publications/publication-dhsm1-dhs-questionnaires-and-manuals.cfm [Accessed 22 Sep 2023].
19 MoHS/Myanmar M of H and S, ICF. Myanmar demographic and health survey 2015-16. Nay Pyi Taw, Myanmar, and Rockville, Maryland USA: Ministry of Health and Sports and ICF; 2017. Available: https://dhsprogram.com/publications/publication-fr324-dhs-final-reports.cfm [Accessed 28 Oct 2021].
20 Bangladesh demographic and health survey 2017-18. Dhakar, Bangladesh, and Rockville, Maryland, USA: NIPORT and ICF. Available: https://dhsprogram.com/publications/publication-FR344-DHS-Final-Reports.cfm [Accessed 28 Oct 2021].
21 Statistics/Cambodia NI of, Health/Cambodia DG for, International ICF. Cambodia demographic and health survey 2014. 2015. Available: https://dhsprogram.com/publications/publication-fr312-dhs-final-reports.cfm [Accessed 28 Oct 2021].
22 National Institute of Preventive and Social medicine (NIPSOM). National STEPS survey for non-communicable diseases risk factors in Bangladesh 2018. Dhakar, Bangladesh: National Institute of Preventive and Social medicine (NIPSOM). Available: https://apps.who.int/iris/handle/10665/332886 [Accessed 28 Oct 2021].
23 University of Health Science, Preventive Medicine Department of the Ministry of Health. Prevalence of non-communicable disease risk factors in Cambodia, STEPS survey country report 2010. Phnom Penh, Cambodia: University of Health Science, Preventive Medicine Department of the Ministry of Health; 2010. Available: https://extranet.who.int/ncdsmicrodata/index.php/catalog/378 [Accessed 28 Oct 2021].
24 Lao people's Democratic Republic - STEPS 2013. Available: https://extranet.who.int/ncdsmicrodata/index.php/catalog/588 [Accessed 28 Oct 2021].
25 National Statistical Office of Thailand. Bangkok, Thailand: National Statistical Office of Thailand; National Statistical Office of Thailand. Thailand Multiple Indicator Cluster Survey 2019, Survey finding report, . 2020Available: https://www.unicef.org/thailand/reports/thailand-multiple-indicator-cluster-survey-2019 [Accessed 28 Oct 2021].
26 Lynch E, Falq G, Sun C, *et al*. Hepatitis C Viraemic and Seroprevalence and risk factors for positivity in Northwest Cambodia: a household cross-sectional Serosurvey. *BMC Infect Dis* 2021;21:223.
27 Komada K, Sugiyama M, Vongphrachanh P, *et al*. Seroprevalence of chronic hepatitis B, as determined from dried blood spots, among children and their mothers in central Lao people's Democratic Republic: a multistage, stratified cluster sampling survey. *Int J Infect Dis* 2015;36:21–6.
28 Ashraf H, Alam NH, Rothermundt C, *et al*. Prevalence and risk factors of hepatitis B and C virus infections in an impoverished urban community in Dhaka, Bangladesh. *BMC Infect Dis* 2010;10:208.
29 Lwin AA, Aye KS, Htun MM, *et al*. Sero-prevalence of hepatitis B and C viral infections in Myanmar: national and regional survey in 2015. *Myanmar Health Sci Res J* 2017;29:167–75.
30 The EquityTool. Equity tool. Available: https://www.equitytool.org/the-equity-tool-2/ [Accessed 28 Oct 2021].
31 Chakraborty NM, Fry K, Behl R, *et al*. Simplified asset indices to measure wealth and equity in health programs: A Reliability and validity analysis using survey data from 16 countries. *Glob Health Sci Pract* 2016;4:141–54.
32 World health survey (WHS). Available: https://apps.who.int/healthinfo/systems/surveydata/index.php/catalog/whs/about [Accessed 20 Apr 2022].
33 van der Zouwen J, Smit JH. Evaluating survey questions by analyzing patterns of behavior codes and question–answer sequences: A diagnostic approach. In: *In: Methods for Testing and Evaluating Survey Questionnaires [Internet*. John Wiley & Sons, Ltd, 2004: 109–30.
34 Presser S, Couper MP, Lessler JT, *et al*. Methods for testing and evaluating survey questions. *Public Opinion Quarterly* 2004;68:109–30.
35 Alemayehu S, Feghali KC, Cowden J, *et al*. Comparative evaluation of published real-time PCR assays for the detection of malaria following MIQE guidelines. *Malar J* 2013;12:277.
36 Wampfler R, Mwingira F, Javati S, *et al*. Strategies for detection of Plasmodium species Gametocytes. *PLOS One* 2013;8:e76316.
37 Rosanas-Urgell A, Mueller D, Betuela I, *et al*. Comparison of diagnostic methods for the detection and Quantification of the four Sympatric Plasmodium species in field samples from Papua New Guinea. *Malar J* 2010;9:361.
38 Hofmann N, Mwingira F, Shekalaghe S, *et al*. Ultra-sensitive detection of Plasmodium Falciparum by amplification of multi-copy Subtelomeric targets. *PLOS Med* 2015;12:e1001788.
39 Case report: case series of human Plasmodium Knowlesi infection on the Southern border of Thailand - PMC. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6896887/ [Accessed 20 Feb 2024].
40 Hartung C, Lerer A, Anokwa Y, *et al*. Open data kit: tools to build information services for developing regions. in: proceedings of the 4TH ACM/IEEE international conference on information and communication technologies and development. New York, NY, USA: Association for Computing Machinery,
41 Andrews JR, Barkume C, Yu AT, *et al*. Integrating facility-based surveillance with Healthcare utilization surveys to estimate Enteric fever incidence: methods and challenges. *J Infect Dis* 2018;218:S268–76.

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42 Aiemjoy K, Seidman JC, Saha S, *et al*. Estimating typhoid incidence from community-based serosurveys: a multicohort study. *Lancet Microbe* 2022;3:e578–87.
43 Falade-Nwulia O, Suarez-Cuervo C, Nelson DR, *et al*. Oral direct-acting agent therapy for hepatitis C virus infection. *Ann Intern Med* 2017;166:637–48.
44 Hepatitis B (Hepb3) immunization coverage among 1-year-olds (%). Available: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/hepatitis-b-(hepb3)-immunization-coverage-among-1-year-olds [Accessed 3 Aug 2023].
45 Gu D, Dupre ME, eds. Thet Ssoe H. Myanmar aging survey. In: *Encyclopedia of Gerontology and Population Aging [Internet]*. Cham: Springer International Publishing, 2021: 3375–8.
46 John K, Bussarawan T, *et al*. The situation of Thailand's older population: an update based on the 2. 2023 Available: https://ink.library.smu.edu.sg/soss_research/1948/
47 Uddin MA, Soivong P, Lasuka D, *et al*. Factors related to quality of life among older adults in Bangladesh: a cross sectional survey. *Nurs Health Sci* 2017;19:518–24.
48 Jankhotkaew J, Chaiyasong S, Waleewong O, *et al*. The impact of heavy drinkers on others' health and well-being in Lao PDR and Thailand. *Journal of Substance Use* 2017;22:617–23.
49 DeSalvo KB, Fan VS, McDonell MB, *et al*. Predicting mortality and healthcare utilization with a single question. *Health Serv Res* 2005;40:1234–46.
50 Benyamini Y, Idler EL. Community studies reporting association between self-rated health and mortality: additional studies. *Res Aging* 1999;21:392–401.
51 Makovski TT, Schmitz S, Zeegers MP, *et al*. Multimorbidity and quality of life: systematic literature review and meta-analysis. *Ageing Res Rev* 2019;53:100903.
52 MORU tropical network policy on sharing data and other outputs. Available: https://www.tropmedres.ac/units/moru-bangkok/bioethics-engagement/data-sharing/moru-tropical-network-policy-on-sharing-data-and-other-outputs [Accessed 17 Oct 2023].

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C

Appendix C for Chapter 3

Appendix C: Appendix for Chapter 3

Table 1: Village and cluster response rate

Cluster	District	Village	Response rate	n Participants	n Eligible
Bangladesh					
1	Rowangchhari	1	100	21	21
		2	95.5	21	22
		3	92.9	13	14
		4	62.5	10	16
Overall			89	65	73
2	Rowangchhari	5	100	21	21
		6	92	23	25
		7	100	18	18
		8	95	19	20
Overall			96.4	81	84
3	Bandarban Sadar	9	100	14	14
		10	94.4	17	18
		11	100	19	19
		12	79.3	23	29
Overall			91.2	73	80
4	Lama	13	90.5	19	21
		14	100	39	39
		15	100	14	14
		16	100	24	24
Overall			98	96	98
5	Lama	17	100	15	15
		18	87	20	23
		19	73.1	19	26
		20	100	22	22

Table 1: Village and cluster response rate *(continued)*

Cluster	District	Village	Response rate	n Participants	n Eligible
Overall			88.4	76	86
6	Ukhiya	21	51.9	14	27
		22	88.5	23	26
		23	60.6	20	33
Overall			89.5	57	86
7	Ukhiya	24	96.4	27	28
		25	76.2	16	21
		26	79.3	23	29
Overall			91	66	78
8	Ukhiya	27	69.7	23	33
		28	82.1	23	28
		29	96	24	25
Overall			91.9	70	86
9	Ukhiya	30	77.8	28	36
		31	68.8	22	32
		32	85.2	23	27
Overall			89.5	73	95
10	Ukhiya	33	89.7	26	29
		34	55.2	16	29
		35	70.8	17	24
Overall			91.5	59	82
11	Ukhiya	36	76.7	23	30
		37	85.2	23	27
		38	80.6	25	31
Overall			94.3	71	88
12	Ukhiya	39	76.2	16	21
		40	52.9	9	17
		41	95.2	20	21
Overall			91.5	45	59
13	Ukhiya	42	95	19	20
		43	96.3	26	27
		44	95.2	20	21

Table 1: Village and cluster response rate *(continued)*

Cluster	District	Village	Response rate	n Participants	n Eligible
Overall			95.6	65	68
14	Ukhiya	45	82.4	28	34
		46	92.6	25	27
		47	86.4	19	22
Overall			86.7	72	83
15	Ukhiya	48	78.3	18	23
		49	95.8	23	24
Overall			87.2	41	47
16	Naikhongchhari	50	88.5	23	26
		51	96.2	25	26
		52	70	21	30
Overall			92.7	69	82
17	Chakaria	53	100	31	31
		54	100	41	41
		55	97.6	41	42
		56	100	27	27
Overall			99.3	140	141
18	Chakaria	57	100	27	27
		58	96.2	25	26
		59	100	25	25
		60	100	27	27
Overall			99	104	105
19	Chakaria	61	100	28	28
		62	100	21	21
		63	100	34	34
		64	100	22	22
Overall			100	105	105
20	Chakaria	65	100	32	32
		66	100	26	26
		67	100	33	33
		68	100	29	29
Overall			100	120	120

Table 1: Village and cluster response rate *(continued)*

Cluster	District	Village	Response rate	n Participants	n Eligible
21	Chakaria	69	100	16	16
		70	100	26	26
		71	100	24	24
		72	100	39	39
Overall			100	105	105
22	Chakaria	73	100	33	33
		74	96.2	25	26
		75	96.4	27	28
Overall			97.7	85	87
Cambodia					
1	Samlout	1	88.2	15	17
		2	100	22	22
		3	64.7	11	17
		4	83.8	31	37
		5	100	22	22
		6	100	21	21
		7	88	22	25
Overall			89.4	144	161
2	Sung	8	86.2	25	29
		9	100	20	20
		10	81	17	21
		11	90	18	20
Overall			88.9	80	90
3	Kampong Lpov	12	85.7	18	21
		13	77.8	14	18
		14	100	19	19
		15	33.3	8	24
		16	83.9	26	31
		17	77.8	14	18
		18	71.4	20	28
		19	93.8	15	16

Table 1: Village and cluster response rate *(continued)*

Cluster	District	Village	Response rate	n Participants	n Eligible
Overall			76.6	134	175
4	Preah Phos	20	90	18	20
		21	82.1	23	28
		22	86.4	19	22
		23	81.8	18	22
	Chhnal Moan	24	89.7	26	29
		25	100	19	19
		26	94.4	17	18
		27	86.7	13	15
		28	90.9	30	33
		29	100	20	20
		30	100	29	29
	Doun Ba	31	100	22	22
		32	92.9	26	28
		33	66.7	16	24
		34	78.6	22	28
		35	88.2	15	17
		36	95.8	23	24
		37	78.6	22	28
Overall			88.7	378	426
	Ou Ta Vau	38			ă
		39	90.3	28	31
		40	81.8	18	22
		41	75	18	24
		42	86.7	26	30
		43	85.2	23	27
		44	100	21	21
		45	100	25	25
		46	100	19	19
		47	82.4	14	17
		48	97.1	34	35
		49	68	17	25

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Table 1: Village and cluster response rate *(continued)*

Cluster	District	Village	Response rate	n Participants	n Eligible
	Pailin	50	85.2	23	27
Overall			87.8	266	303
6	Bar Yakha	51	82.6	19	23
		52	79.2	19	24
		53	88.9	16	18
Overall			83.1	54	65
7	Tuol Lvea	54	75	18	24
		55	85.7	30	35
Overall			81.4	48	59
8	Mukh Reah	56	73.3	11	15
		57	85	17	20
	Prey Tralach	58	90.5	19	21
		59	100	14	14
		60	90.5	19	21
		61	91.3	21	23
	Sdok Pravoek	62	96	24	25
		63	90.5	19	21
		64	79.2	19	24
Overall			88.6	163	184
9	Ta Sanh	65	87.9	29	33
		66	86.4	19	22
Overall	ă		87.3	48	55
10	Ta Taok	67	93.1	27	29
		68	94.7	18	19
		69	85.7	24	28
		70	95.2	20	21
	Ta Sanh	71	94.1	16	17
		72	100	20	20
		73	95.2	20	21
		74	100	16	16
		75	66.7	14	21
Overall			91.1	175	192

Table 1: Village and cluster response rate *(continued)*

Cluster	District	Village	Response rate	n Participants	n Eligible
Thailand					
1	Chiang Khong	1	88	22	25
		2	65.2	15	23
		3	93.3	14	15
		4	93.8	15	16
		5	61.5	8	13
		6	93.3	14	15
		7	80	16	20
		8	100	16	16
Overall			83.9	120	143
2	Chiang Khong	9	86.7	13	15
		10	76.9	10	13
		11	83.3	15	18
		12	86.7	13	15
		13	90.9	10	11
Overall			84.7	61	72
3	Chiang Khong	14	85	17	20
		15	95.5	21	22
Overall			90.5	38	42
4	Khun Tan	16	97.1	34	35
		17	64.3	18	28
		18	84.6	22	26
Overall			83.1	74	89
5	Khun Tan	19	100	22	22
		20	96.7	29	30
		21	100	30	30
		22	87.5	14	16
		23	87.5	21	24
Overall			95.1	116	122
		24	73.5	25	34
		25	100	38	38

Table 1: Village and cluster response rate *(continued)*

Cluster	District	Village	Response rate	n Participants	n Eligible
6	Khun Tan	26	87.9	29	33
		27	81.1	30	37
Overall			85.9	122	142
7	Khun Tan	28	66.7	8	12
		29	77.8	7	9
Overall			71.4	15	21
8	Mae Suai	30	100	20	20
		31	82.4	14	17
		32	74.1	20	27
Overall			84.4	54	64
9	Mae Suai	33	96	24	25
		34	80.8	21	26
		35	82.4	14	17
Overall			86.8	59	68
10	Mae Suai	36	65	13	20
		37	94.1	16	17
		38	93.3	28	30
		39	95.2	20	21
		40	95.2	20	21
		41	95.8	23	24
		42	78.3	18	23
		43	87.5	14	16
Overall			88.4	152	172
11	Mae Suai	44	84	21	25
		45	86.7	13	15
		46	100	16	16
		47	88.2	15	17
		48	75	15	20
		49	75	9	12
		50	74.2	23	31
		51	97.2	35	36
		52	78.3	18	23

Table 1: Village and cluster response rate *(continued)*

Cluster	District	Village	Response rate	n Participants	n Eligible
Overall			84.6	165	195
12	Mae Suai	53	61.9	13	21
		54	75	24	32
		55	78.9	30	38
		56	73.5	25	34
Overall			73.6	92	125
13	Mueng	57	75	12	16
		58			ă
Overall			75	12	16
14	Mueng	59	69.6	16	23
		60	80.8	21	26
Overall			75.5	37	49
15	Mueng	61	72.7	8	11
		62	80.8	21	26
		63	68.2	15	22
Overall			74.6	44	59
16	Mueng	64	81.5	22	27
		65	88	22	25
		66	88.5	23	26
		67	72	18	25
		68	76.5	13	17
Overall			81.7	98	120
17	Wiang Kaen	69	68.8	22	32
		70	84.6	22	26
Overall			75.9	44	58
18	Wiang Khaen	71	83.3	30	36
		72	76.9	30	39
Overall			80	60	75
19	Wiang Khaen	73	80	16	20
		74	84.8	28	33
		75	93.3	14	15
Overall			85.3	58	68

Table 2: Household characteristics, by study site

Characteristic	Bangladesh N = 372	Cambodia N = 355	Thailand N = 472
Ethnicity			
Bangladesh			
Bengali	299 (80.4)	-	-
Marma	48 (12.9)	-	-
Mro	5 (1.3)	-	-
Tanchangya	12 (3.2)	-	-
Khayang	8 (2.2)	-	-
Cambodia			
Khmer	-	343 (96.6)	-
Cham	-	8 (2.3)	-
Thailand			
Thai	-	-	273 (57.8)
Akha	-	-	55 (11.7)
Lahu	-	-	53 (11.2)
Karen	-	-	6 (1.3)
Hmong	-	-	26 (5.5)
Yao/Mien	-	-	43 (9.1)
Tai Yai/Shan	-	-	3 (0.6)
Lisu	-	-	6 (1.3)
Other ethnic group	-	4 (1.1)	7 (1.5)
Household wealth status			
Poorest	84 (22.6)	10 (2.8)	74 (15.7)
Poorer	21 (5.6)	43 (12.1)	94 (19.9)
Middle	117 (31.5)	103 (29.0)	144 (30.5)
Richer	116 (31.2)	99 (27.9)	120 (25.4)
Richest	34 (9.1)	100 (28.2)	40 (8.5)
Type of cooking fuel			
Clean fuel			
Electricity	118 (31.7)	6 (1.7)	2 (0.4)
Liquefied Petroleum Gas (LPG)	50 (13.4)	65 (18.3)	296 (62.7)
Solid fuel			
Charcoal	4 (1.1)	102 (28.7)	75 (15.9)
Wood	200 (53.8)	182 (51.3)	99 (21.0)
Main drinking water source			
Improved			
Piped water: Piped into dwelling	37 (9.9)	11 (3.1)	72 (15.3)
Other improved			
Piped water: Piped to yard/plot	191 (51.3)	1 (0.3)	0 (0.0)
Piped water: Piped to neighbour	71 (19.1)	0 (0.0)	1 (0.2)

Table 2: Household characteristics, by study site *(continued)*

Characteristic	Bangladesh N = 372	Cambodia N = 355	Thailand N = 472
Piped water: Public tap/standpipe	51 (13.7)	2 (0.6)	126 (26.7)
Piped water: Tube well or borehole	18 (4.8)	77 (21.7)	3 (0.6)
Dug well: Protected well	3 (0.8)	9 (2.5)	31 (6.6)
Water from spring: Protected spring	0 (0.0)	0 (0.0)	2 (0.4)
Rainwater	0 (0.0)	5 (1.4)	0 (0.0)
Tanker truck	0 (0.0)	42 (11.8)	3 (0.6)
Cart with small tank	0 (0.0)	7 (2.0)	0 (0.0)
Bottled water	0 (0.0)	8 (2.3)	203 (43.0)
Unimproved			
Dug well: Unprotected well	1 (0.3)	2 (0.6)	1 (0.2)
Surface water (river/dam/Lake/pond/stream/canal/Irrigation channel)	0 (0.0)	187 (52.7)	21 (4.4)
Other	0 (0.0)	4 (1.1)	9 (1.9)
Type of sanitation facility			
Improved			
Flush or pour flush toilet: Flush to piped sewer system	9 (2.4)	0 (0.0)	263 (55.7)
Other improved			
Flush or pour flush toilet: Flush to septic tank	35 (9.4)	207 (58.3)	15 (3.2)
Flush or pour flush toilet: Flush to pit latrine	4 (1.1)	66 (18.6)	185 (39.2)
Flush or pour flush toilet: Flush to somewhere else	1 (0.3)	8 (2.3)	2 (0.4)
Flush or pour flush toilet: Flush, don't know where	0 (0.0)	0 (0.0)	1 (0.2)
Pit latrine: Ventilated improved pit latrine	34 (9.1)	0 (0.0)	5 (1.1)
Pit latrine: Pit latrine with slab	158 (42.5)	0 (0.0)	0 (0.0)
Composting toilet	0 (0.0)	1 (0.3)	0 (0.0)
Unimproved/ no facility			
Pit latrine: Pit latrine without slab/open pit	110 (29.6)	0 (0.0)	0 (0.0)
Bucket toilet	0 (0.0)	0 (0.0)	1 (0.2)
Hanging toilet/hanging latrine	10 (2.7)	0 (0.0)	0 (0.0)
No facility/bush/field	11 (3.0)	63 (17.7)	0 (0.0)
Other	0 (0.0)	10 (2.8)	0 (0.0)

Table 3: Detail characteristics of adult participants, by site

Characteristic	Bangladesh N = 1,166	Cambodia N = 935	Thailand N = 1,199
Age	34 (22, 45)	39 (28, 55)	55 (43, 64)
Age groups			
15-29	491 (42.1)	259 (27.7)	114 (9.5)
30-39	223 (19.1)	211 (22.6)	124 (10.3)
40-49	205 (17.6)	154 (16.5)	209 (17.4)
50-59	137 (11.7)	160 (17.1)	283 (23.6)
60+	110 (9.4)	151 (16.1)	469 (39.1)
Sex- Male	491 (42.1)	427 (45.7)	485 (40.5)
Household size			
1-2 persons	54 (4.6)	56 (6.0)	282 (23.5)
3-5 persons	530 (45.5)	517 (55.3)	619 (51.6)
6 or more	582 (49.9)	362 (38.7)	298 (24.9)
Relationship to the household head			
Head	372 (31.9)	355 (38.0)	472 (39.4)
Wife/ husband	256 (22.0)	256 (27.4)	258 (21.5)
Son/ daughter	310 (26.6)	189 (20.2)	126 (10.5)
Other	228 (19.6)	135 (14.4)	343 (28.6)
Ethnicity			
Bangali	960 (82.3)	-	-
Other (Bangladesh)	206 (17.7)	-	-
Khmer/Cham/other (Cambodia)	-	935 (100.0)	-
Thai	-	-	717 (59.8)
Akha	-	-	151 (12.6)
Lahu	-	-	118 (9.8)
Other (Thailand)	-	-	213 (17.8)
Marital status			
Never married	253 (21.7)	161 (17.2)	115 (9.6)
Currently married	838 (71.9)	697 (74.5)	499 (41.6)
Separated	7 (0.6)	2 (0.2)	16 (1.3)
Divorced	6 (0.5)	2 (0.2)	40 (3.3)
Widowed	62 (5.3)	73 (7.8)	117 (9.8)
Cohabitating	0 (0.0)	0 (0.0)	411 (34.3)
Refuse to answer	0 (0.0)	0 (0.0)	1 (0.1)
Education level			
Never attended school	394 (33.8)	202 (21.6)	282 (23.5)
Primary school uncompleted	179 (15.4)	337 (36.0)	175 (14.6)
Primary school completed	321 (27.5)	192 (20.5)	340 (28.4)
Secondary school completed/ higher	272 (23.3)	204 (21.8)	402 (33.5)
Work status in the past 12 months			
Government employee	6 (0.5)	39 (4.2)	20 (1.7)
Employee			
Non-government employee: State enterprise officer	5 (0.4)	0 (0.0)	1 (0.1)

Table 3: Detail characteristics of adult participants, by site *(continued)*

Characteristic	Bangladesh N = 1,166	Cambodia N = 935	Thailand N = 1,199
Non-government employee: Private company employee	12 (1.0)	3 (0.3)	7 (0.6)
Business: Business owner	46 (3.9)	9 (1.0)	51 (4.3)
Business: Household business assistance	19 (1.6)	8 (0.9)	5 (0.4)
Other self-employed	56 (4.8)	69 (7.4)	27 (2.3)
Agriculture (landowner and farmer)	99 (8.5)	379 (40.5)	683 (57.0)
Agriculture			
Agriculture labourer (other's land)	40 (3.4)	37 (4.0)	51 (4.3)
Labourer: Industrial labourer	6 (0.5)	2 (0.2)	3 (0.3)
Labourer			
Labourer: Day labourer	105 (9.0)	102 (10.9)	60 (5.0)
Labourer: Transport labourer	49 (4.2)	2 (0.2)	0 (0.0)
Labourer: Paid domestic worker	3 (0.3)	1 (0.1)	4 (0.3)
Labourer: Blacksmith/ Goldsmith/other skilled labour	5 (0.4)	2 (0.2)	10 (0.8)
Student	139 (11.9)	43 (4.6)	26 (2.2)
Unpaid work			
Home maker/household work	506 (43.4)	176 (18.8)	139 (11.6)
Retired	16 (1.4)	13 (1.4)	39 (3.3)
Don't work			
Unemployed (able to work, e.g. unwilling to work)	13 (1.1)	3 (0.3)	31 (2.6)
Unemployed (unable to work, e.g. too sick, disabled)	26 (2.2)	30 (3.2)	12 (1.0)
Other	15 (1.3)	17 (1.8)	30 (2.5)

[1] Median (Q1, Q3); n (%)

Note:
Work status- Other were recorded according to free-text in the collapsed categories in the main text. Additional participants were added to argriculture work: n=6 Cambodia; labourer: n=3 Bangladesh, n=1 Cambodia, n=4 Thailand; Employee: n=2 Bangladesh, n=1 Cambodia, n=11 Thailand; unpaid work: n=8 Bangladesh, n=6 Cambodia, n=8 Thailand; Don't work: n=2 Bangladesh, n=3 Cambodia, n=7 Cambodia

Table 4: Slef-percieved health status among adult participants, by age and country. The table describes the frequency of all levels of overall health status and the domains of health.

Variables	Bangladesh				Cambodia				Thailand			
	Overall N = 1,166	15-29 N = 491	30-49 N = 428	50+ N = 247	Overall N = 935	15-29 N = 259	30-49 N = 365	50+ N = 311	Overall N = 1,199	15-29 N = 114	30-49 N = 333	50+ N = 752
Overall health												
Very good	248 (21.3)	136 (27.7)	81 (18.9)	31 (12.6)	22 (2.4)	21 (8.1)	1 (0.3)	0 (0.0)	119 (9.9)	29 (25.4)	41 (12.3)	49 (6.5)
Good	699 (59.9)	320 (65.2)	260 (60.7)	119 (48.2)	177 (18.9)	112 (43.2)	54 (14.8)	11 (3.5)	571 (47.6)	64 (56.1)	187 (56.2)	320 (42.6)
Moderate	171 (14.7)	25 (5.1)	65 (15.2)	81 (32.8)	584 (62.5)	118 (45.6)	278 (76.2)	188 (60.5)	484 (40.4)	21 (18.4)	102 (30.6)	361 (48.0)
Bad	47 (4.0)	10 (2.0)	22 (5.1)	15 (6.1)	136 (14.5)	7 (2.7)	30 (8.2)	99 (31.8)	21 (1.8)	0 (0.0)	3 (0.9)	18 (2.4)
Very bad	1 (0.1)	0 (0.0)	0 (0.0)	1 (0.4)	16 (1.7)	1 (0.4)	2 (0.5)	13 (4.2)	4 (0.3)	0 (0.0)	0 (0.0)	4 (0.5)
Health domains: levels of difficulty												
Work or hosuehold activities												
None	720 (61.7)	384 (78.2)	240 (56.1)	96 (38.9)	345 (36.9)	156 (60.2)	143 (39.2)	46 (14.8)	1,029 (85.8)	112 (98.2)	309 (92.8)	608 (80.9)
Mild	294 (25.2)	88 (17.9)	125 (29.2)	81 (32.8)	205 (21.9)	40 (15.4)	86 (23.6)	79 (25.4)	110 (9.2)	0 (0.0)	21 (6.3)	89 (11.8)
Moderate	143 (12.3)	19 (3.9)	60 (14.0)	64 (25.9)	242 (25.9)	47 (18.1)	85 (23.3)	110 (35.4)	45 (3.8)	1 (0.9)	2 (0.6)	42 (5.6)
Severe	7 (0.6)	0 (0.0)	3 (0.7)	4 (1.6)	139 (14.9)	15 (5.8)	50 (13.7)	74 (23.8)	7 (0.6)	0 (0.0)	1 (0.3)	6 (0.8)

Table 4: Slef-percieved health status among adult participants, by age and country. The table describes the frequency of all levels of overall health status and the domains of health. *(continued)*

Variables	Bangladesh				Cambodia				Thailand			
	Overall N = 1,166	15-29 N = 491	30-49 N = 428	50+ N = 247	Overall N = 935	15-29 N = 259	30-49 N = 365	50+ N = 311	Overall N = 1,199	15-29 N = 114	30-49 N = 333	50+ N = 752
Extreme/ Cannot do	2 (0.2)	0 (0.0)	0 (0.0)	2 (0.8)	4 (0.4)	1 (0.4)	1 (0.3)	2 (0.6)	8 (0.7)	1 (0.9)	0 (0.0)	7 (0.9)
Mobility												
None	562 (48.2)	336 (68.4)	180 (42.1)	46 (18.6)	616 (65.9)	242 (93.4)	285 (78.1)	89 (28.6)	973 (81.2)	111 (97.4)	308 (92.5)	554 (73.7)
Mild	361 (31.0)	115 (23.4)	151 (35.3)	95 (38.5)	148 (15.8)	13 (5.0)	44 (12.1)	91 (29.3)	143 (11.9)	2 (1.8)	17 (5.1)	124 (16.5)
Moderate	216 (18.5)	34 (6.9)	88 (20.6)	94 (38.1)	116 (12.4)	2 (0.8)	24 (6.6)	90 (28.9)	59 (4.9)	1 (0.9)	6 (1.8)	52 (6.9)
Severe	24 (2.1)	6 (1.2)	8 (1.9)	10 (4.0)	49 (5.2)	1 (0.4)	11 (3.0)	37 (11.9)	13 (1.1)	0 (0.0)	2 (0.6)	11 (1.5)
Extreme/ Cannot do	3 (0.3)	0 (0.0)	1 (0.2)	2 (0.8)	6 (0.6)	1 (0.4)	1 (0.3)	4 (1.3)	11 (0.9)	0 (0.0)	0 (0.0)	11 (1.5)
Felfcare												
None	694 (59.5)	373 (76.0)	242 (56.5)	79 (32.0)	803 (85.9)	250 (96.5)	348 (95.3)	205 (65.9)	1,135 (94.7)	113 (99.1)	327 (98.2)	695 (92.4)
Mild	294 (25.2)	90 (18.3)	119 (27.8)	85 (34.4)	99 (10.6)	7 (2.7)	12 (3.3)	80 (25.7)	45 (3.8)	1 (0.9)	6 (1.8)	38 (5.1)
Moderate	162 (13.9)	26 (5.3)	61 (14.3)	75 (30.4)	23 (2.5)	0 (0.0)	4 (1.1)	19 (6.1)	12 (1.0)	0 (0.0)	0 (0.0)	12 (1.6)

Table 4: Slef-percieved health status among adult participants, by age and country. The table describes the frequency of all levels of overall health status and the domains of health. *(continued)*

Variables	Bangladesh				Cambodia				Thailand			
	Overall N = 1,166	15-29 N = 491	30-49 N = 428	50+ N = 247	Overall N = 935	15-29 N = 259	30-49 N = 365	50+ N = 311	Overall N = 1,199	15-29 N = 114	30-49 N = 333	50+ N = 752
Severe	14 (1.2)	2 (0.4)	6 (1.4)	6 (2.4)	8 (0.9)	1 (0.4)	1 (0.3)	6 (1.9)	2 (0.2)	0 (0.0)	0 (0.0)	2 (0.3)
Extreme/ Cannot do	2 (0.2)	0 (0.0)	0 (0.0)	2 (0.8)	2 (0.2)	1 (0.4)	0 (0.0)	1 (0.3)	5 (0.4)	0 (0.0)	0 (0.0)	5 (0.7)
Body ache/ pain												
None	429 (36.8)	295 (60.1)	110 (25.7)	24 (9.7)	424 (45.3)	184 (71.0)	177 (48.5)	63 (20.3)	435 (36.3)	83 (72.8)	153 (45.9)	199 (26.5)
Mild	371 (31.8)	125 (25.5)	171 (40.0)	75 (30.4)	170 (18.2)	39 (15.1)	72 (19.7)	59 (19.0)	493 (41.1)	22 (19.3)	125 (37.5)	346 (46.0)
Moderate	289 (24.8)	64 (13.0)	109 (25.5)	116 (47.0)	221 (23.6)	28 (10.8)	79 (21.6)	114 (36.7)	242 (20.2)	9 (7.9)	50 (15.0)	183 (24.3)
Severe	74 (6.3)	7 (1.4)	35 (8.2)	32 (13.0)	112 (12.0)	7 (2.7)	35 (9.6)	70 (22.5)	25 (2.1)	0 (0.0)	5 (1.5)	20 (2.7)
Extreme/ Cannot do	3 (0.3)	0 (0.0)	3 (0.7)	0 (0.0)	8 (0.9)	1 (0.4)	2 (0.5)	5 (1.6)	4 (0.3)	0 (0.0)	0 (0.0)	4 (0.5)
Concentration												
None	622 (53.3)	333 (67.8)	214 (50.0)	75 (30.4)	504 (53.9)	193 (74.5)	216 (59.2)	95 (30.5)	621 (51.8)	85 (74.6)	212 (63.7)	324 (43.1)
Mild	332 (28.5)	115 (23.4)	139 (32.5)	78 (31.6)	269 (28.8)	50 (19.3)	95 (26.0)	124 (39.9)	416 (34.7)	27 (23.7)	98 (29.4)	291 (38.7)

Table 4: Slef-percieved health status among adult participants, by age and country. The table describes the frequency of all levels of overall health status and the domains of health. *(continued)*

Variables	Bangladesh				Cambodia				Thailand			
	Overall N = 1,166	15-29 N = 491	30-49 N = 428	50+ N = 247	Overall N = 935	15-29 N = 259	30-49 N = 365	50+ N = 311	Overall N = 1,199	15-29 N = 114	30-49 N = 333	50+ N = 752
Moderate	198 (17.0)	40 (8.1)	71 (16.6)	87 (35.2)	133 (14.2)	14 (5.4)	48 (13.2)	71 (22.8)	153 (12.8)	2 (1.8)	23 (6.9)	128 (17.0)
Severe	13 (1.1)	3 (0.6)	3 (0.7)	7 (2.8)	25 (2.7)	1 (0.4)	5 (1.4)	19 (6.1)	7 (0.6)	0 (0.0)	0 (0.0)	7 (0.9)
Extreme/ Cannot do	1 (0.1)	0 (0.0)	1 (0.2)	0 (0.0)	4 (0.4)	1 (0.4)	1 (0.3)	2 (0.6)	2 (0.2)	0 (0.0)	0 (0.0)	2 (0.3)
Seeing												
None	763 (65.4)	417 (84.9)	270 (63.1)	76 (30.8)	477 (51.0)	220 (84.9)	204 (55.9)	53 (17.0)	876 (73.1)	104 (91.2)	276 (82.9)	496 (66.0)
Mild	245 (21.0)	57 (11.6)	108 (25.2)	80 (32.4)	205 (21.9)	29 (11.2)	99 (27.1)	77 (24.8)	267 (22.3)	8 (7.0)	51 (15.3)	208 (27.7)
Moderate	139 (11.9)	17 (3.5)	45 (10.5)	77 (31.2)	169 (18.1)	9 (3.5)	46 (12.6)	114 (36.7)	48 (4.0)	2 (1.8)	6 (1.8)	40 (5.3)
Severe	17 (1.5)	0 (0.0)	5 (1.2)	12 (4.9)	84 (9.0)	1 (0.4)	16 (4.4)	67 (21.5)	7 (0.6)	0 (0.0)	0 (0.0)	7 (0.9)
Extreme/ Cannot do	2 (0.2)	0 (0.0)	0 (0.0)	2 (0.8)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	0 (0.0)	0 (0.0)	1 (0.1)
Sleeping												
None	647 (55.5)	344 (70.1)	218 (50.9)	85 (34.4)	454 (48.6)	193 (74.5)	180 (49.3)	81 (26.0)	744 (62.1)	91 (79.8)	225 (67.6)	428 (56.9)
Mild	330 (28.3)	108 (22.0)	136 (31.8)	86 (34.8)	169 (18.1)	34 (13.1)	72 (19.7)	63 (20.3)	298 (24.9)	16 (14.0)	82 (24.6)	200 (26.6)

Table 4: Slef-percieved health status among adult participants, by age and country. The table describes the frequency of all levels of overall health status and the domains of health. *(continued)*

Variables	Bangladesh				Cambodia				Thailand			
	Overall N = 1,166	15-29 N = 491	30-49 N = 428	50+ N = 247	Overall N = 935	15-29 N = 259	30-49 N = 365	50+ N = 311	Overall N = 1,199	15-29 N = 114	30-49 N = 333	50+ N = 752
Moderate	171 (14.7)	36 (7.3)	65 (15.2)	70 (28.3)	233 (24.9)	28 (10.8)	89 (24.4)	116 (37.3)	140 (11.7)	6 (5.3)	24 (7.2)	110 (14.6)
Severe	17 (1.5)	3 (0.6)	8 (1.9)	6 (2.4)	78 (8.3)	3 (1.2)	24 (6.6)	51 (16.4)	15 (1.3)	1 (0.9)	1 (0.3)	13 (1.7)
Extreme/ Cannot do	1 (0.1)	0 (0.0)	1 (0.2)	0 (0.0)	1 (0.1)	1 (0.4)	0 (0.0)	0 (0.0)	2 (0.2)	0 (0.0)	1 (0.3)	1 (0.1)
Depression												
None	585 (50.2)	286 (58.2)	204 (47.7)	95 (38.5)	412 (44.1)	170 (65.6)	149 (40.8)	93 (29.9)	963 (80.3)	95 (83.3)	258 (77.5)	610 (81.1)
Mild	367 (31.5)	145 (29.5)	145 (33.9)	77 (31.2)	143 (15.3)	39 (15.1)	62 (17.0)	42 (13.5)	183 (15.3)	15 (13.2)	54 (16.2)	114 (15.2)
Moderate	197 (16.9)	53 (10.8)	75 (17.5)	69 (27.9)	257 (27.5)	38 (14.7)	107 (29.3)	112 (36.0)	52 (4.3)	4 (3.5)	20 (6.0)	28 (3.7)
Severe	16 (1.4)	7 (1.4)	3 (0.7)	6 (2.4)	115 (12.3)	11 (4.2)	44 (12.1)	60 (19.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Extreme/ Cannot do	1 (0.1)	0 (0.0)	1 (0.2)	0 (0.0)	8 (0.9)	1 (0.4)	3 (0.8)	4 (1.3)	1 (0.1)	0 (0.0)	1 (0.3)	0 (0.0)

[1] n (%)

Table 5: Univariate logisitics regression on participants' characteristics associated with reporting less good overall health, by site

	Bangladesh			Cambodia			Thailand		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Age groups									
15-29	1.0	Reference		1.0	Reference		1.0	Reference	
30-39	2.6	1.6, 4.3	<0.001	4.8	3.2, 7.4	<0.001	1.9	1.0, 3.5	0.042
40-49	4.2	2.6, 6.8	<0.001	8.5	5.0, 15	<0.001	2.1	1.2, 3.8	0.007
50-59	7.0	4.3, 12	<0.001	41	17, 137	<0.001	4.5	2.7, 7.8	<0.001
60+	10	6.3, 18	<0.001	22	10, 53	<0.001	4.7	2.9, 8.0	<0.001
Sex									
Male	1.0	Reference		1.0	Reference		1.0	Reference	
Female	1.6	1.2, 2.2	0.002	1.4	1.0, 2.0	0.024	1.1	0.9, 1.4	0.3
Household size									
1-2 persons	1.0	Reference		1.0	Reference		1.0	Reference	
3-5 persons	0.4	0.2, 0.7	0.003	0.4	0.1, 0.8	0.035	0.6	0.5, 0.8	<0.001
6 or more	0.3	0.2, 0.6	<0.001	0.3	0.1, 0.8	0.020	0.5	0.4, 0.7	<0.001
Relationship to the household head									
Head	1.0	Reference		1.0	Reference		1.0	Reference	
Wife/ husband	1.0	0.7, 1.4	>0.9	1.1	0.7, 1.9	0.6	1.0	0.8, 1.4	0.8
Son/ daughter	0.2	0.1, 0.4	<0.001	0.1	0.1, 0.2	<0.001	0.5	0.3, 0.8	0.002
Other	0.9	0.6, 1.3	0.5	0.4	0.2, 0.6	<0.001	1.0	0.7, 1.3	0.8
Marital status									

Table 5: Univariate logisitics regression on participants' characteristics associated with reporting less good overall health, by site *(continued)*

	Bangladesh			Cambodia			Thailand		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Never/not currently married	1.0	Reference		1.0	Reference		1.0	Reference	
Currently married/cohabitating	1.2	0.9, 1.7	0.3	5.1	3.6, 7.1	<0.001	0.9	0.7, 1.2	0.4
Education level									
Secondary school completed/ higher	1.0	Reference		1.0	Reference		1.0	Reference	
Never attended school	4.9	3.1, 8.0	<0.001	6.4	3.6, 12	<0.001	1.6	1.2, 2.2	0.003
Primary school uncompleted	2.4	1.3, 4.2	0.003	2.1	1.4, 3.2	<0.001	1.4	1.0, 2.0	0.076
Primary school completed	1.6	1.0, 2.8	0.074	1.1	0.7, 1.7	0.6	2.6	1.9, 3.5	<0.001
Work status									
Agriculture	1.0	Reference		1.0	Reference		1.0	Reference	
Labourer	2.0	1.0, 3.9	0.042	0.8	0.5, 1.4	0.5	1.1	0.7, 1.8	0.6
Employee	0.6	0.3, 1.4	0.2	1.0	0.6, 1.7	>0.9	1.0	0.7, 1.5	>0.9

Table 5: Univariate logisitics regression on participants' characteristics associated with reporting less good overall health, by site *(continued)*

	Bangladesh			Cambodia			Thailand		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Unpaid work	2.1	1.2, 3.8	0.011	0.6	0.4, 0.9	0.008	1.0	0.7, 1.4	>0.9
Don't work	8.6	4.1, 18	<0.001	12	2.5, 210	0.015	1.7	1.1, 2.7	0.014
Wealth status									
Middle	1.0	Reference		1.0	Reference		1.0	Reference	
Poor	1.0	0.7, 1.5	>0.9	1.3	0.8, 2.2	0.3	1.0	0.7, 1.3	>0.9
Rich	1.1	0.8, 1.6	0.5	1.6	1.1, 2.2	0.013	1.2	0.9, 1.6	0.2
Ethnicity									
Bangali	1.0	Reference							
Other (Bangladesh)	0.8	0.5, 1.2	0.3						
Thai							1.0	Reference	
Akha							0.4	0.3, 0.6	<0.001
Lahu							0.4	0.3, 0.7	<0.001
Other (Thailand)							0.5	0.4, 0.7	<0.001

Abbreviations: CI = Confidence Interval, OR = Odds Ratio

Table 6: Univariate logistic regression on participants' characteristics associated with reporting the three most reported major concerns in Bangladesh (i.e. Cost of healthcare, Household amenity-related risk, Work-related exposure to the natural environment)

	Cost of healthcare			Household-related risk: Amenity			Work-related risk: Exposure to nature		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Age groups									
15-29	1.0	Reference		1.0	Reference		1.0	Reference	
30-39	1.3	1.0, 1.8	0.089	0.7	0.5, 1.0	0.047	0.8	0.6, 1.1	0.2
40-49	1.2	0.9, 1.7	0.2	0.9	0.7, 1.3	0.6	0.9	0.6, 1.2	0.5
50-59	2.2	1.5, 3.3	<0.001	0.7	0.4, 1.0	0.040	0.6	0.4, 0.9	0.011
60+	1.5	1.0, 2.2	0.076	0.7	0.4, 1.0	0.078	0.8	0.5, 1.3	0.4
Sex									
Male	1.0	Reference		1.0	Reference		1.0	Reference	
Female	1.1	0.8, 1.3	0.6	1.1	0.9, 1.4	0.5	1	0.7, 1.2	0.7
Ethnicity									
Bangali	1.0	Reference		1.0	Reference		1.0	Reference	
Other (Bangladesh)	0.9	0.7, 1.2	0.5	0.1	0.1, 0.2	<0.001	0.9	0.7, 1.2	0.5
Household size									
1-2 persons	1.0	Reference		1.0	Reference		1.0	Reference	
3-5 persons	1.2	0.7, 2.1	0.6	1.4	0.8, 2.6	0.3	1.6	0.9, 3.2	0.13
6 or more	1.2	0.7, 2.1	0.6	1.8	1.0, 3.3	0.061	1.7	0.9, 3.3	0.10
Relationship to the household head									
Head	1.0	Reference		1.0	Reference		1.0	Reference	
Wife/ husband	0.8	0.6, 1.1	0.13	0.8	0.6, 1.1	0.11	0.7	0.5, 1.0	0.059
Son/ daughter	0.6	0.5, 0.9	0.003	1.1	0.8, 1.5	0.6	1.1	0.8, 1.5	0.6
Other	0.8	0.5, 1.0	0.090	0.7	0.5, 1.0	0.025	1.0	0.7, 1.4	>0.9

Table 6: Univariate logistic regression on participants' characteristics associated with reporting the three most reported major concerns in Bangladesh (i.e. Cost of healthcare, Household amenity-related risk, Work-related exposure to the natural environment) *(continued)*

	Cost of healthcare			Household-related risk: Amenity			Work-related risk: Exposure to nature		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Marital status									
Never/not currently married	1.0	Reference		1.0	Reference		1.0	Reference	
Currently married/cohabitating	1.5	1.1, 1.9	0.004	0.8	0.6, 1.1	0.2	0.9	0.7, 1.1	0.2
Education level									
Secondary school completed/ higher	1.0	Reference		1.0	Reference		1.0	Reference	
Never attended school	3.2	2.3, 4.5	<0.001	1.0	0.7, 1.4	>0.9	0.6	0.4, 0.8	<0.001
Primary school uncompleted	2.7	1.8, 4.0	<0.001	1.0	0.7, 1.5	0.8	0.5	0.3, 0.7	<0.001
Primary school completed	1.8	1.3, 2.6	<0.001	1.1	0.8, 1.6	0.5	0.8	0.6, 1.1	0.12
Work status									
Agriculture	1.0	Reference		1.0	Reference		1.0	Reference	
Labourer	0.9	0.6, 1.5	0.7	2.3	1.5, 3.8	<0.001	0.8	0.5, 1.3	0.3
Employee	0.4	0.3, 0.7	<0.001	1.4	0.9, 2.4	0.2	0.9	0.6, 1.5	0.7
Unpaid work	0.6	0.4, 0.8	0.004	2.5	1.6, 3.7	<0.001	1.0	0.7, 1.4	0.8
Don't work	0.7	0.4, 1.4	0.3	1.8	0.9, 3.5	0.079	0.9	0.5, 1.7	0.7
Wealth status									
Middle	1.0	Reference		1.0	Reference		1.0	Reference	
Poor	1.3	1.0, 1.8	0.080	2.3	1.7, 3.2	<0.001	1.0	0.7, 1.4	0.9

Table 6: Univariate logistic regression on participants' characteristics associated with reporting the three most reported major concerns in Bangladesh (i.e. Cost of healthcare, Household amenity-related risk, Work-related exposure to the natural environment) *(continued)*

	Cost of healthcare			Household-related risk: Amenity			Work-related risk: Exposure to nature		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Rich	0.6	0.4, 0.8	<0.001	1.1	0.8, 1.4	0.7	1.7	1.3, 2.3	<0.001

Abbreviations: CI = Confidence Interval, OR = Odds Ratio

Table 7: Univaraite logistic repgression on participants' characteristics associated with reporting the three most reported major concerns in Cambodia (i.e. Cost, safety and efficiency of healthcare)

	Healthcare: Cost			Healthcare: Efficacy			Healthcare: Safety		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Age groups									
15-29	1.0	Reference		1.0	Reference		1.0	Reference	
30-39	1.0	0.6, 1.6	>0.9	1.0	0.7, 1.5	>0.9	1.2	0.8, 1.7	0.3
40-49	1.6	0.9, 3.0	0.12	1.1	0.7, 1.7	0.7	1.0	0.7, 1.5	>0.9
50-59	0.6	0.4, 1.0	0.037	0.9	0.6, 1.3	0.5	1.2	0.8, 1.9	0.3
60+	0.7	0.4, 1.2	0.2	0.8	0.5, 1.2	0.3	1.0	0.7, 1.5	0.9
Sex									
Male	1.0	Reference		1.0	Reference		1.0	Reference	
Female	1.7	1.2, 2.4	0.001	1.8	1.4, 2.4	<0.001	1.6	1.3, 2.1	<0.001
Household size									
1-2 persons	1.0	Reference		1.0	Reference		1.0	Reference	
3-5 persons	1.8	1.0, 3.4	0.053	1.6	0.9, 2.7	0.12	1.0	0.6, 1.7	>0.9
6 or more	2.1	1.1, 3.9	0.028	1.8	1.0, 3.2	0.040	1.1	0.6, 1.9	0.8

Table 7: Univaraite logistic repgression on participants' characteristics associated with reporting the three most reported major concerns in Cambodia (i.e. Cost, safety and efficiency of healthcare) *(continued)*

	Healthcare: Cost			Healthcare: Efficacy			Healthcare: Safety		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Relationship to the household head									
Head	1.0	Reference		1.0	Reference		1.0	Reference	
Wife/ husband	1.3	0.8, 2.0	0.2	1.3	0.9, 1.8	0.2	1.2	0.9, 1.7	0.2
Son/ daughter	1.1	0.7, 1.7	0.8	1.0	0.7, 1.5	>0.9	0.9	0.6, 1.3	0.5
Other	0.9	0.6, 1.6	0.8	1.3	0.8, 1.9	0.3	1.0	0.7, 1.5	>0.9
Marital status									
Never/not currently married	1.0	Reference		1.0	Reference		1.0	Reference	
Currently married/cohabitating	1.5	1.0, 2.2	0.025	1.7	1.2, 2.2	0.001	1.6	1.2, 2.2	0.001
Education level									
Secondary school completed/ higher	1.0	Reference		1.0	Reference		1.0	Reference	
Never attended school	1.6	1.0, 2.6	0.071	1.2	0.8, 1.8	0.4	0.8	0.5, 1.2	0.3
Primary school uncompleted	1.7	1.1, 2.7	0.015	0.9	0.6, 1.3	0.5	0.8	0.6, 1.1	0.2
Primary school completed	1.4	0.8, 2.3	0.2	1.1	0.7, 1.6	0.7	0.7	0.5, 1.1	0.091
Work status									
Agriculture	1.0	Reference		1.0	Reference		1.0	Reference	
Labourer	2.2	1.1, 4.6	0.030	1.0	0.6, 1.5	0.8	0.8	0.5, 1.2	0.2

Table 7: Univaraite logistic repgression on participants' characteristics associated with reporting the three most reported major concerns in Cambodia (i.e. Cost, safety and efficiency of healthcare) *(continued)*

	Healthcare: Cost			Healthcare: Efficacy			Healthcare: Safety		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Employee	1	0.6, 1.6	0.8	1.6	1.0, 2.5	0.041	1.9	1.2, 2.8	0.003
Unpaid work	0.8	0.5, 1.2	0.3	1.1	0.8, 1.5	0.7	1.2	0.9, 1.7	0.2
Don't work	0.7	0.4, 1.6	0.4	1.4	0.7, 2.7	0.3	1.1	0.6, 2.1	0.7
Wealth status									
Middle	1.0	Reference		1.0	Reference		1.0	Reference	
Poor	1.4	0.8, 2.5	0.3	0.9	0.6, 1.5	0.8	1.3	0.8, 2.0	0.2
Rich	1.1	0.8, 1.6	0.6	1.2	0.9, 1.7	0.2	1.4	1.1, 1.9	0.021

Abbreviations: CI = Confidence Interval, OR = Odds Ratio

Table 8: Univariate logistic regression on participants' characteristics associated with reporting the three most reported major concerns in Thailand (i.e.Timeliness of healthcare, presence of disease, and work-related concern to chemical exposure)

	Healthcare: timeliness			Presence of disease			Work-related risk: chemical exposure		
Variables	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Age groups									
15-29	1.0	Reference		1.0	Reference		1.0	Reference	
30-39	1.5	0.9, 2.7	0.14	0.8	0.5, 1.5	0.5	2.8	1.3, 6.3	0.011
40-49	1.1	0.7, 1.9	0.7	0.7	0.4, 1.2	0.15	2.3	1.1, 5.1	0.026
50-59	0.8	0.5, 1.3	0.3	0.6	0.3, 1	0.029	1.9	0.9, 4.1	0.091
60+	0.6	0.4, 1.0	0.062	0.5	0.3, 0.8	0.005	0.9	0.5, 2.1	0.9
Sex									
Male	1.0	Reference		1.0	Reference		1.0	Reference	
Female	1.5	1.1, 2.0	0.007	1.5	1.1, 2.0	0.016	0.6	0.4, 0.9	0.006

D

Appendix D for Chapter 4

Appendix D: Appendix for Chapter 4

Table 1: Participants' characteristics associated with self-reported fever in the past 30 days before the survey. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value.

	Bangladesh			Cambodia			Thailand
Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq
Age groups							
0-4	100 (38.2%)	Reference		34 (17.3%)	Reference		1 (1.5%)
5-14	72 (17.6%)	0.2 (0.1,0.3)	<0.001	33 (8.4%)	0.2 (0.1,0.5)	<0.001	7 (3.3%)
15-29	65 (12.1%)	0.2 (0.1,0.2)	<0.001	5 (1.5%)	0.0 (0.0,0.1)	<0.001	0 (0.0%)
30-49	64 (14.1%)	0.2 (0.1,0.3)	<0.001	18 (4.4%)	0.1 (0.0,0.2)	<0.001	1 (0.3%)
50+	27 (10.5%)	0.1 (0.1,0.2)	<0.001	12 (3.6%)	0.1 (0.0,0.3)	<0.001	5 (0.6%)
Sex							
Male	156 (17.7%)	Reference		61 (7.2%)	Reference		8 (1.1%)
Female	172 (16.6%)	0.9 (0.7,1.2)	0.542	41 (5.1%)	0.7 (0.4,1.1)	0.106	6 (0.7%)
Season							
Dry season	83 (17.7%)	Reference		24 (5.4%)	Reference		5 (0.4%)
Rainy season	245 (16.9%)	0.9 (0.6,1.4)	0.658	78 (6.4%)	1.0 (0.4,2.5)	0.985	9 (2.5%)
Ethnicity (Bangladesh)							
Bengali	298 (18.5%)	Reference		–	–	–	–
Other (Bangladesh)	30 (9.7%)	0.4 (0.2,0.7)	0.001	–	–	–	–

Table 1: Participants' characteristics associated with self-reported fever in the past 30 days before the survey. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value. *(continued)*

	Bangladesh			Cambodia			Thailand
Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq
Ethnicity (Thailand)							
Thai	–	–	–	–	–	–	3 (0.4%)
Akha	–	–	–	–	–	–	9 (3.7%)
Lahu	–	–	–	–	–	–	1 (0.6%)
Other (Thailand)	–	–	–	–	–	–	1 (0.3%)
Household wealth status							
Middle	77 (14.3%)	Reference		36 (7.6%)	Reference		7 (1.4%)
Poor	117 (21.0%)	1.8 (1.1,2.9)	0.019	10 (4.0%)	0.5 (0.1,1.8)	0.297	2 (0.4%)
Rich	134 (16.2%)	1.2 (0.7,1.9)	0.493	56 (6.0%)	0.7 (0.3,1.7)	0.415	5 (0.9%)
District (Bangladesh)							
Bandarban	61 (12.4%)	Reference		–	–	–	–
Chakaria	116 (17.5%)	1.6 (1.0,2.7)	0.062	–	–	–	–
Ukhiya	151 (19.7%)	2.0 (1.2,3.3)	0.004	–	–	–	–
District (Cambodia)							
Pailin	–	–	–	18 (4.0%)	Reference		–
Koas Krala	–	–	–	15 (3.5%)	0.7 (0.2,2.3)	0.540	–
Rukhakiri	–	–	–	25 (14.4%)	6.9 (1.9,25.2)	0.003	–
Samlot	–	–	–	44 (7.2%)	1.9 (0.7,5.2)	0.236	–
District (Thailand)							
Muang	–	–	–	–	–	–	2 (0.9%)
Chiang Khong	–	–	–	–	–	–	3 (1.2%)
Khun Tan	–	–	–	–	–	–	0 (0.0%)
Mae Suai	–	–	–	–	–	–	9 (1.5%)
Wiang Kean	–	–	–	–	–	–	0 (0.0%)

Table 2: Characteristics of fever episodes, by source of first care sought.

Variables	Bangladesh					Cambodia				
	No care N = 72	**Public** N = 47	**Private** N = 99	**Self-med/ Other** N = 137	**p-value**	**No care** N = 14	**Public** N = 14	**Private** N = 68	**Self-med/ Other** N = 5	**p-value**
Age					0.7					0.025
0-4	21 (18.6%)	16 (14.2%)	34 (30.1%)	42 (37.2%)		3 (8.8%)	9 (26.5%)	21 (61.8%)	1 (2.9%)	
5-14	19 (25.3%)	6 (8.0%)	20 (26.7%)	30 (40.0%)		4 (12.1%)	4 (12.1%)	21 (63.6%)	4 (12.1%)	
15+	32 (19.2%)	25 (15.0%)	45 (26.9%)	65 (38.9%)		7 (20.6%)	1 (2.9%)	26 (76.5%)	0 (0.0%)	
Sex					0.012					0.4
Male	25 (14.8%)	17 (10.1%)	53 (31.4%)	74 (43.8%)		6 (9.8%)	8 (13.1%)	43 (70.5%)	4 (6.6%)	
Female	47 (25.3%)	30 (16.1%)	46 (24.7%)	63 (33.9%)		8 (20.0%)	6 (15.0%)	25 (62.5%)	1 (2.5%)	
Severity of the episode					<0.001					<0.001
Serious	0 (0.0%)	13 (31.0%)	16 (38.1%)	13 (31.0%)		0 (0.0%)	4 (26.7%)	11 (73.3%)	0 (0.0%)	
Moderate	30 (14.4%)	31 (14.9%)	72 (34.6%)	75 (36.1%)		1 (2.3%)	5 (11.6%)	37 (86.0%)	0 (0.0%)	
Slight	42 (40.0%)	3 (2.9%)	11 (10.5%)	49 (46.7%)		13 (30.2%)	5 (11.6%)	20 (46.5%)	5 (11.6%)	
Fever and concomitant conditions					<0.001					<0.001
Fever only	19 (28.8%)	12 (18.2%)	4 (6.1%)	31 (47.0%)		8 (33.3%)	6 (25.0%)	7 (29.2%)	3 (12.5%)	
Fever with other symptoms	53 (18.3%)	35 (12.1%)	95 (32.9%)	106 (36.7%)		6 (7.8%)	8 (10.4%)	61 (79.2%)	2 (2.6%)	
Household size					0.060					0.014
1-2 persons	1 (7.1%)	5 (35.7%)	2 (14.3%)	6 (42.9%)		1 (33.3%)	0 (0.0%)	1 (33.3%)	1 (33.3%)	
3-5 persons	24 (17.1%)	13 (9.3%)	46 (32.9%)	57 (40.7%)		8 (13.1%)	4 (6.6%)	47 (77.0%)	2 (3.3%)	
6 or more	47 (23.4%)	29 (14.4%)	51 (25.4%)	74 (36.8%)		5 (13.5%)	10 (27.0%)	20 (54.1%)	2 (5.4%)	
Household wealth status					0.6					0.10
Poor	27 (21.6%)	15 (12.0%)	38 (30.4%)	45 (36.0%)		2 (22.2%)	1 (11.1%)	4 (44.4%)	2 (22.2%)	

Table 2: Characteristics of fever episodes, by source of first care sought. *(continued)*

Variables	Bangladesh					Cambodia				
	No care N = 72	**Public** N = 47	**Private** N = 99	**Self-med/ Other** N = 137	**p-value**	**No care** N = 14	**Public** N = 14	**Private** N = 68	**Self-med/ Other** N = 5	**p-value**
Middle	21 (24.4%)	13 (15.1%)	23 (26.7%)	29 (33.7%)		2 (5.6%)	7 (19.4%)	26 (72.2%)	1 (2.8%)	
Rich	24 (16.7%)	19 (13.2%)	38 (26.4%)	63 (43.8%)		10 (17.9%)	6 (10.7%)	38 (67.9%)	2 (3.6%)	
District (Bangladesh)					<0.001					
Bandarban	13 (17.6%)	12 (16.2%)	3 (4.1%)	46 (62.2%)						
Chakaria	37 (30.6%)	14 (11.6%)	12 (9.9%)	58 (47.9%)						
Ukhiya	22 (13.8%)	21 (13.1%)	84 (52.5%)	33 (20.6%)						
District (Cambodia)										<0.001
Koas Krala						1 (6.7%)	5 (33.3%)	8 (53.3%)	1 (6.7%)	
Pailin						9 (50.0%)	1 (5.6%)	4 (22.2%)	4 (22.2%)	
Rukhakiri						1 (4.2%)	3 (12.5%)	20 (83.3%)	0 (0.0%)	
Samlot						3 (6.8%)	5 (11.4%)	36 (81.8%)	0 (0.0%)	
Ethnicity					<0.001					
Bengali	65 (20.3%)	43 (13.4%)	99 (30.9%)	113 (35.3%)						
Other (Bangladesh)	7 (20.0%)	4 (11.4%)	0 (0.0%)	24 (68.6%)						
Season					0.4					0.8
Dry season	17 (20.2%)	13 (15.5%)	28 (33.3%)	26 (31.0%)		3 (13.0%)	4 (17.4%)	16 (69.6%)	0 (0.0%)	
Rainy season	55 (20.3%)	34 (12.5%)	71 (26.2%)	111 (41.0%)		11 (14.1%)	10 (12.8%)	52 (66.7%)	5 (6.4%)	

[1] n (%)

[2] Pearson's Chi-squared test; Fisher's exact test

[3] Fisher's exact test

Table 2: Characteristics of fever episodes, by source of first care sought. *(continued)*

Variables	Bangladesh					Cambodia				
	No care N = 72	**Public** N = 47	**Private** N = 99	**Self-med/ Other** N = 137	**p-value**	**No care** N = 14	**Public** N = 14	**Private** N = 68	**Self-med/ Other** N = 5	**p-value**

Note:
One episdoe in Cambodia reported with unknown severity was excluded
* Public: Public care (& NGO clinic)
† Private: Private care
‡ Self-med/ Other: Self-bought medicine/ other

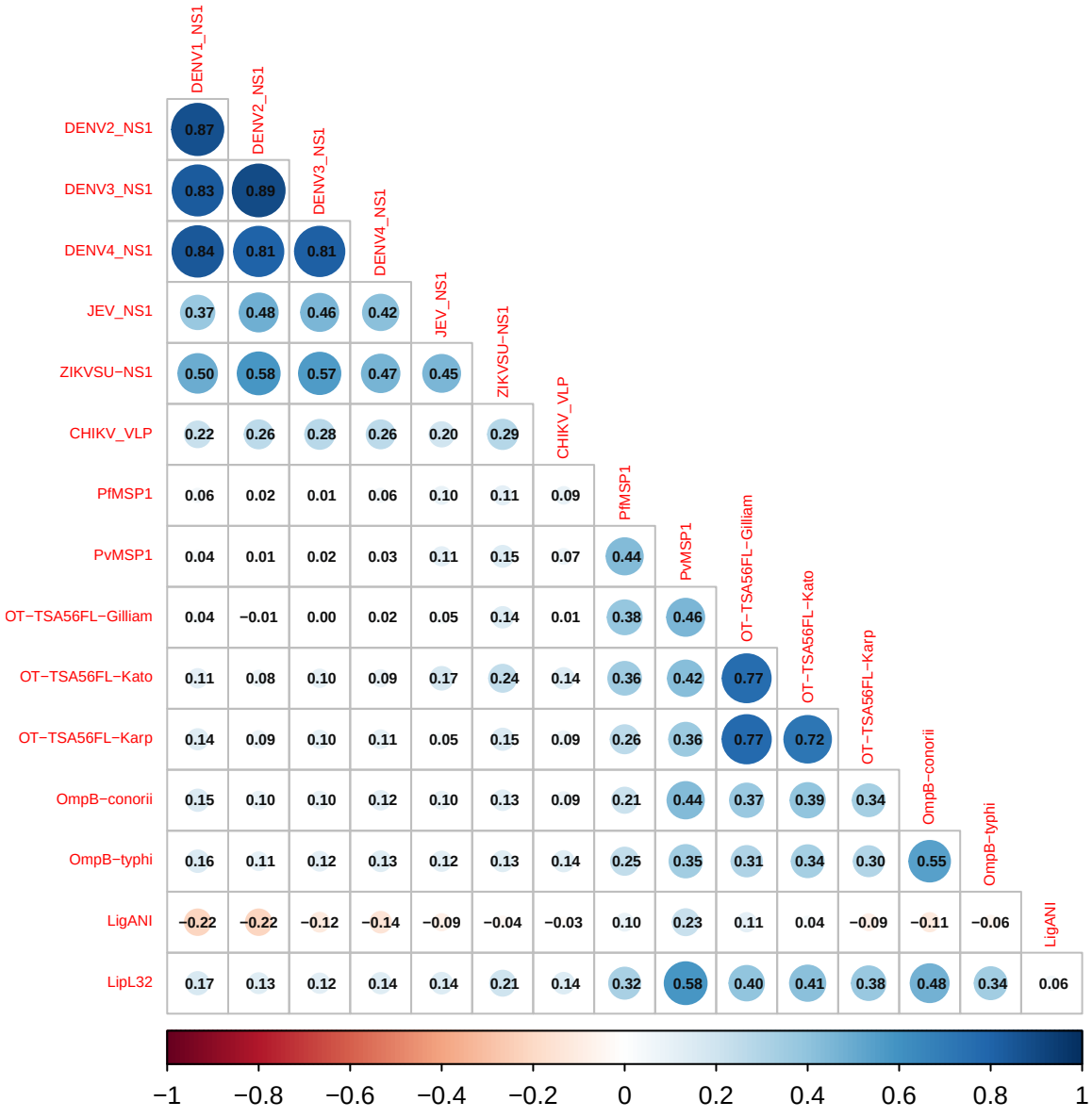


Figure 1: Pearson's correlation of MFI of antigens among participants under 15

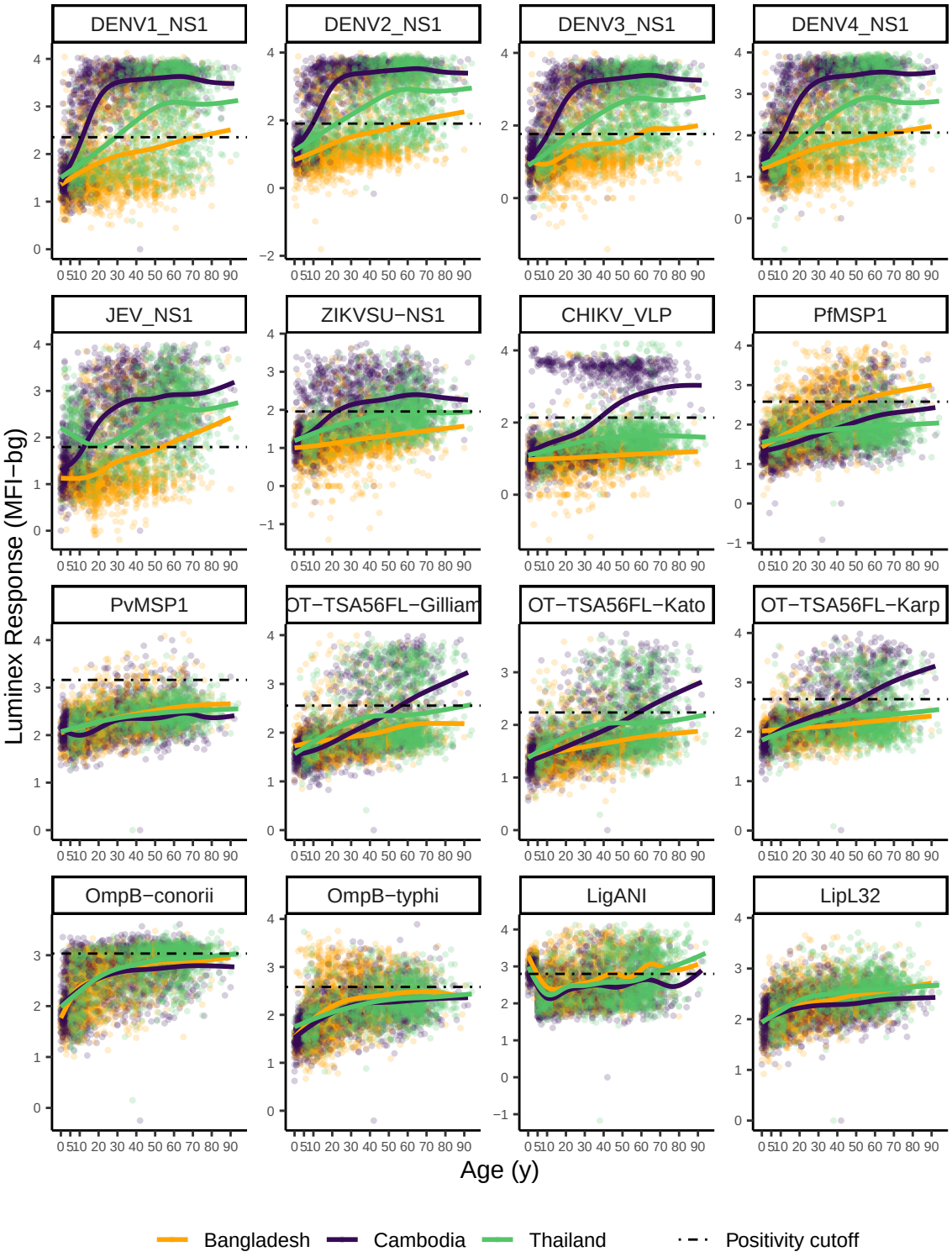


Figure 2: MFI distribution by age. The vertical lines are the seropositivity cutoff value determined by the mixture model for each antigen

Table 3: Seroprevalence, by age and site

			Age groups									
Pathogen	Overall	95% CI	0-4	95% CI	15-29	95% CI	30-49	95% CI	5-14	95% CI	50+	95% CI
Bangladesh												
DENV1-4	471 (27.6)	25.5- 29.7	15 (7.4)	4.17- 11.8	132 (27.3)	23.4- 31.5	160 (37.9)	33.3- 42.7	56 (15.2)	11.7- 19.3	108 (46.8)	40.2- 53.4
JEV	347 (20.3)	18.4- 22.3	4 (2.0)	0.54- 4.94	81 (16.7)	13.5- 20.4	137 (32.5)	28.0- 37.2	25 (6.8)	4.44- 9.87	100 (43.3)	36.8- 49.9
ZIKAV	112 (6.6)	5.43- 7.83	3 (1.5)	0.30- 4.24	32 (6.6)	4.57- 9.21	46 (10.9)	8.09- 14.3	4 (1.1)	0.30- 2.76	27 (11.7)	7.85- 16.5
CHIKV	29 (1.7)	1.14- 2.43	1 (0.5)	0.01- 2.70	9 (1.9)	0.85- 3.50	11 (2.6)	1.31- 4.62	1 (0.3)	<0.01- 1.50	7 (3.0)	1.23- 6.14
P. falciparum	413 (24.2)	22.2- 26.3	4 (2.0)	0.54- 4.94	82 (16.9)	13.7- 20.6	175 (41.5)	36.7- 46.3	24 (6.5)	4.22- 9.55	128 (55.4)	48.8- 61.9
P. vivax	55 (3.2)	2.43- 4.17	0 (0.0)	0- 1.79	8 (1.7)	0.72- 3.23	24 (5.7)	3.68- 8.34	2 (0.5)	0.07- 1.95	21 (9.1)	5.72- 13.6
O. tsutsugamushi	157 (9.2)	7.86- 10.7	1 (0.5)	0.01- 2.70	30 (6.2)	4.22- 8.73	51 (12.1)	9.13- 15.6	24 (6.5)	4.22- 9.55	51 (22.1)	16.9- 28.0
Rickesttia spp.	622 (36.4)	34.1- 38.7	7 (3.4)	1.39- 6.94	177 (36.6)	32.3- 41.0	227 (53.8)	48.9- 58.6	75 (20.4)	16.4- 24.9	136 (58.9)	52.2- 65.3
Leptospira spp.	604 (35.3)	33.1- 37.7	180 (88.2)	83.0- 92.3	99 (20.5)	16.9- 24.3	160 (37.9)	33.3- 42.7	55 (14.9)	11.5- 19.0	110 (47.6)	41.0- 54.3
Cambodia												
DENV1-4	1,097 (75.3)	73.0- 77.5	22 (12.1)	7.73- 17.7	235 (92.9)	89.0- 95.7	356 (98.9)	97.2- 99.7	177 (50.0)	44.7- 55.3	307 (100.0)	98.8- 100.0
JEV	957 (65.7)	63.2- 68.2	28 (15.4)	10.5- 21.5	179 (70.8)	64.7- 76.3	332 (92.2)	89.0- 94.8	121 (34.2)	29.2- 39.4	297 (96.7)	94.1- 98.4
ZIKAV	654 (44.9)	42.3- 47.5	16 (8.8)	5.11- 13.9	122 (48.2)	41.9- 54.6	216 (60.0)	54.7- 65.1	69 (19.5)	15.5- 24.0	231 (75.2)	70.0- 80.0
CHIKV	485 (33.3)	30.9- 35.8	10 (5.5)	2.67- 9.87	49 (19.4)	14.7- 24.8	153 (42.5)	37.3- 47.8	47 (13.3)	9.92- 17.3	226 (73.6)	68.3- 78.5
P. falciparum	163 (11.2)	9.62- 12.9	0 (0.0)	0- 2.01	11 (4.3)	2.19- 7.65	51 (14.2)	10.7- 18.2	4 (1.1)	0.31- 2.87	97 (31.6)	26.4- 37.1
P. vivax	37 (2.5)	1.80- 3.49	0 (0.0)	0- 2.01	5 (2.0)	0.64- 4.55	13 (3.6)	1.94- 6.10	0 (0.0)	0- 1.04	19 (6.2)	3.77- 9.50

Table 3: Seroprevalence, by age and site *(continued)*

Pathogen	Overall	95% CI	0-4	95% CI	15-29	95% CI	30-49	95% CI	5-14	95% CI	50+	95% CI
O. tsutsugamushi	368 (25.3)	23.1- 27.6	0 (0.0)	0- 2.01	39 (15.4)	11.2- 20.5	118 (32.8)	27.9- 37.9	8 (2.3)	0.98- 4.40	203 (66.1)	60.5- 71.4
Rickesttia spp.	356 (24.5)	22.3- 26.7	5 (2.7)	0.90- 6.29	47 (18.6)	14.0- 23.9	138 (38.3)	33.3- 43.6	39 (11.0)	7.95- 14.8	127 (41.4)	35.8- 47.1
Leptospira spp.	382 (26.2)	24.0- 28.6	119 (65.4)	58.0- 72.3	44 (17.4)	12.9- 22.6	96 (26.7)	22.2- 31.6	24 (6.8)	4.39- 9.92	99 (32.2)	27.0- 37.8
Thailand												
DENV1-4	985 (70.1)	67.6- 72.4	5 (9.8)	3.26- 21.4	53 (46.1)	36.8- 55.6	259 (78.0)	73.2- 82.4	26 (16.1)	10.8- 22.8	642 (85.9)	83.2- 88.4
JEV	1,076 (76.5)	74.2- 78.7	34 (66.7)	52.1- 79.2	54 (47.0)	37.6- 56.5	230 (69.3)	64.0- 74.2	98 (60.9)	52.9- 68.5	660 (88.4)	85.8- 90.6
ZIKAV	456 (32.4)	30.0- 34.9	0 (0.0)	0- 6.98	21 (18.3)	11.7- 26.5	111 (33.4)	28.4- 38.8	9 (5.6)	2.59- 10.3	315 (42.2)	38.6- 45.8
CHIKV	87 (6.2)	4.99- 7.58	1 (2.0)	0.05- 10.4	2 (1.7)	0.21- 6.14	20 (6.0)	3.72- 9.15	1 (0.6)	0.02- 3.41	63 (8.4)	6.54- 10.7
P. falciparum	83 (5.9)	4.73- 7.27	0 (0.0)	0- 6.98	2 (1.7)	0.21- 6.14	19 (5.7)	3.48- 8.79	3 (1.9)	0.39- 5.35	59 (7.9)	6.07- 10.1
P. vivax	10 (0.7)	0.34- 1.30	0 (0.0)	0- 6.98	0 (0.0)	0- 3.16	2 (0.6)	0.07- 2.16	0 (0.0)	0- 2.27	8 (1.1)	0.46- 2.10
O. tsutsugamushi	418 (29.7)	27.3- 32.2	1 (2.0)	0.05- 10.4	21 (18.3)	11.7- 26.5	118 (35.5)	30.4- 41.0	10 (6.2)	3.02- 11.1	268 (35.9)	32.4- 39.4
Rickesttia spp.	625 (44.5)	41.8- 47.1	1 (2.0)	0.05- 10.4	38 (33.0)	24.6- 42.4	148 (44.6)	39.2- 50.1	22 (13.7)	8.77- 20.0	416 (55.7)	52.0- 59.3
Leptospira spp.	530 (37.7)	35.2- 40.3	44 (86.3)	73.7- 94.3	32 (27.8)	19.9- 37.0	109 (32.8)	27.8- 38.2	19 (11.8)	7.26- 17.8	326 (43.6)	40.0- 47.3

[1] n (%)

Abbreviations: CI = Confidence Interval, NA

Table 4: Participants' characteristics associated with seropositivity of dengue, Japanese encephalitis, Zika, and chikungunya in Bangladesh Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value.

	DENV			JEV			ZIKAV			CHIKV		
Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Sex												
Male	256 (34.1%)	Reference		183 (24.4%)	Reference		71 (9.5%)	Reference		13 (1.7%)	Reference	
Female	215 (22.4%)	0.5 (0.4,0.6)	<0.001	164 (17.1%)	0.6 (0.4,0.7)	<0.001	41 (4.3%)	0.4 (0.2,0.6)	<0.001	16 (1.7%)	0.9 (0.4,2.1)	0.850
Ethnicity												
Bengali	360 (24.8%)	Reference		188 (12.9%)	Reference		77 (5.3%)	Reference		15 (1.0%)	Reference	
Other (Bangladesh)	111 (43.4%)	2.6 (1.8,3.9)	<0.001	159 (62.1%)	11.2 (8.1,15.5)	<0.001	35 (13.7%)	3.3 (1.9,5.9)	<0.001	14 (5.5%)	7.5 (2.5,22.3)	<0.001
Season												
Dry season	127 (28.7%)	Reference		48 (10.9%)	Reference		23 (5.2%)	Reference		9 (2.0%)	Reference	
Rainy season	344 (27.2%)	1.0 (0.7,1.5)	0.818	299 (23.6%)	3.2 (2.0,5.0)	<0.001	89 (7.0%)	1.5 (0.8,2.8)	0.177	20 (1.6%)	0.8 (0.3,2.6)	0.725
Household wealth status												
Middle	136 (28.5%)	Reference		142 (29.7%)	Reference		33 (6.9%)	Reference		4 (0.8%)	Reference	
Rich	230 (31.4%)	1.2 (0.8,1.7)	0.401	149 (20.4%)	0.6 (0.4,0.9)	0.013	61 (8.3%)	1.2 (0.7,2.2)	0.448	18 (2.5%)	3.8 (0.9,16.6)	0.073
Poor	105 (21.0%)	0.6 (0.4,0.9)	0.020	56 (11.2%)	0.2 (0.1,0.4)	<0.001	18 (3.6%)	0.5 (0.2,1.0)	0.041	7 (1.4%)	2.0 (0.4,10.3)	0.395
District												
Ukhiya	135 (20.8%)	Reference		58 (9.0%)	Reference		18 (2.8%)	Reference		3 (0.5%)	Reference	

Table 4: Participants' characteristics associated with seropositivity of dengue, Japanese encephalitis, Zika, and chikungunya in Bangladesh Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value. *(continued)*

Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Bandarban	156 (37.5%)	2.7 (1.8,3.9)	<0.001	207 (49.8%)	11.0 (7.6,15.9)	<0.001	50 (12.0%)	5.7 (2.9,11.1)	<0.001	16 (3.8%)	11.4 (2.4,53.7)	0.002
Chakaria	180 (27.9%)	1.6 (1.1,2.3)	0.011	82 (12.7%)	1.5 (1.0,2.2)	0.032	44 (6.8%)	2.9 (1.5,5.6)	0.002	10 (1.6%)	4.0 (0.8,19.2)	0.084

Table 5: Participants' characteristics associated with seropositivity of O. tsutsugamushi, Rickettsia, Leptospira, and P falciparum in Bangladesh. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value.

	O. tsutsugamushi			Rickittsia			Leptospira			P. falciparum		
Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Sex												
Male	63 (8.4%)	Reference		264 (35.2%)	Reference		321 (42.8%)	Reference		218 (29.1%)	Reference	
Female	94 (9.8%)	1.2 (0.8,1.7)	0.345	358 (37.3%)	1.1 (0.9,1.3)	0.364	283 (29.5%)	0.5 (0.4,0.6)	<0.001	195 (20.3%)	0.6 (0.5,0.8)	<0.001
Ethnicity												
Bengali	123 (8.5%)	Reference		536 (36.9%)	Reference		423 (29.1%)	Reference		269 (18.5%)	Reference	
Other (Bangladesh)	34 (13.3%)	1.7 (1.1,2.7)	0.028	86 (33.6%)	0.9 (0.7,1.2)	0.322	181 (70.7%)	6.0 (4.4,8.1)	<0.001	144 (56.2%)	5.7 (4.3,7.5)	<0.001
Season												
Dry season	35 (7.9%)	Reference		171 (38.7%)	Reference		120 (27.1%)	Reference		71 (16.1%)	Reference	
Rainy season	122 (9.6%)	1.3 (0.8,2.0)	0.287	451 (35.6%)	0.9 (0.7,1.1)	0.260	484 (38.2%)	1.7 (1.3,2.3)	<0.001	342 (27.0%)	2.1 (1.5,2.9)	<0.001

Table 5: Participants' characteristics associated with seropositivity of O. tsutsugamushi, Rickettsia, Leptospira, and P falciparum in Bangladesh. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value. *(continued)*

Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Household wealth status												
Middle	45 (9.4%)	Reference		168 (35.1%)	Reference		206 (43.1%)	Reference		161 (33.7%)	Reference	
Rich	74 (10.1%)	1.1 (0.7,1.7)	0.764	282 (38.5%)	1.2 (0.9,1.5)	0.237	239 (32.7%)	0.6 (0.5,0.8)	0.002	169 (23.1%)	0.6 (0.4,0.8)	<0.001
Poor	38 (7.6%)	0.8 (0.5,1.3)	0.324	172 (34.5%)	1.0 (0.7,1.3)	0.815	159 (31.9%)	0.6 (0.4,0.8)	0.001	83 (16.6%)	0.4 (0.3,0.5)	<0.001
District												
Ukhiya	48 (7.4%)	Reference		231 (35.6%)	Reference		153 (23.6%)	Reference		122 (18.8%)	Reference	
Bandarban	48 (11.5%)	1.7 (1.0,2.7)	0.038	139 (33.4%)	0.9 (0.7,1.2)	0.470	239 (57.5%)	4.5 (3.4,6.0)	<0.001	193 (46.4%)	3.8 (2.8,5.1)	<0.001
Chakaria	61 (9.5%)	1.3 (0.9,2.1)	0.198	252 (39.1%)	1.2 (0.9,1.5)	0.203	212 (32.9%)	1.6 (1.2,2.1)	<0.001	98 (15.2%)	0.8 (0.6,1.0)	0.091

Table 6: Participants' characteristics associated with seropositivity of dengue, Japanese encephalitis, Zika, and chikungunya in Cambodia. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value.

	DENV			JEV			ZIKAV			CHIKV		
Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Sex												
Male	526 (73.2%)	Reference		459 (63.8%)	Reference		308 (42.8%)	Reference		237 (33.0%)	Reference	
Female	571 (77.5%)	1.3 (1.0,1.6)	0.056	498 (67.6%)	1.2 (1.0,1.5)	0.111	346 (46.9%)	1.2 (1.0,1.6)	0.054	248 (33.6%)	1.1 (0.9,1.4)	0.493

Table 6: Participants' characteristics associated with seropositivity of dengue, Japanese encephalitis, Zika, and chikungunya in Cambodia. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value. *(continued)*

Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Season												
Dry season	319 (76.9%)	Reference		269 (64.8%)	Reference		185 (44.6%)	Reference		139 (33.5%)	Reference	
Rainy season	778 (74.7%)	0.9 (0.7,1.2)	0.394	688 (66.1%)	1.1 (0.8,1.4)	0.694	469 (45.1%)	1.0 (0.8,1.4)	0.799	346 (33.2%)	1.1 (0.8,1.5)	0.704
Household wealth status												
Middle	302 (74.2%)	Reference		270 (66.3%)	Reference		176 (43.2%)	Reference		119 (29.2%)	Reference	
Rich	645 (78.4%)	1.3 (1.0,1.7)	0.102	559 (67.9%)	1.1 (0.8,1.4)	0.576	401 (48.7%)	1.3 (0.9,1.7)	0.132	314 (38.2%)	1.7 (1.2,2.4)	0.007
Poor	150 (66.4%)	0.7 (0.5,1.0)	0.037	128 (56.6%)	0.7 (0.5,0.9)	0.020	77 (34.1%)	0.7 (0.4,1.0)	0.052	52 (23.0%)	0.7 (0.4,1.1)	0.117
District												
Pailin	295 (79.7%)	Reference		231 (62.4%)	Reference		191 (51.6%)	Reference		165 (44.6%)	Reference	
Samlot	434 (77.9%)	0.9 (0.6,1.2)	0.510	384 (68.9%)	1.3 (1.0,1.8)	0.052	268 (48.1%)	0.9 (0.6,1.2)	0.471	154 (27.6%)	0.4 (0.3,0.6)	<0.001
Koas Krala	264 (71.2%)	0.6 (0.4,0.9)	0.007	236 (63.6%)	1.0 (0.8,1.4)	0.771	143 (38.5%)	0.6 (0.4,0.8)	0.003	132 (35.6%)	0.6 (0.4,0.9)	0.024
Rukhakiri	104 (65.8%)	0.5 (0.3,0.7)	<0.001	106 (67.1%)	1.2 (0.8,1.8)	0.350	52 (32.9%)	0.4 (0.3,0.7)	<0.001	34 (21.5%)	0.3 (0.2,0.5)	<0.001

Table 7: Participants' characteristics associated with seropositivity of O. tsutsugamushi, Rickettsia, and Leptospira in Cambodia. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value.

	O. tsutsugamushi			Rickittsia			Leptospira		
Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Sex									
Male	193 (26.8%)	Reference		168 (23.4%)	Reference		227 (31.6%)	Reference	
Female	175 (23.7%)	0.8 (0.7,1.1)	0.174	188 (25.5%)	1.2 (0.9,1.5)	0.249	155 (21.0%)	0.6 (0.4,0.7)	<0.001
Season									
Dry season	95 (22.9%)	Reference		68 (16.4%)	Reference		98 (23.6%)	Reference	
Rainy season	273 (26.2%)	1.2 (0.9,1.6)	0.187	288 (27.7%)	2.1 (1.5,3.1)	<0.001	284 (27.3%)	1.2 (0.9,1.7)	0.147
Household wealth status									
Middle	111 (27.3%)	Reference		98 (24.1%)	Reference		99 (24.3%)	Reference	
Rich	210 (25.5%)	0.9 (0.7,1.2)	0.509	219 (26.6%)	1.2 (0.8,1.7)	0.425	222 (27.0%)	1.2 (0.9,1.6)	0.324
Poor	47 (20.8%)	0.7 (0.5,1.0)	0.072	39 (17.3%)	0.6 (0.4,1.0)	0.069	61 (27.0%)	1.2 (0.8,1.8)	0.499
District									
Pailin	91 (24.6%)	Reference		41 (11.1%)	Reference		88 (23.8%)	Reference	
Samlot	150 (26.9%)	1.1 (0.8,1.5)	0.427	180 (32.3%)	4.3 (2.8,6.7)	<0.001	191 (34.3%)	1.7 (1.2,2.4)	0.001
Koas Krala	94 (25.3%)	1.0 (0.7,1.5)	0.815	95 (25.6%)	2.9 (1.8,4.7)	<0.001	63 (17.0%)	0.7 (0.4,1.0)	0.032
Rukhakiri	33 (20.9%)	0.8 (0.5,1.3)	0.358	40 (25.3%)	2.9 (1.6,5.1)	<0.001	40 (25.3%)	1.1 (0.7,1.7)	0.714

Table 8: Participants' characteristics associated with seropositivity of dengue, Japanese encephalitis, Zika, and chikungunya in Thailand. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value.

	DENV			JEV			ZIKAV			CHIKV		
Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Sex												

Table 8: Participants' characteristics associated with seropositivity of dengue, Japanese encephalitis, Zika, and chikungunya in Thailand. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value. *(continued)*

Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Male	406 (67.4%)	Reference		479 (79.6%)	Reference		200 (33.2%)	Reference		38 (6.3%)	Reference	
Female	579 (72.0%)	1.2 (0.9,1.6)	0.240	597 (74.3%)	0.7 (0.5,0.9)	0.011	256 (31.8%)	0.9 (0.7,1.2)	0.382	49 (6.1%)	1.0 (0.6,1.5)	0.921
Ethnicity												
Thai	648 (86.5%)	Reference		656 (87.6%)	Reference		345 (46.1%)	Reference		58 (7.7%)	Reference	
Lahu	85 (55.9%)	0.2 (0.1,0.3)	<0.001	112 (73.7%)	0.4 (0.2,0.6)	<0.001	31 (20.4%)	0.3 (0.2,0.4)	<0.001	8 (5.3%)	0.7 (0.3,1.5)	0.329
Akha	108 (52.2%)	0.1 (0.1,0.2)	<0.001	130 (62.8%)	0.2 (0.1,0.3)	<0.001	32 (15.5%)	0.2 (0.1,0.3)	<0.001	7 (3.4%)	0.4 (0.2,1.0)	0.038
Other (Thailand)	144 (48.3%)	0.1 (0.1,0.2)	<0.001	178 (59.7%)	0.2 (0.1,0.3)	<0.001	48 (16.1%)	0.2 (0.1,0.3)	<0.001	14 (4.7%)	0.6 (0.3,1.1)	0.114
Season												
Dry season	800 (74.2%)	Reference		867 (80.4%)	Reference		386 (35.8%)	Reference		72 (6.7%)	Reference	
Rainy season	185 (56.4%)	0.3 (0.2,0.5)	<0.001	209 (63.7%)	0.4 (0.3,0.6)	<0.001	70 (21.3%)	0.5 (0.3,0.7)	<0.001	15 (4.6%)	0.7 (0.4,1.2)	0.205
Household wealth status												
Middle	291 (69.0%)	Reference		307 (72.7%)	Reference		125 (29.6%)	Reference		24 (5.7%)	Reference	
Rich	395 (79.3%)	1.8 (1.1,3.0)	0.017	392 (78.7%)	1.3 (0.9,2.0)	0.176	209 (42.0%)	1.9 (1.3,2.9)	0.001	34 (6.8%)	1.2 (0.7,2.2)	0.536
Poor	299 (61.5%)	0.6 (0.4,1.0)	0.055	377 (77.6%)	1.2 (0.8,1.8)	0.377	122 (25.1%)	0.8 (0.5,1.2)	0.232	29 (6.0%)	1.1 (0.6,2.0)	0.864
District												
Muang	106 (55.8%)	Reference		127 (66.8%)	Reference		36 (18.9%)	Reference		14 (7.4%)	Reference	

Table 8: Participants' characteristics associated with seropositivity of dengue, Japanese encephalitis, Zika, and chikungunya in Thailand. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value. *(continued)*

Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Chiang Khong	185 (85.6%)	5.8 (3.2,10.6)	<0.001	188 (87.0%)	3.8 (2.1,6.8)	<0.001	101 (46.8%)	4.2 (2.5,7.1)	<0.001	15 (6.9%)	0.9 (0.4,2.1)	0.849
Khun Tan	303 (93.8%)	14.9 (7.7,28.7)	<0.001	293 (90.7%)	5.5 (3.1,9.9)	<0.001	173 (53.6%)	5.5 (3.4,9.2)	<0.001	26 (8.0%)	1.1 (0.5,2.3)	0.867
Mae Suai	310 (60.1%)	1.3 (0.8,2.0)	0.277	366 (70.9%)	1.2 (0.8,1.9)	0.358	123 (23.8%)	1.4 (0.9,2.3)	0.154	27 (5.2%)	0.7 (0.3,1.4)	0.321
Wiang Kean	81 (50.3%)	0.8 (0.5,1.5)	0.546	102 (63.4%)	0.9 (0.5,1.5)	0.609	23 (14.3%)	0.7 (0.4,1.3)	0.290	5 (3.1%)	0.4 (0.1,1.2)	0.097

Table 9: Participants' characteristics associated with seropositivity of O. tsutsugamushi, Rickettsia, and Leptospira in Thailand. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value.

	O. tsutsugamushi			Rickittsia			Leptospira		
Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Sex									
Male	202 (33.6%)	Reference		266 (44.2%)	Reference		294 (48.8%)	Reference	
Female	216 (26.9%)	0.7 (0.5,0.9)	0.005	359 (44.7%)	1.0 (0.8,1.3)	0.992	236 (29.4%)	0.4 (0.3,0.5)	<0.001
Ethnicity									
Thai	110 (14.7%)	Reference		388 (51.8%)	Reference		249 (33.2%)	Reference	
Lahu	80 (52.6%)	8.8 (5.2,14.8)	<0.001	62 (40.8%)	0.6 (0.4,1.0)	0.031	80 (52.6%)	2.4 (1.5,3.7)	<0.001
Akha	100 (48.3%)	7.4 (4.6,12.0)	<0.001	66 (31.9%)	0.4 (0.3,0.6)	<0.001	95 (45.9%)	1.8 (1.2,2.7)	0.003
Other (Thailand)	128 (43.0%)	6.0 (3.9,9.2)	<0.001	109 (36.6%)	0.5 (0.4,0.7)	<0.001	106 (35.6%)	1.1 (0.7,1.5)	0.710
Season									
Dry season	304 (28.2%)	Reference		507 (47.0%)	Reference		416 (38.6%)	Reference	
Rainy season	114 (34.8%)	1.4 (0.9,2.1)	0.118	118 (36.0%)	0.6 (0.5,0.8)	0.002	114 (34.8%)	0.9 (0.6,1.2)	0.353
Household wealth status									

Table 9: Participants' characteristics associated with seropositivity of O. tsutsugamushi, Rickettsia, and Leptospira in Thailand. Univariate logistic regression was presented with crude odds ratio (cOR) and corresponding p-value. *(continued)*

Variables	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value	Freq	cOR (95%CI)	p-value
Middle	132 (31.3%)	Reference		163 (38.6%)	Reference		171 (40.5%)	Reference	
Poor	177 (36.4%)	1.4 (0.9,2.1)	0.156	201 (41.4%)	1.1 (0.8,1.6)	0.401	226 (46.5%)	1.3 (0.9,1.8)	0.114
Rich	109 (21.9%)	0.6 (0.4,0.9)	0.011	261 (52.4%)	1.8 (1.3,2.5)	<0.001	133 (26.7%)	0.5 (0.4,0.7)	<0.001
District									
Muang	89 (46.8%)	Reference		81 (42.6%)	Reference		82 (43.2%)	Reference	
Mae Suai	221 (42.8%)	0.8 (0.5,1.3)	0.339	205 (39.7%)	0.9 (0.6,1.3)	0.553	229 (44.4%)	1.1 (0.7,1.6)	0.800
Wiang Kean	42 (26.1%)	0.4 (0.2,0.7)	0.002	59 (36.6%)	0.8 (0.5,1.3)	0.313	64 (39.8%)	0.8 (0.5,1.4)	0.497
Chiang Khong	29 (13.4%)	0.1 (0.1,0.2)	<0.001	101 (46.8%)	1.2 (0.8,1.9)	0.471	78 (36.1%)	0.7 (0.4,1.2)	0.168
Khun Tan	37 (11.5%)	0.1 (0.1,0.2)	<0.001	179 (55.4%)	1.7 (1.1,2.6)	0.017	77 (23.8%)	0.4 (0.2,0.6)	<0.001

Table 10. Seropositivity across flaviviruses and chikungunya, overall and by site.

Characteristic	Overall N = 4,571	Bangladesh N = 1,709	Cambodia N = 1,456	Thailand N = 1,406
Pathogens				
none	1,492 (32.6)	1,066 (62.4)	261 (17.9)	165 (11.7)
DENV	502 (11.0)	257 (15.0)	117 (8.0)	128 (9.1)
DENV-CHIKV	44 (1.0)	8 (0.5)	31 (2.1)	5 (0.4)
DENV-JEV	705 (15.4)	109 (6.4)	208 (14.3)	388 (27.6)
DENV-JEV-CHIKV	131 (2.9)	2 (0.1)	114 (7.8)	15 (1.1)
DENV-JEV-ZIKAV	722 (15.8)	76 (4.4)	282 (19.4)	364 (25.9)
DENV-JEV-ZIKAV-CHIKV	359 (7.9)	6 (0.4)	293 (20.1)	60 (4.3)
DENV-ZIKAV	70 (1.5)	13 (0.8)	32 (2.2)	25 (1.8)
DENV-ZIKAV-CHIKV	20 (0.4)	0 (0.0)	20 (1.4)	0 (0.0)
JEV	433 (9.5)	142 (8.3)	49 (3.4)	242 (17.2)
JEV-CHIKV	10 (0.2)	3 (0.2)	3 (0.2)	4 (0.3)
JEV-ZIKAV	19 (0.4)	9 (0.5)	7 (0.5)	3 (0.2)
JEV-ZIKAV-CHIKV	1 (0.0)	0 (0.0)	1 (0.1)	0 (0.0)
ZIKAV	27 (0.6)	8 (0.5)	15 (1.0)	4 (0.3)
ZIKAV-CHIKV	4 (0.1)	0 (0.0)	4 (0.3)	0 (0.0)
CHIKV	32 (0.7)	10 (0.6)	19 (1.3)	3 (0.2)

[1] n (%)

Note:
CHIKV: chikungunya virus; DENV: Dengue virus; JEV: Japanese encephalitis virus; ZIKAV: Zika virus

E

Appendix E for Chapter 7

Appendix E. Appendix for Chapter 7

Table 1: Physical examinations, laboratory test, and self-reported healthcare utilisation among all adult participants for each country, by age groups

Variables	Cambodia			Thailand		
	Overall N = 896	15-49 N = 593	50+ N = 303	Overall N = 1,174	15-49 N = 429	50+ N = 745
Physical examiniation and laboratory results						
Height (cm)	157.0 (152.0,164.0)	159.0 (153.0,165.0)	156.0 (151.0,162.0)	155.0 (150.0,161.5)	157.0 (152.0,164.2)	154.0 (150.0,160.0)
Weight (kg)	56.2 (50.0,64.3)	56.9 (50.3,64.7)	55.5 (48.3,63.2)	58.0 (50.1,65.0)	60.0 (53.0,69.4)	56.3 (50.0,64.0)
BMI (kg/cm^2)						
Underweight (BMI<18.5/ BMI by age<-2SD	78 (8.7)	39 (6.6)	39 (12.9)	83 (7.1)	19 (4.4)	64 (8.6)
Normal (18.5<=BMI<25/ -2SD<=BMI by age<1SD)	560 (62.5)	377 (63.6)	183 (60.4)	651 (55.5)	230 (53.6)	421 (56.5)
Overweight (25<=BMI<30/ 1SD<=BMI by age<2SD)	208 (23.2)	144 (24.3)	64 (21.1)	323 (27.5)	120 (28.0)	203 (27.2)
Obese (BMI>=30/ BMI by age >=2SD)	50 (5.6)	33 (5.6)	17 (5.6)	117 (10.0)	60 (14.0)	57 (7.7)
Blood pressure category (mmHg)						
Normal (SBP<140 & DBP<90)	763 (85.2)	535 (90.2)	228 (75.2)	796 (67.8)	340 (79.3)	456 (61.2)

Table 1: Physical examinations, laboratory test, and self-reported healthcare utilisation among all adult participants for each country, by age groups *(continued)*

Variables	Cambodia			Thailand		
	Overall N = 896	15-49 N = 593	50+ N = 303	Overall N = 1,174	15-49 N = 429	50+ N = 745
Mild HTN (160>SBP>=140/ 100>DBP>=90)	96 (10.7)	41 (6.9)	55 (18.2)	264 (22.5)	62 (14.5)	202 (27.1)
Moderate HTN(SBP>=160/ DBP>=100)	37 (4.1)	17 (2.9)	20 (6.6)	114 (9.7)	27 (6.3)	87 (11.7)
TC category						
Normal (<190md/dL)	489 (54.6)	355 (59.9)	134 (44.2)	695 (59.2)	254 (59.2)	441 (59.2)
Elevated (190-239md/dL)	295 (32.9)	177 (29.8)	118 (38.9)	382 (32.5)	150 (35.0)	232 (31.1)
High (>=240md/dL)	112 (12.5)	61 (10.3)	51 (16.8)	97 (8.3)	25 (5.8)	72 (9.7)
HDL category						
Abnormal (<40md/dL)	205 (22.9)	105 (17.7)	100 (33.0)	134 (11.4)	43 (10.0)	91 (12.2)
Normal (>=40mg/dL)	691 (77.1)	488 (82.3)	203 (67.0)	1,040 (88.6)	386 (90.0)	654 (87.8)
HbA1c category						
Normal (<5.7%)	810 (90.4)	564 (95.1)	246 (81.2)	873 (74.4)	382 (89.0)	491 (65.9)
Prediabetes (5.7-6.4%)	42 (4.7)	19 (3.2)	23 (7.6)	186 (15.8)	22 (5.1)	164 (22.0)
Diabetes (>=6.5%)	44 (4.9)	10 (1.7)	34 (11.2)	115 (9.8)	25 (5.8)	90 (12.1)
Self-reported screening and disease history						
Cholesterol						
Cholesterol ever measured	114 (12.7)	62 (10.5)	52 (17.2)	737 (62.8)	194 (45.2)	543 (72.9)
Raised cholesterol previously diagnosed	39 (4.4)	17 (2.9)	22 (7.3)	206 (17.5)	28 (6.5)	178 (23.9)
Currently taking medication	5 (0.6)	2 (0.3)	3 (1.0)	181 (15.4)	22 (5.1)	159 (21.3)
Hypertension						
Blood pressure ever measured	463 (51.7)	245 (41.3)	218 (71.9)	1,094 (93.2)	386 (90.0)	708 (95.0)
Hypertension diagnosed	122 (13.6)	28 (4.7)	94 (31.0)	301 (25.6)	38 (8.9)	263 (35.3)

Table 1: Physical examinations, laboratory test, and self-reported healthcare utilisation among all adult participants for each country, by age groups *(continued)*

Variables	Cambodia			Thailand		
	Overall N = 896	15-49 N = 593	50+ N = 303	Overall N = 1,174	15-49 N = 429	50+ N = 745
Currently taking medication	69 (7.7)	11 (1.9)	58 (19.1)	246 (21.0)	25 (5.8)	221 (29.7)
Diabetes						
Blood sugar level ever measured	240 (26.8)	123 (20.7)	117 (38.6)	978 (83.3)	299 (69.7)	679 (91.1)
Diabetes previously diagnosed	42 (4.7)	14 (2.4)	28 (9.2)	124 (10.6)	18 (4.2)	106 (14.2)
Currently taking medication or insulin injection	22 (2.5)	5 (0.8)	17 (5.6)	106 (9.0)	15 (3.5)	91 (12.2)
Chronic lung disease						
Chronic lung previously diagnosed	90 (10.0)	43 (7.3)	47 (15.5)	20 (1.7)	2 (0.5)	18 (2.4)
Currently taking medication	4 (0.4)	1 (0.2)	3 (1.0)	10 (0.9)	0 (0.0)	10 (1.3)
Asthma						
Asthma previously diagnosed	14 (1.6)	9 (1.5)	5 (1.7)	29 (2.5)	6 (1.4)	23 (3.1)
Taking medication or treatment for asthma	1 (0.1)	0 (0.0)	1 (0.3)	19 (1.6)	1 (0.2)	18 (2.4)
Heart disease						
Had heart attack, checst pain, or stroke	84 (9.4)	47 (7.9)	37 (12.2)	50 (4.3)	13 (3.0)	37 (5.0)

Taking medication to prevent or treat heart disease	5 (0.6)	3 (0.5)	2 (0.7)	33 (2.8)	5 (1.2)	28 (3.8)

[1] Median (Q1,Q3); n (%)

Note:
Participants who had incomplete physical examination, laboratory test, or questionnaire interview results were excluded from the analysis (Cambodia=17, Thailand=11).
SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HTN: Hypertension; HbA1c: haemoglobin A1c; TC: Total cholesterol;HDL: High-Density Lipoprotein

* BMI classification: participants 15-17 years were evaluated against BMI by age chart, and participants 18 years or older were evaluated by the fixed cut off

† Currently taking medication: Had been taking medication prescribed by a health professional to treat the corresponding disease in the past 30 days before survey

Table 2: Ten-year-CVD risks among participants who were 40-74 years, by the Revised Pooled Cohort Equation and the WHO CVD laboratory-based risk chart for Southeast Asians, by age groups

	Cambodia			Thailand		
10-year CVD risk evaluation	40-49 N = 130	50-59 N = 134	60+ N = 112	40-49 N = 199	50-59 N = 271	60+ N = 370
RPCE score (median, IQR)	1.3 (0.5, 2.6)	3.9 (1.6, 8.6)	7.5 (4.8, 15.0)	1.1 (0.4, 2.4)	2.6 (1.3, 6.0)	7.0 (4.1, 11.8)
WHO risk chart score (median, IQR)	2.0 (1.0, 3.0)	5.0 (3.0, 8.0)	10.0 (8.0, 14.0)	2.0 (1.0, 3.0)	5.0 (3.0, 8.0)	10.0 (7.0, 13.0)
Blood pressure > 160/100 mmHg	10 (7.7%)	8 (6.0%)	11 (9.8%)	15 (7.5%)	28 (10.3%)	36 (9.7%)
Total cholesterol> 320mg/dL	2 (1.5%)	1 (0.7%)	0 (0.0%)	0 (0.0%)	4 (1.5%)	0 (0.0%)
High 10-year risk, n (%)						
RPCE- High risk	4 (3.1%)	42 (31.3%)	56 (50.0%)	7 (3.5%)	48 (17.7%)	170 (45.9%)

Table 2: Ten-year-CVD risks among participants who were 40-74 years, by the Revised Pooled Cohort Equation and the WHO CVD laboratory-based risk chart for Southeast Asians, by age groups *(continued)*

10-year CVD risk evaluation	Cambodia			Thailand		
	40-49 N = 130	50-59 N = 134	60+ N = 112	40-49 N = 199	50-59 N = 271	60+ N = 370
WHO CVD risk chart-High risk	12 (9.2%)	12 (9.0%)	14 (12.5%)	16 (8.0%)	33 (12.2%)	48 (13.0%)

[1] Median (Q1, Q3); n (%)

Note:
Participants aged 40-74 who reported previous heart disease were excluded from the analysis (Cambodia: n=54, Thailand: n=41)
The high 10-year-CVD risk was defined as 7.5% or higher score according to RPCE, or 20% or higher WHO CVD risk score or blood pressure>160/100 mmHg or total cholesterol >=320 mg/dL according to the WHO CVD risk chart

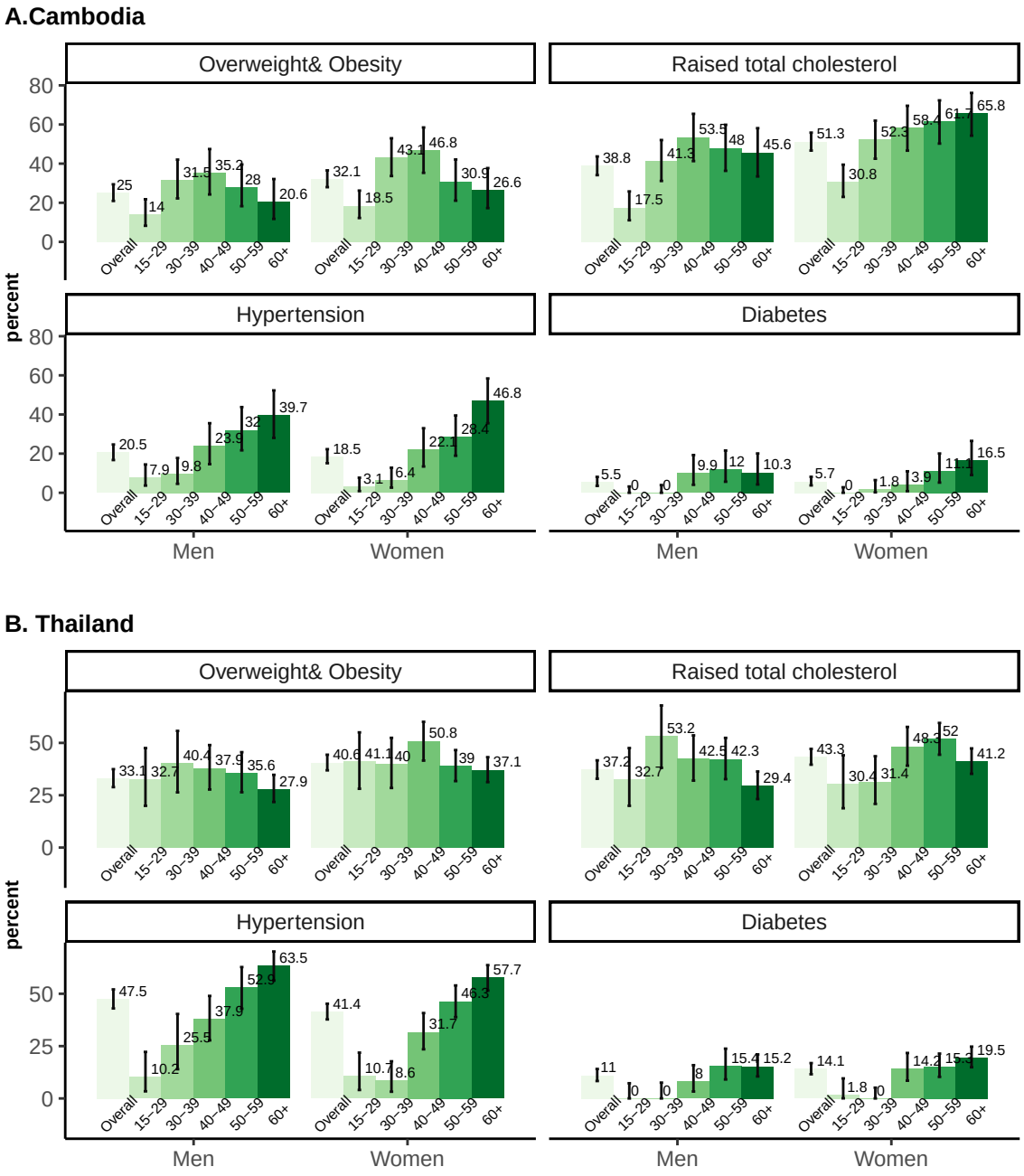


Figure 1: Proportion of participants who had overweight and obesity, raised total cholesterol, hypertension, or diabetes in Cambodia (A) and Thailand (B), by age groups and sex

References

Academy of Medical Sciences. (2018). *Multimorbidity: A priority for global health research*.

Aekplakorn, W., Chariyalertsak, S., Kessomboon, P., Assanangkornchai, S., Taneepanichskul, S., & Putwatana, P. (2018). Prevalence of Diabetes and Relationship with Socioeconomic Status in the Thai Population: National Health Examination Survey, 2004-2014. *Journal of Diabetes Research*, *2018*, 1654530. https://doi.org/10.1155/2018/1654530

Ahmed, A., Sayeed, A., Tanwi, T. S., Saha, N., Hanson, M., Protyai, D. A., Hossain, A. T., Ahmed, A., Rahman, F., Akter, E., Nusrat, N., Badsha, M. S., Rahman, A., Islam, M. K., Alam, Md. S., Nahar, Q., Arifeen, S. E., Rahman, A. E., & Tahsina, T. (2023). Trends and inequity in improved sanitation facility utilisation in bangladesh: Evidence from bangladesh demographic and health surveys. *BMC Research Notes*, *16*, 303. https://doi.org/10.1186/s13104-023-06555-0

Ahmed, S. M., Adams, A. M., Chowdhury, M., & Bhuiya, A. (2000). Gender, socioeconomic development and health-seeking behaviour in Bangladesh. *Social Science & Medicine*, *51*(3), 361–371. https://doi.org/10.1016/S0277-9536(99)00461-X

Aiemjoy, K., Aragie, S., Wittberg, D. M., Tadesse, Z., Callahan, E. K., Gwyn, S., Martin, D., Keenan, J. D., & Arnold, B. F. (2020). Seroprevalence of antibodies against Chlamydia trachomatis and enteropathogens and distance to the nearest water source among young children in the Amhara Region of Ethiopia. *PLOS Neglected Tropical Diseases*, *14*(9), e0008647. https://doi.org/10.1371/journal.pntd.0008647

Aiemjoy, K., Katuwal, N., Vaidya, K., Shrestha, S., Thapa, M., Teunis, P., Bogoch, I. I., Trowbridge, P., Blacksell, S. D., Paris, D. H., Wangrangsimakul, T., Varghese, G. M., Maude, R. J., Tamrakar, D., & Andrews, J. R. (2024). Estimating the seroincidence of scrub typhus using antibody dynamics after infection. *The American Journal of Tropical Medicine and Hygiene*, *111*(2), 267–276. https://doi.org/10.4269/ajtmh.23-0475

Aiemjoy, K., Seidman, J. C., Saha, S., Munira, S. J., Sajib, M. S. I., Sium, S. M. A., Sarkar, A., Alam, N., Zahan, F. N., Kabir, M. S., Tamrakar, D., Vaidya, K., Shrestha, R., Shakya, J., Katuwal, N., Shrestha, S., Yousafzai, M. T., Iqbal, J., Dehraj, I. F., ... Andrews, J. R. (2022). Estimating typhoid incidence from community-based serosurveys: A multicohort study. *The Lancet Microbe*, *3*(8), e578–e587. https://doi.org/10.1016/S2666-5247(22)00114-8

Alam, M. Z. (2022). Ethnic inequalities in access to WASH in bangladesh. *The Lancet Global Health*, *10*(8), e1086–e1087. https://doi.org/10.1016/S2214-109X(22)00232-7

Alemayehu, S., Feghali, K. C., Cowden, J., Komisar, J., Ockenhouse, C. F., & Kamau, E. (2013). Comparative evaluation of published real-time PCR assays for the detection of malaria following MIQE guidelines. *Malaria Journal*, *12*, 277. https://doi.org/10.1186/1475-2875-12-277

Allen, S. F., Wetherell, M. A., & Smith, M. A. (2017). The cohen–hoberman inventory of physical symptoms: Factor structure, and preliminary tests of reliability and validity in the general population. *Psychology & Health*, *32*(5), 567–587. https://doi.org/10.1080/08870446.2017.1290237

Allotey, P., Davey, T., & Reidpath, D. D. (2014). NCDs in low and middle-income countries - assessing the capacity of health systems to respond to population needs. *BMC Public Health*, *14*(2), S1. https://doi.org/10.1186/1471-2458-14-S2-S1

Al-Mahtab, M. (2017). Past, Present, and Future of Viral Hepatitis in Bangladesh. *Euroasian Journal of Hepato-Gastroenterology*, *6*(1), 43–44. https://doi.org/10.5005/jp-journals-10018-1164

Al-Zubayer, M. A., Ahammed, B., Sarder, M. A., Kundu, S., Majumder, U. K., & Islam, S. M. S. (2021). Double and triple burden of non-communicable diseases and its determinants among adults in bangladesh: Evidence from a recent demographic and health survey. *International Journal of Clinical Practice*, e14613. http://ovidsp.ovid.com/ ovidweb.cgi?T=JS&PAGE=reference&D=medp&NEWS=N&AN=3423 %[20210708//

American Diabetes Association. (2013). Diagnosis and classification of diabetes mellitus. *Diabetes Care*, *37*(Supplement_1), S81–S90. https://doi.org/10.2337/dc14-S081

Andrews, J. R., Baker, S., Marks, F., Alsan, M., Garrett, D., Gellin, B. G., Saha, S. K., Qamar, F. N., Yousafzai, M. T., Bogoch, I. I., Antillon, M., Pitzer, V. E., Kim, J.-H., John, J., Gauld, J., Mogasale, V., Ryan, E. T., Luby, S. P., & Lo, N. C. (2019). Typhoid conjugate vaccines: A new tool in the fight against antimicrobial resistance. *The Lancet Infectious Diseases*, *19*(1), e26–e30. https://doi.org/10.1016/S1473-3099(18)30350-5

Andrews, J. R., Barkume, C., Yu, A. T., Saha, S. K., Qamar, F. N., Garrett, D., & Luby, S. P. (2018). Integrating facility-based surveillance with healthcare utilization surveys to estimate enteric fever incidence: Methods and challenges. *The Journal of Infectious Diseases*, *218*(suppl_4), S268–S276. https://doi.org/10.1093/infdis/jiy494

Andrews, J. R., Vaidya, K., Saha, S., Yousafzai, M. T., Hemlock, C., Longley, A., Aiemjoy, K., Yu, A. T., Bogoch, I. I., Tamrakar, D., Date, K., Saha, S. K., Garrett, D. O., Luby, S. P., & Qamar, F. (2020). Healthcare utilization patterns for acute febrile illness in bangladesh, nepal, and pakistan: Results from the surveillance for enteric fever in asia project. *Clinical Infectious Diseases*, *71*(Supplement_3), S248–S256. https://doi.org/10.1093/cid/ciaa1321

Annear, P. L., Grundy, J., Ir, P., Jacobs, B., Men, C., Nachtnebel, M., Oum, S., Robins, A., & Ros, C. E. (2015). *The Kingdom of Cambodia health system review*. https://apo.who.int/publications/i/item/9789290616917

Antillon, M., Saad, N. J., Baker, S., Pollard, A. J., & Pitzer, V. E. (2018). The Relationship Between Blood Sample Volume and Diagnostic Sensitivity of Blood Culture for Typhoid and Paratyphoid Fever: A Systematic Review and Meta-Analysis. *The Journal of Infectious Diseases*, *218*(suppl_4), S255–S267. https://doi.org/10.1093/infdis/jiy471

Apidechkul, T. (2019). Sexual behaviors and seroprevalence of HIV, HBV, and HCV among hill tribe youths of northern thailand. *BMC Public Health*, *19*(1), 1101. https://doi.org/10.1186/s12889-019-7459-9

Apidechkul, T., Laingoen, O., & Suwannaporn, S. (2016). Inequity in Accessing Health Care Service in Thailand in 2015: A Case Study of the Hill Tribe People in Mae Fah Luang District, Chiang Rai, Thailand. *Journal of Health Research*, *30*(1), 67–71. https://he01.tci-thaijo.org/index.php/jhealthres/article/view/78030

Arnett, D. K., Blumenthal, R. S., Albert, M. A., Buroker, A. B., Goldberger, Z. D., Hahn, E. J., Himmelfarb, C. D., Khera, A., Lloyd-Jones, D., McEvoy, J. W., Michos, E. D., Miedema, M. D., Muñoz, D., Smith, S. C., Virani, S. S., Williams, K. A., Yeboah, J., & Ziaeian, B. (2019). 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: A report of the american college of cardiology/american heart association task force on clinical practice guidelines. *Circulation*, *140*(11), e596–e646. https://doi.org/10.1161/CIR.0000000000000678

Arnold, B. F., Laan, M. J. van der, Hubbard, A. E., Steel, C., Kubofcik, J., Hamlin, K. L., Moss, D. M., Nutman, T. B., Priest, J. W., & Lammie, P. J. (2017). Measuring changes in transmission of neglected tropical diseases, malaria, and enteric pathogens from quantitative antibody levels. *PLOS Neglected Tropical Diseases*, *11*(5), e0005616. https://doi.org/10.1371/journal.pntd.0005616

Arnold, B. F., Scobie, H. M., Priest, J. W., & Lammie, P. J. (2018). *Integrated serologic surveillance of population immunity and disease transmission*. *24*(7). https://doi.org/10.3201/eid2407.171928

Aromataris E, & Munn Z (Eds.). (2020). Chapter 11: Scoping reviews. In *JBI Manual for Evidence Synthesis*. JBI.

Ashour, M. (2017). Individual and socioeconomic disparities in health-seeking behaviours and out-of-pocket payments in the gaza strip in 2013: Results from a household survey. *The Lancet*, *390*, S38. https://doi.org/10.1016/S0140-6736(17)32039-1

Ashraf, H., Alam, N. H., Rothermundt, C., Brooks, A., Bardhan, P., Hossain, L., Salam, M. A., Hassan, M. S., Beglinger, C., & Gyr, N. (2010). Prevalence and risk factors of hepatitis b and c virus infections in an impoverished urban community in dhaka, bangladesh. *BMC Infectious Diseases*, *10*, 208. https://doi.org/10.1186/1471-2334-10-208

Asogwa, O. A., Boateng, D., Marzà-Florensa, A., Peters, S., Levitt, N., Olmen, J. van, & Klipstein-Grobusch, K. (2022). Multimorbidity of non-communicable diseases in low-income and middle-income countries: a systematic review and meta-analysis. *BMJ Open*, *12*(1), e049133. https://doi.org/10.1136/bmjopen-2021-049133

Attavanich, W., Chantarat, S., Chenphuengpawn, J., Mahasuweerachai, P., & Thampanishvong, K. (2019). Farms, Farmers and Farming: a Perspective through Data and Behavioral Insights. *Puey Ungphakorn Institute for Economic Research*, *PIER Discussion Papers 122*.

Aye Aye Lwin, Khin Saw Aye, Moh Moh Htun, Yi Yi Kyaw, Ko Ko Zaw, Toe Thiri Aung, Myat Phone Kyaw, Khin Pyone Kyi, & Kyaw Zin Thant. (2017). Seroprevalence of Hepatitis B and C Viral infections in myanmar: National and regional survey in 2015. *Myanmar Health Sciences Research Journal*, *29*(3), 167–175.

Bangladesh Bureau of Statistics. (2023). *Population & Housing Census 2022*. Bangladesh Bureau of Statisitcs, Statistics and Informatics Division, Ministry of Planning, Goverment of the People's Republic of Bangladesh.

Banik, S., Datta, A., Ghosh, A., Ghosh, K. Y., & Debi, H. (2022). The prevalence of hepatitis B virus infection in Bangladesh: a systematic review and meta-analysis. *Epidemiology & Infection*, *150*. https://doi.org/10.1017/S0950268822000061

Benaglia, T., Chauveau, D., Hunter, D. R., & Young, D. S. (2010). mixtools: An R Package for Analyzing Mixture Models. *Journal of Statistical Software*, *32*, 1–29. https://doi.org/10.18637/jss.v032.i06

Benyamini, Y., & Idler, E. L. (1999). Community Studies Reporting Association between Self-Rated Health and Mortality: Additional Studies, 1995 to 1998. *Research on Aging*, *21*(3), 392–401. https://doi.org/10.1177/0164027599213002

Blacksell, S. D., Luksameetanasan, R., Kalambaheti, T., Aukkanit, N., Paris, D. H., McGready, R., Nosten, F., Peacock, S. J., & Day, N. P. J. (2008). Genetic typing of the 56-kDa type-specific antigen gene of contemporary orientia tsutsugamushi isolates causing human scrub typhus at two sites in north-eastern and western thailand. *FEMS Immunology & Medical Microbiology*, *52*(3), 335–342. https://doi.org/10.1111/j.1574-695X.2007.00375.x

Bollyky, T. J., Hulland, E. N., Barber, R. M., Collins, J. K., Kiernan, S., Moses, M., Pigott, D. M., Jr, R. C. R., Sorensen, R. J. D., Abbafati, C., Adolph, C., Allorant, A., Amlag, J. O., Aravkin, A. Y., Bang-Jensen, B., Carter, A., Castellano, R., Castro, E., Chakrabarti, S., … Dieleman, J. L. (2022). Pandemic preparedness and COVID-19: An exploratory analysis of infection and fatality rates, and contextual factors associated with preparedness in 177 countries, from jan 1, 2020, to sept 30, 2021. *The Lancet*, *399*(10334), 1489–1512. https://doi.org/10.1016/S0140-6736(22)00172-6

Bonell, A., Lubell, Y., Newton, P. N., Crump, J. A., & Paris, D. H. (2017). Estimating the burden of scrub typhus: A systematic review. *PLOS Neglected Tropical Diseases*, *11*(9), e0005838. https://doi.org/10.1371/journal.pntd.0005838

Borompichaichatkul, N. (2021, February 9). *United Nations Expert Group Meeting on the Impact of the Covid-19 Pandamic on Conducting Population and Housing Censuses and on Census Data Quality Concerns*.

Boufous, S., Ivers, R., Senserrick, T., Stevenson, M., Norton, R., & Williamson, A. (2010). Accuracy of self-report of on-road crashes and traffic offences in a cohort of young drivers: the DRIVE study. *Injury Prevention*, *16*(4), 275–277. https://doi.org/10.1136/ip.2009.024877

Bygbjerg, I. C. (2012). Double burden of noncommunicable and infectious diseases in developing countries. *Science*, *337*(6101), 1499–1501. https://doi.org/10.1126/science.1223466

Byron Jaeger. (2020). *PooledCohort: Predicted Risk for CVD using Pooled Cohort Equations, PREVENT Equations, and Other Contemporary CVD Risk Calculators*.

Cantor-Graae, E., Chak, T., Sunbaunat, K., Jarl, J., & Larsson, C. A. (2014). Long-term psychiatric consequences of exposure to trauma in Cambodia: a regional household survey. *Social science & medicine (1982)*, *123*, 133–140. https://doi.org/10.1016/j.socscimed.2014.10.049

Chaisiri, K., Tanganuchitcharnchai, A., Kritiyakan, A., Thinphovong, C., Tanita, M., Morand, S., & Blacksell, S. D. (2022). Risk factors analysis for neglected human rickettsioses in rural communities in Nan province, Thailand: A community-based observational study along a landscape gradient. *PLOS Neglected Tropical Diseases*, *16*(3), e0010256. https://doi.org/10.1371/journal.pntd.0010256

Chakraborty, N. M., Fry, K., Behl, R., & Longfield, K. (2016). Simplified Asset Indices to Measure Wealth and Equity in Health Programs: A Reliability and Validity Analysis Using Survey Data From 16 Countries. *Global Health: Science and Practice*, *4*(1), 141–154. https://doi.org/10.9745/GHSP-D-15-00384

Chan, Y. L., Patterson, C. L., Priest, J. W., Stresman, G., William, T., Chua, T. H., Tetteh, K., Lammie, P., Drakeley, C., & Fornace, K. M. (2022). Assessing seroprevalence and associated risk factors for multiple infectious diseases in

Sabah, Malaysia using serological multiplex bead assays. *Frontiers in Public Health*, *10*. https://doi.org/10.3389/fpubh.2022.924316

Chandna, A., Chew, R., Shwe Nwe Htun, N., Peto, T. J., Zhang, M., Liverani, M., Brummaier, T., Phommasone, K., Perrone, C., Pyae Phyo, A., Sattabongkot, J., Roobsoong, W., Nguitragool, W., Sen, A., Ibna Zaman, S., Sandar Zaw, A., Batty, E., Waithira, N., Abdad, M. Y., … Lubell, Y. (2022). Defining the burden of febrile illness in rural south and southeast asia: An open letter to announce the launch of the rural febrile illness project. *Wellcome Open Research*, *6*, 64. https://doi.org/10.12688/wellcomeopenres.16393.2

Chappuis, F., Alirol, E., d'Acremont, V., Bottieau, E., & Yansouni, C. P. (2013). Rapid diagnostic tests for non-malarial febrile illness in the tropics. *Clinical Microbiology and Infection: The Official Publication of the European Society of Clinical Microbiology and Infectious Diseases*, *19*(5), 422–431. https://doi.org/10.1111/1469-0691.12154

Charrel, R. N. (2016). Diagnosis of arboviral infections – a quagmire of cross reactions and complexities. *Travel Medicine and Infectious Disease*, *14*(1), 11–12. https://doi.org/10.1016/j.tmaid.2016.01.006

Cheng, L., Sit, J. W. H., Choi, K.-C., Chair, S.-Y., Li, X., & He, X. (2017). Effectiveness of Interactive Self-Management Interventions in Individuals With Poorly Controlled Type 2 Diabetes: A Meta-Analysis of Randomized Controlled Trials. *Worldviews on Evidence-Based Nursing*, *14*(1), 65–73. https://doi.org/10.1111/wvn.12191

Chham, S., Buffel, V., Van Olmen, J., Chhim, S., Ir, P., & Wouters, E. (2022). The cascade of hypertension care in Cambodia: evidence from a cross-sectional population-based survey. *BMC Health Services Research*, *22*(1), 838. https://doi.org/10.1186/s12913-022-08232-7

Chham, S., Van Olmen, J., Van Damme, W., Chhim, S., Buffel, V., Wouters, E., & Ir, P. (2023). Scaling-up integrated type-2 diabetes and hypertension care in cambodia: What are the barriers to health system performance? *Frontiers in Public Health*, *11*. https://doi.org/10.3389/fpubh.2023.1136520

Chhim, S., Piola, P., Housen, T., Herbreteau, V., & Tol, B. (2021). Malaria in Cambodia: A Retrospective Analysis of a Changing Epidemiology 2006–2019. *International Journal of Environmental Research and Public Health*, *18*(4), 1960. https://doi.org/10.3390/ijerph18041960

Chia, C. W., Egan, J. M., & Ferrucci, L. (2018). Age-related changes in glucose metabolism, hyperglycemia, and cardiovascular risk. *Circulation Research*, *123*(7), 886–904. https://doi.org/10.1161/CIRCRESAHA.118.312806

Chongsuvivatwong, V., Phua, K. H., Yap, M. T., Pocock, N. S., Hashim, J. H., Chhem, R., Wilopo, S. A., & Lopez, A. D. (2011). Health and health-care systems in southeast Asia: diversity and transitions. *The Lancet*, *377*(9763), 429–437. https://doi.org/10.1016/S0140-6736(10)61507-3

Chooi, Y. C., Ding, C., & Magkos, F. (2019). The epidemiology of obesity. *Metabolism*, *92*, 6–10. https://doi.org/10.1016/j.metabol.2018.09.005

Cleary, P. D. (1997). Subjective and objective measures of health: which is better when? *Journal of Health Services Research & Policy*, *2*(1), 3–4. https://doi.org/10.1177/135581969700200102

Cleven, L., Krell-Roesch, J., Nigg, C. R., & Woll, A. (2020). The association between physical activity with incident obesity, coronary heart disease, diabetes and hypertension in adults: a systematic review of longitudinal studies published after 2012. *BMC Public Health*, *20*(1), 726. https://doi.org/10.1186/s12889-020-08715-4

Coalition for Global Hepatitis Elimination. (2025a). *National Hepatitis Elimination Profiles- Bangladesh*.

Coalition for Global Hepatitis Elimination. (2025b). *National Hepatitis Elimination Profiles- Thailand*. https://www.globalhep.org/sites/default/files/content/national_profiles/files/2025-03/2025-03-13_Hepatitis%20Infographic_Thailand_converted.pdf

Cochran, W. G. (1977). *Sampling techniques*. John Wiley & Sons, Ltd.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Coker, R. J., Hunter, B. M., Rudge, J. W., Liverani, M., & Hanvoravongchai, P. (2011). Emerging infectious diseases in southeast Asia: regional challenges to control. *The Lancet*, *377*(9765), 599–609. https://doi.org/10.1016/S0140-6736(10)62004-1

Council for International Organizations of Medical Sciences (CIOMS). (2016). *International Ethical Guidelines for Health-related Research involving Humans*. https://doi.org/10.56759/rgxl7405

Coutinho, M., Gerstein, H. C., Wang, Y., & Yusuf, S. (1999). The relationship between glucose and incident cardiovascular events. A metaregression analysis of published data from 20 studies of 95,783 individuals followed for 12.4 years. *Diabetes Care*, *22*(2), 233–240. https://doi.org/10.2337/diacare.22.2.233

Cox, K., Moghaddam, N., Bird, L., & Elkan, R. (2011). Feedback of trial results to participants: A survey of clinicians' and patients' attitudes and experiences. *European Journal of Oncology Nursing*, *15*(2), 124–129. https://doi.org/10.1016/j.ejon.2010.06.009

Croft, Trevor N., Aileen M. J. Marshall, Courtney K. Allen, et al. (2018). *Guide to DHS statistics*.

Crump, J. A., Luby, S. P., & Mintz, E. D. (2004). The global burden of typhoid fever. *Bulletin of the World Health Organization*, *82*(5), 346–353.

Czernichow, S., Kengne, A.-P., Stamatakis, E., Hamer, M., & Batty, G. D. (2011). Body mass index, waist circumference and waist-hip ratio: which is the better discriminator of cardiovascular disease mortality risk?: evidence from an individual-participant meta-analysis of 82 864 participants from nine cohort studies. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *12*(9), 680–687. https://doi.org/10.1111/j.1467-789X.2011.00879.x

Dans, A., Ng, N., Varghese, C., Tai, E. S., Firestone, R., & Bonita, R. (2011). The rise of chronic non-communicable diseases in southeast asia: Time for action.

The Lancet, *377*(9766), 680–689. https://doi.org/10.1016/S0140-6736(10)61506-1

Department of Economic and Social Affairs, United Nations. (2008). *Designing household survey samples: Practical guidelines*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://unstats.un.org/unsd/publication/seriesf/seriesf_98e.pdf

Diepart, J.-C., & Ngin, C. (2020). *Internal Migration in Cambodia* (M. Bell, A. Bernard, E. Charles-Edwards, & Y. Zhu, Eds.; pp. 137–162). Springer International Publishing. https://doi.org/10.1007/978-3-030-44010-7_8

Dittrich, S., Boutthasavong, L., Keokhamhoung, D., Phuklia, W., Craig, S. B., Tulsiani, S. M., Burns, M.-A., Weier, S. L., Dance, D. A. B., Davong, V., Vongsouvath, M., Mayxay, M., Phetsouvanh, R., Newton, P. N., & Woods, K. (2018). A Prospective Hospital Study to Evaluate the Diagnostic Accuracy of Rapid Diagnostic Tests for the Early Detection of Leptospirosis in Laos. *The American Journal of Tropical Medicine and Hygiene*, *98*(4), 1056–1060. https://doi.org/10.4269/ajtmh.17-0702

Dixon-Woods, M., Jackson, C., Windridge, K. C., & Kenyon, S. (2006). Receiving a summary of the results of a trial: qualitative study of participants' views. *BMJ (Clinical research ed.)*, *332*(7535), 206–210. https://doi.org/10.1136/bmj.38675.677963.3A

Do, E.-J., Kim, J.-E., Park, J.-M., Lee, K.-M., Jung, M.-Y., Lee, H.-J., Cho, H.-W., Choi, Y.-J., Lee, S.-H., Park, K.-H., & Jang, W.-J. (2009). Development of recombinant OmpA and OmpB proteins as diagnostic antigens for rickettsial disease. *Microbiology and Immunology*, *53*(7), 368–374. https://doi.org/10.1111/j.1348-0421.2009.00142.x

Doum, D., Overgaard, H. J., Mayxay, M., Suttiprapa, S., Saichua, P., Ekalaksananan, T., Tongchai, P., Rahman, M. S., Haque, U., Phommachanh, S., Pongvongsa, T., Rocklöv, J., Paul, R., & Pientong, C. (2020). Dengue Seroprevalence and Seroconversion in Urban and Rural Populations in Northeastern

Thailand and Southern Laos. *International journal of environmental research and public health*, *17*(23). https://doi.org/10.3390/ijerph17239134

Edemekong, P. F., Bomgaars, D. L., Sukumaran, S., & Schoo, C. (2022). *Activities of Daily Living*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK470404/

Ekplakom, W. (2014). *Report of the 5th Thai National Examination Survey 2014*.

Elm, E. von, Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., Vandenbroucke, J. P., & STROBE Initiative. (2007). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet (London, England)*, *370*(9596), 1453–1457. https://doi.org/10.1016/S0140-6736(07)61602-X

Endale, A., Medhin, G., Darfiro, K., Kebede, N., & Legesse, M. (2021). Magnitude of antibody cross-reactivity in medically important mosquito-borne flaviviruses: A systematic review. *Infection and Drug Resistance*, *14*, 4291–4299. https://doi.org/10.2147/IDR.S336351

Evangelista, K. V., Lourdault, K., Matsunaga, J., & Haake, D. A. (2017). Immunoprotective properties of recombinant LigA and LigB in a hamster model of acute leptospirosis. *PLOS ONE*, *12*(7), e0180004. https://doi.org/10.1371/journal.pone.0180004

Evans, R. G., & Stoddart, G. L. (1990). Producing health, consuming health care. *Social Science & Medicine (1982)*, *31*(12), 1347–1363. https://doi.org/10.1016/0277-9536(90)90074-3

Evertsz, N., Bull, S., & Pratt, B. (2023). What constitutes equitable data sharing in global health research? A scoping review of the literature on low-income and middle-income country stakeholders' perspectives. *BMJ Global Health*, *8*(3). https://doi.org/10.1136/bmjgh-2022-010157

Fisher, R., Lustig, Y., Sklan, E. H., & Schwartz, E. (2023). The Role of NS1 Protein in the Diagnosis of Flavivirus Infections. *Viruses*, *15*(2), 572. https://doi.org/10.3390/v15020572

Fox, J., & Monette, G. (1992). Generalized collinearity diagnostics. *Journal of the American Statistical Association*, *87*(417), 178–183. https://doi.org/10.2307/2290467

Fox-Lewis, A., Hopkins, J., Sar, P., Sao, S., Pheaktra, N., Day, N. P. J., Blacksell, S. D., & Turner, P. (2019). Seroprevalence of dengue virus and rickettsial infections in cambodian children. *The American Journal of Tropical Medicine and Hygiene*, *100*(3), 635–638. https://doi.org/10.4269/ajtmh.18-0865

Fritzell, C., Rousset, D., Adde, A., Kazanji, M., Kerkhove, M. D. V., & Flamand, C. (2018). Current challenges and implications for dengue, chikungunya and Zika seroprevalence studies worldwide: A scoping review. *PLOS Neglected Tropical Diseases*, *12*(7), e0006533. https://doi.org/10.1371/journal.pntd.0006533

Ge, P., Dong, C., Ren, X., Weiderpass, E., Zhang, C., Fan, H., Zhang, J., Zhang, Y., & Xi, J. (2015). The High Prevalence of Low HDL-Cholesterol Levels and Dyslipidemia in Rural Populations in Northwestern China. *PLOS ONE*, *10*(12), e0144104. https://doi.org/10.1371/journal.pone.0144104

Global Burden of Disease Collaborative Network. (2022). *Global burden of disease study 2021 (GBD 2021) results*. https://vizhub.healthdata.org/gbd-results/

Global Burden of Disease Collaborative Network. (2020). *Global Burden of Disease Study 2019 (GBD 2019) Results*.

Global health Observatory. (2023). *Hepatitis B (HepB3) immunization coverage among 1-year-olds (*. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/hepatitis-b-(hepb3)-immunization-coverage-among-1-year-olds-(-)

Gonwong, S., Chuenchitra, T., Khantapura, P., Islam, D., Ruamsap, N., Swierczewski, B. E., & Mason, C. J. (2017). Nationwide Seroprevalence of Leptospirosis among Young Thai Men, 2007–2008. *The American Journal of Tropical Medicine and Hygiene*, *97*(6), 1682. https://doi.org/10.4269/ajtmh.17-0163

Gonwong, S., Mason, C. J., Chuenchitra, T., Khanijou, P., Islam, D., Ruamsap, N., Kana, K., Tabprasit, S., Vesely, B. A., Demons, S. T., Waters, N. C., Swierczewski, B. E., Crawford, J. M., & Jones, J. W. (2022). Nationwide Seroprevalence of Scrub Typhus, Typhus, and Spotted Fever in Young Thai Men. *The American Journal of Tropical Medicine and Hygiene*, *106*(5), 1363. https://doi.org/10.4269/ajtmh.20-1512

Groves, R. M., Fowler, F. J., Couper, M., Lepkowski, J. M., Singer, E., & Tourangeau, R. (2009). *Survey methodology* (Second edition). Wiley. http://bvbr.bib-bvb.de:8991/F?func=service&doc_library=BVB01&doc_number=017384720&line_number=0001&func_code=DB_RECORDS&service_type=MEDIA

Grubbs, J. C., Millum, J., Rietmeijer, C. A., & Kilmarx, P. H. (2021). Return of positive test results to participants in sexually transmitted infection prevalence studies: Research ethics and responsibilities. *Sexually Transmitted Diseases*, *48*(11), 834. https://doi.org/10.1097/OLQ.0000000000001429

Grundy, S. M., Stone, N. J., Bailey, A. L., Beam, C., Birtcher, K. K., Blumenthal, R. S., Braun, L. T., De Ferranti, S., Faiella-Tommasino, J., Forman, D. E., Goldberg, R., Heidenreich, P. A., Hlatky, M. A., Jones, D. W., Lloyd-Jones, D., Lopez-Pajares, N., Ndumele, C. E., Orringer, C. E., Peralta, C. A., ... Yeboah, J. (2019). 2018 AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA/PCNA Guideline on the Management of Blood Cholesterol. *Journal of the American College of Cardiology*, *73*(24), e285–e350. https://doi.org/10.1016/j.jacc.2018.11.003

Gryseels, C., Kuijpers, L. M. F., Jacobs, J., & Peeters Grietens, K. (2019). 'substandard' is the standard, who decides what is appropriate? Exploring healthcare provision in cambodia. *Critical Public Health*, *29*(4), 460–472. https://doi.org/10.1080/09581596.2019.1591614

Guidet, B., Lange, D. W. de, Boumendil, A., Leaver, S., Watson, X., Boulanger, C., Szczeklik, W., Artigas, A., Morandi, A., Andersen, F., Zafeiridis, T., Jung, C., Moreno, R., Walther, S., Oeyen, S., Schefold, J. C., Cecconi, M., Marsh, B., Joannidis, M., ... VIP2 study group. (2020). The contribution of frailty,

cognition, activity of daily life and comorbidities on outcome in acutely admitted patients over 80 years in European ICUs: the VIP2 study. *Intensive Care Medicine*, *46*(1), 57–69. https://doi.org/10.1007/s00134-019-05853-1

Haenssgen, M. J., Charoenboon, N., Early, A., & Althaus, T. (2023). Community-level incidence and treatment seeking during febrile illness: Insights from health behaviour surveys in rural Thailand and Laos. *Tropical medicine & international health: TM & IH*. https://doi.org/10.1111/tmi.13926

Haile, L. M., Kamenov, K., Briant, P. S., Orji, A. U., Steinmetz, J. D., Abdoli, A., Abdollahi, M., Abu-Gharbieh, E., Afshin, A., Ahmed, H., Rashid, T. A., Akalu, Y., Alahdab, F., Alanezi, F. M., Alanzi, T. M., Hamad, H. A., Ali, L., Alipour, V., Al-Raddadi, R. M., … Chadha, S. (2021). Hearing loss prevalence and years lived with disability, 1990–2019: Findings from the Global Burden of Disease Study 2019. *The Lancet*, *397*(10278), 996–1009. https://doi.org/10.1016/S0140-6736(21)00516-X

Haldar, K., Alam, M. S., Koepfli, C., Lobo, N. F., Phru, C. S., Islam, M. N., Faiz, A., Khan, W. A., & Haque, R. (2023). Bangladesh in the era of malaria elimination. *Trends in Parasitology*, *39*(9), 760–773. https://doi.org/10.1016/j.pt.2023.06.009

Han, D., Nagpal, S., & Bauhoff, S. (2022). The quality of primary care in cambodia: An assessment of knowledge and effort of public sector maternal and child care providers. *Health Systems & Reform*, *8*(1), 2124903. https://doi.org/10.1080/23288604.2022.2124903

Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W., & Borriello, G. (2010). *Open data kit: Tools to build information services for developing regions*. 112. https://doi.org/10.1145/2369220.2369236

Haug, C. J., Kieny, M. P., & Murgue, B. (2016). The zika challenge. *New England Journal of Medicine*, *374*(19), 1801–1803. https://doi.org/10.1056/NEJMp1603734

Health Metrics, I. for, & Evaluation. (2019). *Global burden of disease study 2019 (GBD 2019) data input sources tool | GHDx*. https://ghdx.healthdata.org/gbd-2019/data-input-sources

Heath, K., & Hill, A. (2024). WHO hepatitis c elimination targets: The global equity challenge. *The Lancet Gastroenterology & Hepatology*, *9*(4), 286–288. https://doi.org/10.1016/S2468-1253(23)00408-9

Heinze, G., Wallisch, C., & Dunkler, D. (2018). Variable selection – A review and recommendations for the practicing statistician. *Biometrical Journal*, *60*(3), 431–449. https://doi.org/10.1002/bimj.201700067

Hiller, J., Schatz, K., & Drexler, H. (2017). Gender influence on health and risk behavior in primary prevention: a systematic review. *Journal of Public Health*, *25*(4), 339–349. https://doi.org/10.1007/s10389-017-0798-z

Hinkle, D. E., Wiersma, W., & Jurs, S. G. (1988). *Solutions manual: Applied statistics for the behavioral sciences*. Houghton Mifflin.

Hofmann, N., Mwingira, F., Shekalaghe, S., Robinson, L. J., Mueller, I., & Felger, I. (2015). Ultra-Sensitive Detection of Plasmodium falciparum by Amplification of Multi-Copy Subtelomeric Targets. *PLOS Medicine*, *12*(3), e1001788. https://doi.org/10.1371/journal.pmed.1001788

Hosmer, D. W., & Lemesbow, S. (1980). Goodness of fit tests for the multiple logistic regression model. *Communications in Statistics - Theory and Methods*, *9*(10), 1043–1069. https://doi.org/10.1080/03610928008827941

Hossain, M. S., Noman, A. A., Mamun, S. A. A., & Mosabbir, A. A. (2023). Twenty-two years of dengue outbreaks in Bangladesh: epidemiology, clinical spectrum, serotypes, and future disease risks. *Tropical Medicine and Health*, *51*(1), 37. https://doi.org/10.1186/s41182-023-00528-6

Hotez, P. J., Bottazzi, M. E., Strych, U., Chang, L.-Y., Lim, Y. A. L., Goodenow, M. M., & AbuBakar, S. (2015). Neglected tropical diseases among the Association of Southeast Asian Nations (ASEAN): overview and update. *PLoS neglected tropical diseases*, *9*(4), e0003575. https://doi.org/10.1371/journal.pntd.0003575

Howe, L. D., Galobardes, B., Matijasevich, A., Gordon, D., Johnston, D., Onwujekwe, O., Patel, R., Webb, E. A., Lawlor, D. A., & Hargreaves, J. R. (2012). Measuring socio-economic position for epidemiological studies in low- and middle-income countries: A methods of measurement in epidemiology paper. *International Journal of Epidemiology*, *41*(3), 871–886. https://doi.org/10.1093/ije/dys037

Huffman, M. D., Xavier, D., & Perel, P. (2017). Uses of polypills for cardiovascular disease and evidence to date. *The Lancet*, *389*(10073), 1055–1065. https://doi.org/10.1016/S0140-6736(17)30553-6

Hunsawong, T., Buddhari, D., Rungrojcharoenkit, K., Suthangkornkul, R., Mongkolsirichaikul, D., Lohachanakul, J., Tayong, K., Sirikajornpan, K., Rodpradit, P., Poolpanichupatam, Y., Klungthong, C., Utennam, D., Kaewhiran, S., Cotrone, T. S., Fernandez, S., & Jones, A. R. (2022). Anti-arbovirus antibodies cross-react with severe acute respiratory syndrome coronavirus 2. *Microbiology Spectrum*, *10*(6), e02639–22. https://doi.org/10.1128/spectrum.02639-22

ICF. (2020). *Demographic and health survey interviewer's manual*. ICF. https://dhsprogram.com/publications/publication-dhsm1-dhs-questionnaires-and-manuals.cfm

ICF International. (2012). *Demographic and health survey sampling and household listing manual*. ICF International.

Idler, E. L., & Benyamini, Y. (1997). Self-rated health and mortality: a review of twenty-seven community studies. *Journal of Health and Social Behavior*, *38*(1), 21–37.

Institute for Health Metrics and Evaluation. (2021). *Global Burden of Disease Study 2021 (GBD 2021) Sources Tool | GHDx*. https://ghdx.healthdata.org/gbd-2021/sources.

Ir, P., Men, C., Lucas, H., Meessen, B., Decoster, K., Bloom, G., & Damme, W. V. (2010). Self-Reported Serious Illnesses in Rural Cambodia: A Cross-Sectional Survey. *PLOS ONE*, *5*(6), e10930. https://doi.org/10.1371/journal.pone.0010930

Islam, Md. A., Mahmud, Md. S., Das, S., & Razu, S. R. (2023). Socioeconomic Determinants of Household Size in Bangladesh: Evidence from the Bangladesh Demographic and Health Survey Data. *Dr. Sulaiman Al Habib Medical Journal*, *5*(1), 10–22. https://doi.org/10.1007/s44229-022-00025-8

Jampaklay, A. (2020). *Internal Migration in Thailand* (M. Bell, A. Bernard, E. Charles-Edwards, & Y. Zhu, Eds.; pp. 185–206). Springer International Publishing. https://doi.org/10.1007/978-3-030-44010-7_10

Janssen, M. F., Szende, A., Cabases, J., Ramos-Goñi, J. M., Vilagut, G., & König, H. H. (2019). Population norms for the EQ-5D-3L: A cross-country analysis of population surveys for 20 countries. *The European Journal of Health Economics*, *20*(2), 205–216. https://doi.org/10.1007/s10198-018-0955-5

Jaruratanasirikul, S., Thammaratchuchai, S., & Sriplung, H. (2017). Trends of childhood diabetes in Southern Thailand: 20-year experience in a tertiary medical center. *World journal of pediatrics: WJP*, *13*(6), 566–570. https://doi.org/10.1007/s12519-017-0049-y

Jellinger, P. S., Handelsman, Y., Rosenblit, P. D., Bloomgarden, Z. T., Fonseca, V. A., Garber, A. J., Grunberger, G., Guerin, C. K., Bell, D. S. H., Mechanick, J. I., Pessah-Pollack, R., Wyne, K., Smith, D., Brinton, E. A., Fazio, S., Davidson, M., Jellinger, P. S., Handelsman, Y., Bell, D. S. H., ... Davidson, M. H. (2017). American association of clinical endocrinologists and american college of endocrinology guidelines for management of dyslipidemia and prevention of cardiovascular disease. *Endocrine Practice*, *23*, 1–87. https://doi.org/10.4158/EP171764.APPGL

Jeroen K Van Ginneken, & George Groenewold. (2012). A single-vs. Multi-item self-rated health status measure: A 21-country study. *The Open Public Health Journal*, 1–9. https://apps.who.int/healthinfo/systems/surveydata/index.php/citations/52427

Jinia Afroz, Fatema Tuz Jubyda, Sanzida Sharmin, Masud Rana, Amit Kumar Dey, Tasmia Farzana, & Murshed Hasan Sarkar. (2023). Prevalence of hepatitis b and c, and syphilis among aspirant migrant workers of bangladesh. *Afri Health*

Sci., *23*(2), 161–168. https://doi.org/https://dx.doi.org/10.4314/ahs.v23i2.17

Jobayer, M., Chowdhury, S. S., Shamsuzzaman, S. M., & Islam, M. S. (2016). Prevalence of Hepatitis B Virus, Hepatitis C Virus, and HIV in Overseas Job Seekers of Bangladesh with the Possible Routes of Transmission. *Mymensingh medical journal: MMJ*, *25*(3), 530–535.

Joseph, P., Roshandel, G., Gao, P., Pais, P., Lonn, E., Xavier, D., Avezum, A., Zhu, J., Liu, L., Sliwa, K., Gamra, H., Bangdiwala, S. I., Teo, K., Diaz, R., Dans, A., Lopez-Jaramillo, P., Prabhakaran, D., Castellano, J. M., Fuster, V., ... Yusuf, S. (2021). Fixed-dose combination therapies with and without aspirin for primary prevention of cardiovascular disease: An individual participant data meta-analysis. *The Lancet*, *398*(10306), 1133–1146. https://doi.org/10.1016/S0140-6736(21)01827-4

K. Van Ginneken, J., & Groenewold, G. (2012). A Single- . Multi-Item Self-Rated Health Status Measure: A 21-Country Study. *The Open Public Health Journal*, *5*(1). https://doi.org/10.2174/1874944501205010001

Kaehler, N., Adhikari, B., Cheah, P. Y., Seidlein, L. von, Day, N. P. J., Dondorp, A. M., & Pell, C. (2022). Community engagement for malaria elimination in the Greater Mekong Sub-region: a qualitative study among malaria researchers and policymakers. *Malaria Journal*, *21*(1), 46. https://doi.org/10.1186/s12936-022-04069-x

Kaikeaw, S., Punpuing, S., Chamchan, C., & Prasartkul, P. (2023). Socioeconomic inequalities in health outcomes among thai older population in the era of universal health coverage: Trends and decomposition analysis. *International Journal for Equity in Health*, *22*(1), 144. https://doi.org/10.1186/s12939-023-01952-0

Kamal, S. M. M., Hossain, A., Sultana, S., Begum, V., Haque, N., Ahmed, J., Rahman, T. M. A., Hyder, K. A., Hossain, S., Rahman, M., Ahsan, C. R., Aung, K. J. M., Islam, A., Hasan, R., & Van Deun, A. (2015). Anti-tuberculosis drug resistance in Bangladesh: Reflections from the first nationwide survey. *The*

International Journal of Tuberculosis and Lung Disease : The Official Journal of the International Union Against Tuberculosis and Lung Disease, *19*(2), 151–156. https://doi.org/10.5588/ijtld.14.0200

Kaptoge, S., Pennells, L., Bacquer, D. D., Cooney, M. T., Kavousi, M., Stevens, G., Riley, L. M., Savin, S., Khan, T., Altay, S., Amouyel, P., Assmann, G., Bell, S., Ben-Shlomo, Y., Berkman, L., Beulens, J. W., Björkelund, C., Blaha, M., Blazer, D. G., … Angelantonio, E. D. (2019). World health organization cardiovascular disease risk charts: Revised models to estimate risk in 21 global regions. *The Lancet Global Health*, *7*(10), e1332–e1345. https://doi.org/10.1016/S2214-109X(19)30318-3

Kasim, S. S., Ibrahim, N., Malek, S., Ibrahim, K. S., Aziz, M. F., Song, C., Chia, Y. C., Ramli, A. S., Negishi, K., & Mat Nasir, N. (2023). Validation of the general Framingham Risk Score (FRS), SCORE2, revised PCE and WHO CVD risk scores in an Asian population. *The Lancet Regional Health. Western Pacific*, *35*, 100742. https://doi.org/10.1016/j.lanwpc.2023.100742

Kayesh, M. E. H., Khalil, I., Kohara, M., & Tsukiyama-Kohara, K. (2023). Increasing Dengue Burden and Severe Dengue Risk in Bangladesh: An Overview. *Tropical Medicine and Infectious Disease*, *8*(1), 32. https://doi.org/10.3390/tropicalmed8010032

Kenmoe, S., Tagnouokam, P. A. N., Nde, C. K., Mella-Tamko, G. F., & Njouom, R. (2018). Using dried blood spot for the detection of HBsAg and anti-HCV antibodies in cameroon. *BMC Research Notes*, *11*, 818. https://doi.org/10.1186/s13104-018-3931-3

Kheng, C., Meas, V., Pen, S., Sar, P., & Turner, P. (2020). Salmonella typhi and paratyphi a infections in cambodian children, 2012–2016. *International Journal of Infectious Diseases*, *97*, 334–336. https://doi.org/10.1016/j.ijid.2020.06.054

Kisiangani, I., Mohamed, S. F., Kyobutungi, C., Tindana, P., Ghansah, A., Ramsay, M., & Asiki, G. (2022). Perspectives on returning individual and aggregate genomic research results to study participants and communities in Kenya: a

qualitative study. *BMC Medical Ethics*, *23*(1), 27. https://doi.org/10.1186/s12910-022-00767-y

Komada, K., Sugiyama, M., Vongphrachanh, P., Xeuatvongsa, A., Khamphaphongphane, B., Kitamura, T., Kiyohara, T., Wakita, T., Oshitani, H., & Hachiya, M. (2015). Seroprevalence of chronic hepatitis B, as determined from dried blood spots, among children and their mothers in central Lao People's Democratic Republic: a multistage, stratified cluster sampling survey. *International journal of infectious diseases: IJID: official publication of the International Society for Infectious Diseases*, *36*, 21–26. https://doi.org/10.1016/j.ijid.2015.04.020

Kshatri, J. S., Bhattacharya, D., Praharaj, I., Mansingh, A., Parai, D., Kanungo, S., Palo, S. K., Giri, S., Pattnaik, M., Barik, S. R., Dash, G. C., Choudhary, H. R., Turuk, J., Mandal, N. N., & Pati, S. (2021). Seroprevalence of SARS-CoV-2 in bhubaneswar, india: Findings from three rounds of community surveys. *Epidemiology and Infection*, *149*, e139. https://doi.org/10.1017/S0950268821000972

Kuijpers, L. M. F., Phe, T., Veng, C. H., Lim, K., Ieng, S., Kham, C., Fawal, N., Fabre, L., Hello, S. L., Vlieghe, E., Weill, F.-X., Jacobs, J., & Peetermans, W. E. (2017). The clinical and microbiological characteristics of enteric fever in Cambodia, 2008-2015. *PLOS Neglected Tropical Diseases*, *11*(9), e0005964. https://doi.org/10.1371/journal.pntd.0005964

Lancet, T. (2017). Polypills: An essential medicine for cardiovascular disease. *The Lancet*, *389*(10073), 984. https://doi.org/10.1016/S0140-6736(17)30695-5

Laohaudomchok, W., Nankongnab, N., Siriruttanapruk, S., Klaimala, P., Lianchamroon, W., Ousap, P., Jatiket, M., Kajitvichyanukul, P., Kitana, N., Siriwong, W., Hemachudhah, T., Satayavivad, J., Robson, M., Jaacks, L., Barr, D. B., Kongtip, P., & Woskie, S. (2020). Pesticide use in thailand: Current situation, health risks, and gaps in research and policy. *Human and Ecological*

Risk Assessment: An International Journal, *27*(5), 1147–1169. https://doi.org/10.1080/10807039.2020.1808777

Laoprasopwattana, K., Suntharasaj, T., Petmanee, P., Suddeaugrai, O., & Geater, A. (2016). Chikungunya and dengue virus infections during pregnancy: seroprevalence, seroincidence and maternal–fetal transmission, southern Thailand, 2009–2010. *Epidemiology & Infection*, *144*(2), 381–388. https://doi.org/10.1017/S0950268815001065

Leonardi, M., Bickenbach, J., Ustun, T. B., Kostanjsek, N., Chatterji, S., & MHADIE Consortium. (2006). The definition of disability: what is in a name? *Lancet (London, England)*, *368*(9543), 1219–1221. https://doi.org/10.1016/S0140-6736(06)69498-1

Leung, C. Y., Huang, H.-L., Abe, S. K., Saito, E., Islam, Md. R., Rahman, Md. S., Ikeda, A., Sawada, N., Tamakoshi, A., Gao, Y.-T., Koh, W.-P., Shu, X.-O., Sakata, R., Tsuji, I., Kim, J., Park, S. K., Nagata, C., You, S.-L., Yuan, J.-M., … Inoue, M. (2022). Association of marital status with total and cause-specific mortality in asia. *JAMA Network Open*, *5*(5), e2214181. https://doi.org/10.1001/jamanetworkopen.2022.14181

Levy, D. T., Graham, A. L., Mabry, P. L., Abrams, D. B., & Orleans, C. T. (2010). Modeling the impact of smoking-cessation treatment policies on quit rates. *American Journal of Preventive Medicine*, *38*(3, Supplement), S364–S372. https://doi.org/10.1016/j.amepre.2009.11.016

Li, X., Yang, C., Lv, J., Liu, H., Zhang, L., Yin, M., Guo, Z., & Zhang, R. (2023). Global, regional, and national epidemiology of migraine and tension-type headache in youths and young adults aged 15–39 years from 1990 to 2019: Findings from the global burden of disease study 2019. *The Journal of Headache and Pain*, *24*(1), 126. https://doi.org/10.1186/s10194-023-01659-1

Lim, C., Paris, D. H., Blacksell, S. D., Laongnualpanich, A., Kantipong, P., Chierakul, W., Wuthiekanun, V., Day, N. P. J., Cooper, B. S., & Limmathurotsakul, D. (2015). How to Determine the Accuracy of an Alternative Diagnostic Test when It Is Actually Better than the Reference Tests: A Re-Evaluation of

Diagnostic Tests for Scrub Typhus Using Bayesian LCMs. *PloS One*, *10*(5), e0114930. https://doi.org/10.1371/journal.pone.0114930

Limkittikul, K., Chanthavanich, P., Lee, K. S., Lee, J.-S., Chatchen, S., Lim, S.-K., Arunsodsai, W., Yoon, I.-K., & Lim, J. K. (2022). Dengue virus seroprevalence study in Bangphae district, Ratchaburi, Thailand: A cohort study in 2012-2015. *PLOS Neglected Tropical Diseases*, *16*(1), e0010021. https://doi.org/10.1371/journal.pntd.0010021

Linsuwanon, P., Auysawasdi, N., Wongwairot, S., Leepitakrat, S., Rodkhamtook, W., Wanja, E., Monkanna, T., Wegner, M., Davidson, S., Poovorawan, Y., Poole-Smith, B., Limsuwon, C., & McCardle, P. (2021). Assessing scrub typhus and rickettsioses transmission risks in the chiang rai province of northern thailand. *Travel Medicine and Infectious Disease*, *42*, 102086. https://doi.org/10.1016/j.tmaid.2021.102086

Liverani, M., Nguon, C., Sok, R., Kim, D., Nou, P., Nguon, S., & Yeung, S. (2017). Improving access to health care amongst vulnerable populations: a qualitative study of village malaria workers in Kampot, Cambodia. *BMC Health Services Research*, *17*(1), 1–11. https://doi.org/10.1186/s12913-017-2282-4

Low, V. L., Tan, T. K., Khoo, J. J., Lim, F. S., & AbuBakar, S. (2020). An overview of rickettsiae in southeast asia: Vector-animal-human interface. *Acta Tropica*, *202*, 105282. https://doi.org/10.1016/j.actatropica.2019.105282

Lubell, Y., Chandna, A., Smithuis, F., White, L., Wertheim, H. F. L., Redard-Jacot, M., Katz, Z., Dondorp, A., Day, N., White, N., & Dittrich, S. (2019). Economic considerations support c-reactive protein testing alongside malaria rapid diagnostic tests to guide antimicrobial therapy for patients with febrile illness in settings with low malaria endemicity. *Malaria Journal*, *18*(1), 442. https://doi.org/10.1186/s12936-019-3059-5

Lynch, E., Falq, G., Sun, C., Bunchhoeung, P. D. T., Huerga, H., Loarec, A., Dousset, J.-P., Marquardt, T., Paih, M. L., & Maman, D. (2021). Hepatitis C viraemic and seroprevalence and risk factors for positivity in Northwest

Cambodia: a household cross-sectional serosurvey. *BMC infectious diseases*, *21*(1), 223. https://doi.org/10.1186/s12879-021-05826-0

Mahipala, P., Dorji, G., Tisocki, K., & Rani, M. (2019). A critical review of addressing cardiovascular and other non-communicable diseases through a primary health care approach in the south-east asia region. *Cardiovascular Diagnosis and Therapy*, *9*(2), 150–157. https://doi.org/10.21037/cdt.2018.09.03

Makovski, T. T., Schmitz, S., Zeegers, M. P., Stranges, S., & Akker, M. van den. (2019). Multimorbidity and quality of life: Systematic literature review and meta-analysis. *Ageing Research Reviews*, *53*, 100903. https://doi.org/10.1016/j.arr.2019.04.005

Mamun-Al-Mahtab, Karim, F., Foster, G., Akbar, S. F., & Rahman, S. (2011). Prevalence and risk factors of asymptomatic hepatitis c virus infection in bangladesh. *Journal of Clinical and Experimental Hepatology*, *1*(1), 13–16. https://doi.org/10.1016/S0973-6883(11)60111-4

Maneewatchararangsri, S., Doungchawee, G., Kalambaheti, T., Luvira, V., Soonthornworasiri, N., Vattanatham, P., Chaisri, U., & Adisakwattana, P. (2021). Evaluation of a genus-specific rGroEL1-524 IgM-ELISA and commercial ELISA kits during the course of leptospirosis in thailand. *Scientific Reports*, *11*, 19785. https://doi.org/10.1038/s41598-021-99377-8

Mannino, D. M., & Buist, A. S. (2007). Global burden of COPD: risk factors, prevalence, and future trends. *Lancet (London, England)*, *370*(9589), 765–773. https://doi.org/10.1016/S0140-6736(07)61380-4

Marcus, M. E., Ebert, C., Geldsetzer, P., Theilmann, M., Bicaba, B. W., Andall-Brereton, G., Bovet, P., Farzadfar, F., Gurung, M. S., Houehanou, C., Malekpour, M.-R., Martins, J. S., Moghaddam, S. S., Mohammadi, E., Norov, B., Quesnel-Crooks, S., Wong-McClure, R., Davies, J. I., Hlatky, M. A., … Vollmer, S. (2021). Unmet need for hypercholesterolemia care in 35 low- and middle-income countries: A cross-sectional study of nationally representative surveys. *PLOS Medicine*, *18*(10), e1003841. https://doi.org/10.1371/journal.pmed.1003841

Marjenberg, Z., Wright, C., Pooley, N., Cheung, K. W., Shimakawa, Y., Vargas-Zambrano, J. C., & Vidor, E. (2022). Hepatitis B surface antigen prevalence and the rates of mother-to-child transmission of hepatitis b virus after the introduction of infant vaccination programs in south east asia and western pacific regions: A systematic review. *International Journal of Infectious Diseases*, *124*, 65–75. https://doi.org/10.1016/j.ijid.2022.09.003

Masud Ahmed, S. (2001). Differing Health and Health-Seeking Behaviour: Ethnic Minorities of the Chittagong Hill Tracts, Bangladesh. *Asia Pacific Journal of Public Health*, *13*(2), 100–108. https://doi.org/10.1177/101053950101300208

Mathers, C. D., & Loncar, D. (2006). Projections of Global Mortality and Burden of Disease from 2002 to 2030. *PLOS Medicine*, *3*(11), e442. https://doi.org/10.1371/journal.pmed.0030442

Mayxay, M., Sengvilaipaseuth, O., Chanthongthip, A., Dubot-Pérès, A., Rolain, J.-M., Parola, P., Craig, S. B., Tulsiani, S., Burns, M.-A., Khanthavong, M., Keola, S., Pongvongsa, T., Raoult, D., Dittrich, S., & Newton, P. N. (2015). Causes of Fever in Rural Southern Laos. *The American journal of tropical medicine and hygiene*, *93*(3), 517–520. https://doi.org/10.4269/ajtmh.14-0772

Mensah, G. A., Roth, G. A., & Fuster, V. (2019). The global burden of cardiovascular diseases and risk factors. *JACC*, *74*(20), 2529–2532. https://doi.org/10.1016/j.jacc.2019.10.009

Metrics for Management. (2016). *The Cambodia Equity Tool*. https://www.equitytool.org/cambodia/

Metrics for Management. (2022a). *The Thailand Equity Tool*. https://www.equitytool.org/thailand/

Metrics for Management. (2022b). *The Bangladesh EquityTool*. https://www.equitytool.org/bangladesh/

Micallef, J. M., Kaldor, J. M., & Dore, G. J. (2006). Spontaneous viral clearance following acute hepatitis C infection: a systematic review of longitudinal studies.

Journal of Viral Hepatitis, *13*(1), 34–41. https://doi.org/10.1111/j.1365-2893.2005.00651.x

Mickey, R. M., & Greenland, S. (1989). The impact of confounder selection criteria on effect estimation. *American Journal of Epidemiology*, *129*(1), 125–137. https://doi.org/10.1093/oxfordjournals.aje.a115101

Milligan, P., Njie, A., & Bennett, S. (2004). Comparison of two cluster sampling methods for health surveys in developing countries. *International Journal of Epidemiology*, *33*(3), 469–476. https://doi.org/10.1093/ije/dyh096

Ministry of Health & Family Welfare of Bangladesh. (2021). *National Strategic Plan For Malaria Elimination In Bangladesh: 2021-2025*.

Ministry of Health and Family Welfare of Bangladesh. (2022). *Health Bulletin 2022*.

Ministry of Health Cambodia. (2020). *National strategic plan for viral hepatitis b and c. (NSP 2020–2024)*. http://cdcmoh.gov.kh/prevention-control/viral-hepatitis

Ministry of Health of Cambodia. (2007). *Health sector strategic plan: 2008–15*.

Ministry of Health of Cambodia. (2013). *National strategic plan for the prevention and control of non-communicable diseases (2013–2020)*.

Ministry of Health of Cambodia. (2023). *2023 STEPS Country report Cambodia*. https://www.who.int/publications/m/item/2023-steps-country-report-cambodia

Mipatrini, D., Balcilar, M., Dembech, M., Ergüder, T., & Ursu, P. (2019). *Survey on the health status, services utilization and determinants of health of the Syrian refugee population in Turkey (2019)*. https://doi.org/10.13140/RG.2.2.20296.37124

Mitra, S., Posarac, A., & Vick, B. C. (2011). *Disability and Poverty in Developing Countries: A Snapshot from the World Health Survey* ({{SSRN Scholarly Paper}} No. 1908128). World Bank Social Protection Working Paper No. 1109. https://doi.org/10.2139/ssrn.1908128

Moonpanane, K., Pitchalard, K., Thepsaw, J., Singkhorn, O., & Potjanamart, C. (2022). Healthcare service utilization of hill tribe children in underserved communities in Thailand: barriers to access. *BMC Health Services Research*, *22*(1), 1114. https://doi.org/10.1186/s12913-022-08494-1

Moroz, H. E., Naddeo, J. J., Ariyapruchya, K., Glinskaya, E. E., Jain, H., Lamanna, F., Laowong, P., Nair, A., Palacios, R. J., Tansanguanwong, P., Viriyataveekul, S., Walker, T., & Yang, J. (2022). *Aging and the Labor Market in Thailand : Labor Markets and Social Policy in a Rapidly Transforming and Aging Thailand : Aging and the Labor Market in Thailand (English)*. https://policycommons.net/artifacts/2288512/aging-and-the-labor-market-in-thailand/3048799/

Murray, C. J. L. (2022). The Global Burden of Disease Study at 30 years. *Nature Medicine*, *28*(10), 2019–2026. https://doi.org/10.1038/s41591-022-01990-1

Murray, G. L. (2013). The lipoprotein LipL32, an enigma of leptospiral biology. *Veterinary Microbiology*, *162*(2), 305–314. https://doi.org/10.1016/j.vetmic.2012.11.005

Mutz, J., & Lewis, C. M. (2022). Cross-classification between self-rated health and health status: longitudinal analyses of all-cause mortality and leading causes of death in the UK. *Scientific Reports*, *12*(1), 459. https://doi.org/10.1038/s41598-021-04016-x

Naghavi, M., Ong, K. L., Aali, A., Ababneh, H. S., Abate, Y. H., Abbafati, C., Abbasgholizadeh, R., Abbasian, M., Abbasi-Kangevari, M., Abbastabar, H., ElHafeez, S. A., Abdelmasseh, M., Abd-Elsalam, S., Abdelwahab, A., Abdollahi, M., Abdollahifar, M.-A., Abdoun, M., Abdulah, D. M., Abdullahi, A., … Murray, C. J. L. (2024). Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: A systematic analysis for the global burden of disease study 2021. *The Lancet*, *403*(10440), 2100–2132. https://doi.org/10.1016/S0140-6736(24)00367-2

National Institute of Statistics. (2022a). *General population census of Cambodia 2019. Series thematic report on age and sex composition.*

National Institute of Statistics. (2022b). *Report of Cambodia socio-economic survey 2021.*

National Institute of Statistics (NIH) Cambodia, MInistry of Health (MoH), & ICF. (2023). *Cambodia Demographic and Health Survey 2021–22.*

National Institute of Statistics, Directorate General for Health, & ICF International. (2015). *Cambodia Demographic and Health Survey 2014.*

National Statistical Office of Thailand. (2012). *The 2010 Population and Housing Census.*

National Statistical Office of Thailand. (2020a). *Thailand Multiple Indicator Cluster Survey 2019, Survey finding report.* National Statistical Office of Thailand.

National Statistical Office of Thailand. (2020b). *Thailand multiple indicator cluster survey 2019, survey finding report.* https://www.unicef.org/thailand/reports/thailand-multiple-indicator-cluster-survey-2019

National Statistical Office of Thailand. (2021). *The 2021 Health Behavior of Population Survey.* https://www.nso.go.th/nsoweb/nso/survey_detail/w6?set_lang=en

National Statistical Office of Thailand. (2023). *Number of Population from Registration by Age, Sex, Region and Province: 2021-2022.* http://statbbi.nso.go.th/staticreport/page

Neyhouser, C., Quinn, I., Hillgrove, T., Chan, R., Chhea, C., Peou, S., & Sambath, P. (2018). A qualitative study on gender barriers to eye care access in Cambodia. *BMC Ophthalmology, 18*(1), 217. https://doi.org/10.1186/s12886-018-0890-3

Ngernna, S., Rachaphaew, N., Thammapalo, S., Prikchoo, P., Kaewnah, O., Manopwisedjaroen, K., Phumchuea, K., Suansomjit, C., Roobsoong, W., Sattabongkot, J., Cui, L., & Nguitragool, W. (2019). *Case Report: Case Series of Human Plasmodium knowlesi Infection on the Southern Border of Thailand.* https://doi.org/10.4269/ajtmh.19-0063

Noranate, N., Takeda, N., Chetanachan, P., Sittisaman, P., A-nuegoonpipat, A., & Anantapreecha, S. (2014). Characterization of Chikungunya Virus-Like Particles. *PLOS ONE*, *9*(9), e108169. https://doi.org/10.1371/journal.pone.0108169

Nutbeam, D. (1986). Health promotion glossary. *Health Promotion*, *1*(1), 113–127. https://www.jstor.org/stable/45153790

O'Donnell, R. R., Rolfes, J., Wu, S., Abdalla, M., Marsiglia, F. F., Mei, P., An, P. L., Senanuch, P., Bhatarasakoon, P., Savuon, K., Koy, V., Tao, H., & Kessler, R. (2022). Evaluating the gap of integrated behavioral health programs for NCDs in China, Vietnam, Cambodia and Thailand. *Asian Journal of Health Sciences*, *8*(1), ID39. https://doi.org/10.15419/ajhs.v8i1.510

O'Flaherty, K., Roe, M., & Fowkes, F. J. (2022). The role of naturally acquired antimalarial antibodies in subclinical Plasmodium spp. infection. *Journal of Leukocyte Biology*, *111*(5), 1097–1105. https://doi.org/10.1002/JLB.5MR1021-537R

Olmen, J. van, Eggermont, N., Pelt, M. van, Hen, H., Man, J. de, Schellevis, F., Peters, D. H., & Bigdeli, M. (2016). Patient-centred innovation to ensure access to diabetes care in cambodia: The case of MoPoTsyo. *Journal of Pharmaceutical Policy and Practice*, *9*(1), 1. https://doi.org/10.1186/s40545-016-0050-1

Ork, V., Woodring, J., Shafiqul Hossain, Md., Wasley, A., Nagashima, S., Yamamoto, C., Chuon, C., Sugiyama, A., Ohisa, M., Akita, T., Ko, K., Mao, B., & Tanaka, J. (2019). Hepatitis b surface antigen seroprevalence among pre- and post-vaccine cohorts in cambodia, 2017. *Vaccine*, *37*(35), 5059–5066. https://doi.org/10.1016/j.vaccine.2019.06.073

Paakkari, L., & Okan, O. (2020). COVID-19: Health literacy is an underestimated problem. *The Lancet Public Health*, *5*(5), e249–e250. https://doi.org/10.1016/S2468-2667(20)30086-4

Palakai, R., Sornpaisarn, B., Sawangdee, Y., Chuanwan, S., Saonuam, P., Katewongsa, P., & Rehm, J. (2023). The cost-effectiveness of improved brief in-

terventions for tobacco cessation in thailand. *Frontiers in Public Health*, *11*, 1289561. https://doi.org/10.3389/fpubh.2023.1289561

Pantoja, T., Opiyo, N., Lewin, S., Paulsen, E., Ciapponi, A., Wiysonge, C. S., Herrera, C. A., Rada, G., Peñaloza, B., Dudley, L., Gagnon, M.-P., Marti, S. G., & Oxman, A. D. (2017). Implementation strategies for health systems in low-income countries: an overview of systematic reviews. *Cochrane Database of Systematic Reviews*, *9*. https://doi.org/10.1002/14651858.CD011086.pub2

Pattanaphesaj, J., Thavorncharoensap, M., Ramos-Goñi, J. M., Tongsiri, S., Ingsrisawang, L., & Teerawattananon, Y. (2018). The EQ-5D-5L Valuation study in Thailand. *Expert Review of Pharmacoeconomics & Outcomes Research*, *18*(5), 551–558. https://doi.org/10.1080/14737167.2018.1494574

Paul, K. K., Sazzad, H. M. S., Rahman, M., Sultana, S., Hossain, M. J., Ledermann, J. P., Burns, P., Friedman, M. S., Flora, M. S., Fischer, M., Hills, S., Luby, S. P., & Gurley, E. S. (2020). Hospital-based surveillance for Japanese encephalitis in Bangladesh, 2007–2016: Implications for introduction of immunization. *International Journal of Infectious Diseases*, *99*, 69–74. https://doi.org/10.1016/j.ijid.2020.07.026

Paul, R. C., Rahman, M., Wiesen, E., Patel, M., Banik, K. C., Sharif, A. R., Sultana, S., Rahman, M., Liyanage, J., Abeysinghe, N., Kamili, S., Murphy, T., Luby, S. P., & Mast, E. E. (2018). Hepatitis b surface antigen seroprevalence among prevaccine and vaccine era children in bangladesh. *The American Journal of Tropical Medicine and Hygiene*, *99*(3), 764–771. https://doi.org/10.4269/ajtmh.17-0721

Pell, C. L., Adhikari, B., Thwin, M. M., Kajeechiwa, L., Nosten, S., Nosten, F. H., Sahan, K. M., Smithuis, F. M., Nguyen, T.-N., Hien, T. T., Tripura, R., Peto, T. J., Sanann, N., Nguon, C., Pongvongsa, T., Phommasone, K., Mayxay, M., Mukaka, M., Peerawaranun, P., … Seidlein, L. von. (2019). Community engagement, social context and coverage of mass anti-malarial administration: Comparative findings from multi-site research in the Greater

Mekong sub-Region. *PLOS ONE*, *14*(3), e0214280. https://doi.org/10.1371/journal.pone.0214280

Peltzer, K., Pengpid, S., Puckpinyo, A., Yi, S., & Anh, L. V. (2016). The utilization of traditional, complementary and alternative medicine for non-communicable diseases and mental disorders in health care patients in Cambodia, Thailand and Vietnam. *BMC complementary and alternative medicine*, *16*, 92. https://doi.org/10.1186/s12906-016-1078-0

Pirie, K., Peto, R., Reeves, G. K., Green, J., & Beral, V. (2013). The 21st century hazards of smoking and benefits of stopping: A prospective study of one million women in the UK. *The Lancet*, *381*(9861), 133–141. https://doi.org/10.1016/S0140-6736(12)61720-6

Pirillo, A., Casula, M., Olmastroni, E., Norata, G. D., & Catapano, A. L. (2021). Global epidemiology of dyslipidaemias. *Nature Reviews Cardiology*, *18*(10), 689–700. https://doi.org/10.1038/s41569-021-00541-4

Population Research, N. I. of, Training, & ICF. (2020). *Bangladesh Demographic and Health Survey 2017-18*. https://dhsprogram.com/publications/publication-FR344-DHS-Final-Reports.cfm

Posuwan, N., Wanlapakorn, N., Sa-nguanmoo, P., Wasitthankasem, R., Vichaiwattana, P., Klinfueng, S., Vuthitanachot, V., Sae-lao, S., Foonoi, M., Fakthongyoo, A., Makaroon, J., Srisingh, K., Asawarachun, D., Owatanapanich, S., Wutthiratkowit, N., Tohtubtiang, K., Yoocharoen, P., Vongpunsawad, S., & Poovorawan, Y. (2016). The Success of a Universal Hepatitis B Immunization Program as Part of Thailand's EPI after 22 Years' Implementation. *PLOS ONE*, *11*(3), e0150499. https://doi.org/10.1371/journal.pone.0150499

Presser, S., Couper, M. P., Lessler, J. T., Martin, E., Martin, J., Rothgeb, J. M., & Singer, E. (2004). Methods for testing and evaluating survey questions. *Public Opinion Quarterly*, *68*(1), 109–130. https://doi.org/10.1093/poq/nfh008

Preventive, N. I. of, & Social Medicine. (2018). *National STEPS survey for non-communicable diseases risk factors in Bangladesh 2018*. https://apps.who.int/iris/handle/10665/332886

Pu, F., Lin, J., Wei, Y., Li, J., Liao, X., Shi, L., Zeng, X., & Hu, W. (2024). Association of dietary behavior patterns of middle-aged and older adults with their obesity metabolic phenotype: A cross-sectional study. *BMC Public Health*, *24*(1), 2311. https://doi.org/10.1186/s12889-024-19781-3

R Core Team. (2024). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing.

Rachmat, A., Kelly, G. C., Hontz, R. D., Supaprom, C., Heang, V., Hip, P., Garcia-Rivera, J. A., Prom, S., Chhea, C., Sutherland, I. W., Corson, K. S., & Letizia, A. G. (2022). Clinical and epidemiologic evaluation of a 2020 chikungunya outbreak in Cambodia. *BMC Infectious Diseases*, *22*(1), 949. https://doi.org/10.1186/s12879-022-07936-9

Raghupathi, V., & Raghupathi, W. (2020). The influence of education on health: An empirical assessment of OECD countries for the period 1995–2015. *Archives of Public Health*, *78*(1), 20. https://doi.org/10.1186/s13690-020-00402-5

Razzaque, A., Nahar, L., Akter Khanam, M., & Kim Streatfield, P. (2010). Socio-demographic differentials of adult health indicators in Matlab, Bangladesh: self-rated health, health state, quality of life and disability level. *Global Health Action*, *3*. https://doi.org/10.3402/gha.v3i0.4618

Reiter, J. T., Dobmeyer, A. C., & Hunter, C. L. (2018). The Primary Care Behavioral Health (PCBH) Model: An Overview and Operational Definition. *Journal of Clinical Psychology in Medical Settings*, *25*(2), 109–126. https://doi.org/10.1007/s10880-017-9531-x

Revicki, D. A., Kleinman, L., & Cella, D. (2014). A history of health-related quality of life outcomes in psychiatry. *Dialogues in Clinical Neuroscience*, *16*(2), 127–135. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4140507/

Rosa, M. C. da, Martins, G., Rocha, B. R., Correia, L., Ferronato, G., Lilenbaum, W., & Dellagostin, O. A. (2019). Assessment of the immunogenicity of the leptospiral LipL32, LigAni, and LigBrep recombinant proteins in the sheep model. *Comparative Immunology, Microbiology and Infectious Diseases*, *65*, 176–180. https://doi.org/10.1016/j.cimid.2019.05.012

Rosanas-Urgell, A., Mueller, D., Betuela, I., Barnadas, C., Iga, J., Zimmerman, P. A., Portillo, H. A. del, Siba, P., Mueller, I., & Felger, I. (2010). Comparison of diagnostic methods for the detection and quantification of the four sympatric Plasmodium species in field samples from Papua New Guinea. *Malaria Journal*, *9*, 361. https://doi.org/10.1186/1475-2875-9-361

Roshandel, G., Khoshnia, M., Poustchi, H., Hemming, K., Kamangar, F., Gharavi, A., Ostovaneh, M. R., Nateghi, A., Majed, M., Navabakhsh, B., Merat, S., Pourshams, A., Nalini, M., Malekzadeh, F., Sadeghi, M., Mohammadifard, N., Sarrafzadegan, N., Naemi-Tabiei, M., Fazel, A., ... Malekzadeh, R. (2019). Effectiveness of polypill for primary and secondary prevention of cardiovascular diseases (PolyIran): A pragmatic, cluster-randomised trial. *The Lancet*, *394*(10199), 672–683. https://doi.org/10.1016/S0140-6736(19)31791-X

RStudio Team. (2020). *RStudio*. RStudio, PBC,.

Rutstein, S. O., & Johnson, K. (2004). *The DHS wealth index*. https://dhsprogram.com/publications/publication-cr6-comparative-reports.cfm

Saha, U. R., Chattapadhayay, A., & Richardus, J. H. (2019). Trends, prevalence and determinants of childhood chronic undernutrition in regional divisions of Bangladesh: Evidence from demographic health surveys, 2011 and 2014. *PloS one*, *14*(8), e0220062. https://doi.org/10.1371/journal.pone.0220062

Sakboonyarat, B., Pima, W., Chokbumrungsuk, C., Pimpak, T., Khunsri, S., Ukritchon, S., Imjaijitt, W., Mungthin, M., Kaewput, W., Bhopdhornangkul, B., Sathavarodom, N., Tatsanavivat, P., & Rangsin, R. (2021). National trends in the prevalence of glycemic control among patients with type 2 diabetes receiving continuous care in Thailand from 2011 to 2018. *Scientific Reports*, *11*(1), 14260. https://doi.org/10.1038/s41598-021-93733-4

Sakboonyarat, B., Poovieng, J., Srisawat, P., Hatthachote, P., Mungthin, M., Rangsin, R., & Jongcherdchootrakul, K. (2023). Prevalence, awareness, and control of hypertension and associated factors among Royal Thai Army personnel in thailand from 2017 to 2021. *Scientific Reports*, *13*, 6946. https://doi.org/10.1038/s41598-023-34023-z

Sakboonyarat, B., Pornpongsawad, C., Sangkool, T., Phanmanas, C., Kesonphaet, N., Tangthongtawi, N., Limsakul, A., Assavapisitkul, R., Thangthai, T., Janenopparkarnjana, P., Varodomvitaya, P., Dachoviboon, W., Laohasara, J., Kruthakool, N., Limprasert, S., Mungthin, M., Hatthachote, P., & Rangsin, R. (2020). Trends, prevalence and associated factors of obesity among adults in a rural community in Thailand: serial cross-sectional surveys, 2012 and 2018. *BMC Public Health*, *20*(1), 850. https://doi.org/10.1186/s12889-020-09004-w

Salje, H., Cummings, D. A. T., Rodriguez-Barraquer, I., Katzelnick, L. C., Lessler, J., Klungthong, C., Thaisomboonsuk, B., Nisalak, A., Weg, A., Ellison, D., Macareo, L., Yoon, I.-K., Jarman, R., Thomas, S., Rothman, A. L., Endy, T., & Cauchemez, S. (2018). Reconstruction of antibody dynamics and infection histories to evaluate dengue risk. *Nature*, *557*(7707), 719–723. https://doi.org/10.1038/s41586-018-0157-4

Salje, H., Paul, K. K., Paul, R., Rodriguez-Barraquer, I., Rahman, Z., Alam, M. S., Rahman, M., Al-Amin, H. M., Heffelfinger, J., & Gurley, E. (2019). Nationally-representative serostudy of dengue in bangladesh allows generalizable disease burden estimates. *eLife*, *8*, e42869. https://doi.org/10.7554/eLife.42869

Schmelzer, J., Dugan, E., Blach, S., Coleman, S., Cai, Z., DePaola, M., Estes, C., Gamkrelidze, I., Jerabek, K., Ma, S., Montoya, S., Razavi-Shearer, D., Razavi-Shearer, K., Robbins-Scott, S., Razavi, H., & El Sayed, M. H. (2020). Global prevalence of hepatitis C virus in children in 2018: a modelling study. *The Lancet Gastroenterology & Hepatology*, *5*(4), 374–392. https://doi.org/10.1016/S2468-1253(19)30385-1

Sen, A. (2015). Universal health care: The affordable dream. *Harvard Public Health Review*, *5*, 1–8. https://www.jstor.org/stable/48503117

Shalowitz, D. I., & Miller, F. G. (2008). Communicating the Results of Clinical Research to Participants: Attitudes, Practices, and Future Directions. *PLOS Medicine*, *5*(5), e91. https://doi.org/10.1371/journal.pmed.0050091

Shrestha, N. (2020). Detecting Multicollinearity in Regression Analysis. *American Journal of Applied Mathematics and Statistics*, *8*, 39–42. https://doi.org/10.12691/ajams-8-2-1

Shrestha, P., Dahal, P., Ogbonnaa-Njoku, C., Das, D., Stepniewska, K., Thomas, N. V., Hopkins, H., Crump, J. A., Bell, D., Newton, P. N., Ashley, E. A., & Guérin, P. J. (2020). Non-malarial febrile illness: A systematic review of published aetiological studies and case reports from Southern Asia and South-eastern Asia, 1980–2015. *BMC Medicine*, *18*(1), 299. https://doi.org/10.1186/s12916-020-01745-0

Shrestha, P., Roberts, T., Homsana, A., Myat, T. O., Crump, J. A., Lubell, Y., & Newton, P. N. (2018). Febrile illness in asia: Gaps in epidemiology, diagnosis and management for informing health policy. *Clinical Microbiology and Infection*, *24*(8), 815–826. https://doi.org/10.1016/j.cmi.2018.03.028

Smith, G. (2018). Step away from stepwise. *Journal of Big Data*, *5*(1), 32. https://doi.org/10.1186/s40537-018-0143-6

Somprasong, K., Apidechkul, T., Kullawong, N., Upala, P., Tamornpark, R., Chomchoei, C., Yeemard, F., Khunthason, S., Keawdounglek, V., & Wongfu, C. (2020). Prevalence of and factors associated with hypertension among the hill tribe population aged 35 years and over in northern thailand: A cross-sectional study. *American Journal of Cardiovascular Disease*, *10*(1), 6–16. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7218683/

Southeast Asia Tobacco Control Alliance. (2023). *SEATCA FCTC SCORECARD: Measuring implementation of the WHO framework convention on tobbaco control*.

Stanaway, J. D., Reiner, R. C., Blacker, B. F., Goldberg, E. M., Khalil, I. A., Troeger, C. E., Andrews, J. R., Bhutta, Z. A., Crump, J. A., Im, J., Marks, F., Mintz, E., Park, S. E., Zaidi, A. K. M., Abebe, Z., Abejie, A. N., Adedeji, I. A., Ali, B. A., Amare, A. T., … Hay, S. I. (2019). The global burden of typhoid and paratyphoid fevers: A systematic analysis for the global burden

of disease study 2017. *The Lancet Infectious Diseases*, *19*(4), 369–381. https://doi.org/10.1016/S1473-3099(18)30685-6

Stormacq, C., Van den Broucke, S., & Wosinski, J. (2019). Does health literacy mediate the relationship between socioeconomic status and health disparities? Integrative review. *Health Promotion International*, *34*(5), e1–e17. https://doi.org/10.1093/heapro/day062

Sudjaritruk, T., Kaewpoowat, Q., Prasarakee, C., Sarachai, S., Taurel, A.-F., Sricharoen, N., Assawawongprom, P., Saheng, J., Harris, R., Nealon, J., & Yoksan, S. (2022). Seroepidemiological study of Japanese encephalitis virus in Chiang Mai: Immunity and susceptibility 28 years after introduction of a vaccination programme. *PLOS Neglected Tropical Diseases*, *16*(8), e0010674. https://doi.org/10.1371/journal.pntd.0010674

Sweatt, K., Garvey, W. T., & Martins, C. (2024). Strengths and Limitations of BMI in the Diagnosis of Obesity: What is the Path Forward? *Current Obesity Reports*, *13*(3), 584–595. https://doi.org/10.1007/s13679-024-00580-1

Tamaoki, M., Honda, I., Nakanishi, K., Cheam, S., Okawada, M., & Sakakibara, H. (2022). Prevalence of Metabolic Syndrome and Its Components in Urban Cambodia: A Cross-Sectional Study. *Journal of Epidemiology and Global Health*, *12*(3), 224–231. https://doi.org/10.1007/s44197-022-00053-5

Tan, M., Bhadoria, A. S., Cui, F., Tan, A., Holten, J. V., Easterbrook, P., Ford, N., Han, Q., Lu, Y., Bulterys, M., & Hutin, Y. (2021). Estimating the proportion of people with chronic hepatitis B virus infection eligible for hepatitis B antiviral treatment worldwide: A systematic review and meta-analysis. *The Lancet Gastroenterology & Hepatology*, *6*(2), 106–119. https://doi.org/10.1016/S2468-1253(20)30307-1

Tangcharoensathien, V., Witthayapipopsakul, W., Panichkriangkrai, W., Patcharanarumol, W., & Mills, A. (2018). Health systems development in thailand: A solid platform for successful implementation of universal health coverage. *The Lancet*, *391*(10126), 1205–1223. https://doi.org/10.1016/S0140-6736(18)30198-3

Tareque, M. I., Saito, Y., & Kawahara, K. (2015). Healthy life expectancy and the correlates of self-rated health in Bangladesh in 1996 and 2002. *BMC Public Health*, *15*(1), 312. https://doi.org/10.1186/s12889-015-1640-6

Tasak, N., Apidechkul, T., Law, A. C. K., Abdad, M. Y., Srichan, P., Perrone, C., Tanganuchitcharnchai, A., Wongsantichon, J., & Blacksell, S. D. (2023). Prevalence of and factors associated with scrub typhus exposure among the hill tribe population living in high incidence areas in Thailand: a cross-sectional study. *BMC Public Health*, *23*(1), 2394. https://doi.org/10.1186/s12889-023-17313-z

Taubman Ben-Ari, O., Eherenfreund Hager, A., & Prato, C. G. (2016). The value of self-report measures as indicators of driving behaviors among young drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *39*, 33–42. https://doi.org/10.1016/j.trf.2016.03.005

Te, V., Chhim, S., Buffel, V., Damme, W. V., Olmen, J. van, Ir, P., & Wouters, E. (2023). Evaluation of Diabetes Care Performance in Cambodia Through the Cascade-of-Care Framework: Cross-Sectional Study. *JMIR Public Health and Surveillance*, *9*(1), e41902. https://doi.org/10.2196/41902

Teunis, P. F. M., & Eijkeren, J. C. H. van. (2020). Estimation of seroconversion rates for infectious diseases: Effects of age and noise. *Statistics in Medicine*, *39*(21), 2799–2814. https://doi.org/10.1002/sim.8578

Teunis, P. F. M., Eijkeren, J. C. H. van, Graaf, W. F. de, Marinovi, A. B., & Kretzschmar, M. E. E. (2016). Linking the seroresponse to infection to within-host heterogeneity in antibody production. *Epidemics*, *16*, 33–39. https://doi.org/10.1016/j.epidem.2016.04.001

Teunis, P., Lai, K., Orwa, C., Aiemjoy, K., & Morrison, D. E. (2024). *Serocalculator: Estimating infection rates from serological data*. https://github.com/UCD-SERG/serocalculator

Thanh, D. P., Thompson, C. N., Rabaa, M. A., Sona, S., Sopheary, S., Kumar, V., Moore, C., Thieu, N. T. V., Wijedoru, L., Holt, K. E., Wong, V., Pickard, D., Thwaites, G. E., Day, N., Dougan, G., Turner, P., Parry, C. M., & Baker,

S. (2016). The Molecular and Spatial Epidemiology of Typhoid Fever in Rural Cambodia. *PLOS Neglected Tropical Diseases*, *10*(6), e0004785. https://doi.org/10.1371/journal.pntd.0004785

The CDA Foundation. (2024a). *Hepatitis B – Bangladesh*. Available from https://cdafound.org/polaris-countries-database/.

The CDA Foundation. (2024b). *Hepatitis B – Cambodia*. Available from https://cdafound.org/polaris-countries-database/.

The CDA Foundation. (2024c). *Hepatitis B – Thailand*. Available from https://cdafound.org/polaris-countries-database/.

The CDA Foundation. (2024d). *Hepatitis C – Bangladesh*. Available from https://cdafound.org/polaris-countries-database/.

The CDA Foundation. (2024e). *Hepatitis C – Cambodia*. Available from https://cdafound.org/polaris-countries-database/.

The CDA Foundation. (2024f). *Hepatitis C – Thailand*. Available from https://cdafound.org/polaris-countries-database/.

The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications (DCCT/EDIC) Study Research Group. (2005). Intensive diabetes treatment and cardiovascular disease in patients with type 1 diabetes. *New England Journal of Medicine*, *353*(25), 2643–2653. https://doi.org/10.1056/NEJMoa052187

The Lancet Rheumatology. (2023). The global epidemic of low back pain. *The Lancet Rheumatology*, *5*(6), e305. https://doi.org/10.1016/S2665-9913(23)00133-9

The World Health Organization. (2024). *WHO position paper on dengue vaccines, May 2024*.

The World Organization of National Colleges, & Academies and Academic Associations of General Practitioners/Family Physicians (WONCA). (2021). *ICPC-3 International Classification of Primary Care* (3rd Edition). CRC Press.

Thigpen, M. C., Sarath, S., Soeung, S. C., Vichit, O., Kitsutani, P., Sandhu, H., Gregory, C., Fischer, M., Morn, C., & Hills, S. L. (2022). Improving community

coverage of japanese encephalitis vaccination: Lessons learned from a mass campaign in battambang province, cambodia. *BMC Public Health*, *22*(1), 2244. https://doi.org/10.1186/s12889-022-14428-7

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., Levac, D., Ng, C., Sharpe, J. P., Wilson, K., Kenny, M., Warren, R., Wilson, C., Stelfox, H. T., & Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, *16*(1), 15. https://doi.org/10.1186/s12874-016-0116-4

Tseng, H.-M., Lu, J. R., & Gandek, B. (2003). Cultural issues in using the SF-36 health survey in asia: Results from taiwan. *Health and Quality of Life Outcomes*, *1*, 72. https://doi.org/10.1186/1477-7525-1-72

Tuangratananon, T., Julchoo, S., Phaiyarom, M., Panichkriangkrai, W., Pudpong, N., Patcharanarumol, W., & Tangcharoensathien, V. (2021). Healthcare providers' perspectives on integrating NCDs into primary healthcare in Thailand: a mixed method study. *Health Research Policy and Systems*, *19*(1), 139. https://doi.org/10.1186/s12961-021-00791-1

Umberson, D. (1992). Gender, marital status and the social control of health behavior. *Social Science & Medicine*, *34*(8), 907–917. https://doi.org/10.1016/0277-9536(92)90259-S

University of Oxford. (2025). *A Cluster-randomised, Open-label Trial to Compare the Impact of Combined Mass Vaccine and Drug Administrations, Mass Drug Administration, Mass Vaccinations, or no Intervention on Plasmodium Falciparum Malaria Transmission (NCT06068530)* [Clinical Trial Registration]. https://clinicaltrials.gov/study/NCT06068530.

Upala, P., Apidechkul, T., Tamornpark, R., Chomchoei, C., & Yeemard, F. (2020). Seroprevalence and factors associated with hepatitis B infection among the hill tribe adult population in Thailand: a cross-sectional study. *BMC Infectious Diseases*, *20*(1), 494. https://doi.org/10.1186/s12879-020-05221-1

Upala, P., Apidechkul, T., Wongfu, C., Khunthason, S., Kullawong, N., Keawdounglek, V., Chomchoei, C., Yeemard, F., & Tamornpark, R. (2021). Factors

associated with hypertriglyceridemia among the hill tribe people aged 30 years and over, Thailand: a cross-sectional study. *BMC Public Health*, *21*(1), 581. https://doi.org/10.1186/s12889-021-10632-z

Verbrugge, L. M. (1979). Marital status and health. *Journal of Marriage and Family*, *41*(2), 267–285. https://doi.org/10.2307/351696

Villarroel, P. M. S., Hamel, R., Gumpangseth, N., Yainoy, S., Koomhin, P., Missé, D., & Wichit, S. (2024). Global seroprevalence of Zika virus in asymptomatic individuals: A systematic review. *PLOS Neglected Tropical Diseases*, *18*(4), e0011842. https://doi.org/10.1371/journal.pntd.0011842

Voigt, K., & King, N. B. (2017). Out of alignment? Limitations of the global burden of disease in assessing the allocation of global health aid. *Public Health Ethics*, *10*(3), 244–256. https://doi.org/10.1093/phe/phx012

Vollset, S. E., Ababneh, H. S., Abate, Y. H., Abbafati, C., Abbasgholizadeh, R., Abbasian, M., Abbastabar, H., Magied, A. H. A. A. A., ElHafeez, S. A., Abdelkader, A., Abdelmasseh, M., Abd-Elsalam, S., Abdi, P., Abdollahi, M., Abdoun, M., Abdullahi, A., Abebe, M., Abiodun, O., Aboagye, R. G., … Murray, C. J. L. (2024). Burden of disease scenarios for 204 countries and territories, 2022–2050: A forecasting analysis for the global burden of disease study 2021. *The Lancet*, *403*(10440), 2204–2256. https://doi.org/10.1016/S0140-6736(24)00685-8

Vongpunsawad, S., Intharasongkroh, D., Thongmee, T., & Poovorawan, Y. (2017). Seroprevalence of antibodies to dengue and chikungunya viruses in Thailand. *PLOS ONE*, *12*(6), e0180560. https://doi.org/10.1371/journal.pone.0180560

Vos, T., Lim, S. S., Abbafati, C., Abbas, K. M., Abbasi, M., Abbasifard, M., Abbasi-Kangevari, M., Abbastabar, H., Abd-Allah, F., Abdelalim, A., Abdollahi, M., Abdollahpour, I., Abolhassani, H., Aboyans, V., Abrams, E. M., Abreu, L. G., Abrigo, M. R. M., Abu-Raddad, L. J., Abushouk, A. I., … Murray, C. J. L. (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: A systematic analysis for the global burden

of disease study 2019. *The Lancet*, *396*(10258), 1204–1222. https://doi.org/10.1016/S0140-6736(20)30925-9

Wakabayashi, M., McKetin, R., Banwell, C., Yiengprugsawan, V., Kelly, M., Seubsman, S., Iso, H., Sleigh, A., & Thai Cohort Study Team. (2015). Alcohol consumption patterns in thailand and their relationship with non-communicable disease. *BMC Public Health*, *15*(1), 1297. https://doi.org/10.1186/s12889-015-2662-9

Wampfler, R., Mwingira, F., Javati, S., Robinson, L., Betuela, I., Siba, P., Beck, H.-P., Mueller, I., & Felger, I. (2013). Strategies for Detection of Plasmodium species Gametocytes. *PLOS ONE*, *8*(9), e76316. https://doi.org/10.1371/journal.pone.0076316

Wang, Q., Ma, T., Ding, F., Lim, A., Takaya, S., Saraswati, K., Sartorius, B., Day, N. P. J., & Maude, R. J. (2024). Global and regional seroprevalence, incidence, mortality of, and risk factors for scrub typhus: A systematic review and meta-analysis. *International Journal of Infectious Diseases*, *146*, None. https://doi.org/10.1016/j.ijid.2024.107151

Wang, Q., Zhao, Z., Zhang, X., Li, X., Zhu, M., Li, P., Yang, Z., Wang, Y., Yan, G., Shang, H., Cao, Y., Fan, Q., & Cui, L. (2016). Naturally Acquired Antibody Responses to Plasmodium vivax and Plasmodium falciparum Merozoite Surface Protein 1 (MSP1) C-Terminal 19 kDa Domains in an Area of Unstable Malaria Transmission in Southeast Asia. *PLOS ONE*, *11*(3), e0151900. https://doi.org/10.1371/journal.pone.0151900

Wangrangsimakul, T., Althaus, T., Mukaka, M., Kantipong, P., Wuthiekanun, V., Chierakul, W., Blacksell, S. D., Day, N. P., Laongnualpanich, A., & Paris, D. H. (2018). Causes of acute undifferentiated fever and the utility of biomarkers in Chiangrai, northern Thailand. *PLoS neglected tropical diseases*, *12*(5), e0006477. https://doi.org/10.1371/journal.pntd.0006477

Washirasaksiri, C., Srivanichakorn, W., Godsl, Ian F, Kositamongkol, C., Chariyalertsak, S., Kessomboon, P., Assanangkornchai, S., Taneepanichskul, S., Neelapaichit, N., Phisalprapa, P., Johnston, D. G., Oliver, N. S., & Aekplakorn, W.

(2021). Increasing glycaemia is associated with a significant decline in HDL cholesterol in women with prediabetes in two national populations. *Scientific Reports*, *11*(1), 12194. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=prem&
%[20210609// https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8190299/pdf/41598_2021_Arti

Wasitthankasem, R., Posuwan, N., Vichaiwattana, P., Theamboonlers, A., Klinfueng, S., Vuthitanachot, V., Thanetkongtong, N., Saelao, S., Foonoi, M., Fakthongyoo, A., Makaroon, J., Srisingh, K., Asawarachun, D., Owatanapanich, S., Wutthiratkowit, N., Tohtubtiang, K., Yoocharoen, P., Vongpunsawad, S., & Poovorawan, Y. (2016). Decreasing Hepatitis C Virus Infection in Thailand in the Past Decade: Evidence from the 2014 National Survey. *PLOS ONE*, *11*(2), e0149362. https://doi.org/10.1371/journal.pone.0149362

Watkins, D. A., Msemburi, W. T., Pickersgill, S. J., Kawakatsu, Y., Gheorghe, A., Dain, K., Johansson, K. A., Said, S., Renshaw, N., Tolla, M. T., Twea, P. D., Varghese, C., Chalkidou, K., Ezzati, M., & Norheim, O. F. (2022). NCD countdown 2030: Efficient pathways and strategic investments to accelerate progress towards the sustainable development goal target 3.4 in low-income and middle-income countries. *The Lancet*, *399*(10331), 1266–1278. https://doi.org/10.1016/S0140-6736(21)02347-3

WHO expert consultation. (2004). Appropriate body-mass index for asian populations and its implications for policy and intervention strategies. *The Lancet*, *363*(9403), 157–163. https://doi.org/10.1016/S0140-6736(03)15268-3

Wijedoru, L. P. M., Kumar, V., Chanpheaktra, N., Chheng, K., Smits, H. L., Pastoor, R., Nga, T. V. T., Baker, S., Wuthiekanun, V., Peacock, S. J., Putchhat, H., & Parry, C. M. (2012). Typhoid fever among hospitalized febrile children in Siem Reap, Cambodia. *Journal of Tropical Pediatrics*, *58*(1), 68–70. https://doi.org/10.1093/tropej/fmr032

Wilson, P. W. F., D'Agostino, R. B., Levy, D., Belanger, A. M., Silbershatz, H., & Kannel, W. B. (1998). Prediction of coronary heart disease using risk factor categories. *Circulation*, *97*(18), 1837–1847. https://doi.org/10.1161/01.CIR.97.18.1837

Wipasa, J., Suphavilai, C., Okell, L. C., Cook, J., Corran, P. H., Thaikla, K., Liewsaree, W., Riley, E. M., & Hafalla, J. C. R. (2010). Long-Lived Antibody and B Cell Memory Responses to the Human Malaria Parasites, Plasmodium falciparum and Plasmodium vivax. *PLOS Pathogens*, *6*(2), e1000770. https://doi.org/10.1371/journal.ppat.1000770

Wood, S. N. (2017). *Generalized additive models: An introduction with r, second edition* (2nd edition). Chapman; Hall/CRC.

World Bank. (2022). *Population ages 65 and above (*. https://data.worldbank.org

World Health Organization. (n.d.). *WHO Immunization Data portal - Detail Page*. https://immunizationdata.who.int/global/wiise-detail-page

World Health Organization. (2000). Obesity: preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organization Technical Report Series*, *894*.

World Health Organization. (2003). *World health survey 2002: questionnaire*. https://apps.who.int/healthinfo/systems/surveydata/index.php/catalog/73/related-materials

World Health Organization. (2007). *Growth reference 5-19 years - BMI-for-age (5-19 years)*. https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age

World Health Organization. (2013). *WHO informal consultation on fever management in peripheral health care settings: A global review of evidence and practice*. https://www.who.int/publications/i/item/9789241506489

World Health Organization. (2014a). *WHO Guidelines For Indoor Air Polution: Household Fuel Combustion*. https://iris.who.int/bitstream/handle/10665/141496/9789241548885_eng.pdf?sequence=1

World Health Organization. (2014b). *Improving mortality statistics as part of strengthening Civil Registration and Vital Statistics Systems: Guidance for country strategies and partner support/ Outcome of a technical meeting, 4-5 November 2014* (No. WOH/HIS/HSI/2014.4).

World Health Organization. (2015). *Service availability and readiness assessment (SARA)*. https://www.who.int/data/data-collection-tools/service-availability-and-readiness-assessment-(sara)

World Health Organization. (2016). *Global health sector strategy on viral hepatitis 2016-2021: Towards ending viral hepatitis*.

World Health Organization. (2017a). *Global Nutrition Monitoring Framework: Operational guidance for tracking progress in meeting targets for 2025*.

World Health Organization. (2017b). *World malaria report 2017*.

World Health Organization. (2017c). *STEPwise approach to NCD risk factor surveillance (STEPS) manual*. http://www.who.int/ncds/surveillance/steps/manual/en/

World Health Organization. (2018a). *Guidelines for the care and treatment of persons diagnosed with chronic hepatitis C virus infection*. World Health Organization.

World Health Organization. (2018b). *International classification of functioning, disability and health (ICF)*. https://icd.who.int/dev11/l-icf/en

World Health Organization. (2018c). *Typhoid vaccines: WHO position paper*.

World Health Organization. (2019). *Life expectancy at birth (years)*. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/life-expectancy-at-birth-(years)

World Health Organization. (2020a). *HEARTS: Technical package for cardiovascular disease management in primary health care: Risk-based CVD management*.

World Health Organization. (2020b). *WHO package of essential noncommunicable (PEN) disease interventions*.

World Health Organization. (2021). Existence of a health surveillance system. In *The GHO data repository*. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/existence-of-a-health-surveillance-system.

World Health Organization. (2022). *Updated recommendations on treatment of adolescents and children with chronic HCV infection, and HCV simplified service delivery and diagnostics*.

World Health Organization. (2024a). *Global hepatitis report 2024: Action for access in low- and middle-income countries*.

World Health Organization. (2024b). *Guidelines for the prevention, diagnosis, care and treatment for people with chronic hepatitis B infection*.

World Health Organization. (2024c). Health data overview for Bangladesh. In *datadot*. https://data.who.int/countries/050.

World Health Organization (WHO). (2019). Laos STEPS Noncommunicable Disease Risk Factors Survey 2013. In *WHO NCD Microdata Repository*. https://ghdx.healthdata.org steps-noncommunicable-disease-risk-factors-survey-2013.

World Health Organization (WHO). (2024a). Health data overview for Cambodia. In *World Health Organization Data*. https://data.who.int/countries/116.

World Health Organization (WHO). (2024b). Health data overview for Thailand. In *World Health Organization Data*. https://data.who.int/countries/764.

World Health Organization. Regional Office for South-East Asia. (2019a). *2019 Health SDG profile: Bangladesh*. World Health Organization. Regional Office for South-East Asia.

World Health Organization. Regional Office for South-East Asia. (2019b). *2019 Health SDG profile: Thailand*. https://apps.who.int/iris/handle/10665/327767

World Health Organization. Regional Office for the Western Pacific. (2018). *UHC and SDG country profiles : Cambodia* (No. WPR/2018/DHS/003). WHO Regional Office for the Western Pacific.

Xu, X., Wu, C., Lou, Z., Peng, C., Jiang, L., Wu, T., Zeng, T., Dong, Y., & Ruan, B. (2023). Changing incidence of hepatitis B and persistent infection risk in adults: a population-based follow-up study from 2011 in China. *BMC Public Health*, *23*(1), 256. https://doi.org/10.1186/s12889-023-15130-y

Yadlowsky, S., Hayward, R. A., Sussman, J. B., McClelland, R. L., Min, Y.-I., & Basu, S. (2018). Clinical implications of revised pooled cohort equations for estimating atherosclerotic cardiovascular disease risk. *Annals of Internal Medicine*, *169*(1), 20–29. https://doi.org/10.7326/M17-3011

Yamada, N., Saorith, K., Yamakami, K., Onozaki, I., Boran, S., Fujiki, A., Eang, M. T., & Mori, T. (2007). The national tuberculosis drug resistance survey in Cambodia, 2000-2001. *The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease*, *11*(12), 1321–1327.

Yan, L. D., Hanvoravongchai, P., Aekplakorn, W., Chariyalertsak, S., Kessomboon, P., Assanangkornchai, S., Taneepanichskul, S., Neelapaichit, N., & Stokes, A. C. (2020). Universal coverage but unmet need: National and regional estimates of attrition across the diabetes care continuum in Thailand. *PLOS ONE*, *15*(1), e0226286. https://doi.org/10.1371/journal.pone.0226286

Yang, J. J., Yu, D., Wen, W., Shu, X.-O., Saito, E., Rahman, S., Gupta, P. C., He, J., Tsugane, S., Xiang, Y.-B., Gao, Y.-T., Koh, W.-P., Tamakoshi, A., Irie, F., Sadakane, A., Tsuji, I., Kanemura, S., Matsuo, K., Nagata, C., ... Zheng, W. (2019). Tobacco smoking and mortality in asia: A pooled meta-analysis. *JAMA Network Open*, *2*(3), e191474. https://doi.org/10.1001/jamanetworkopen.2019.1474

Yildirim, M., Gaynes, B. N., Keskinocak, P., Pence, B. W., & Swann, J. (2022). The cost-effectiveness of depression screening for the general adult population. *Journal of Affective Disorders*, *303*, 306–314. https://doi.org/10.1016/j.jad.2022.02.044

Yman, V., White, M. T., Asghar, M., Sundling, C., Sondén, K., Draper, S. J., Osier, F. H. A., & Färnert, A. (2019). Antibody responses to merozoite antigens after natural Plasmodium falciparum infection: kinetics and longevity in absence of re-exposure. *BMC Medicine*, *17*, 22. https://doi.org/10.1186/s12916-019-1255-3

Yorsaeng, R., Suntronwong, N., Thongpan, I., Chuchaona, W., Lestari, F. B., Pasittungkul, S., Puenpa, J., Atsawawaranunt, K., Sharma, C., Sudhinaraset, N., Mungaomklang, A., Kitphati, R., Wanlapakorn, N., & Poovorawan, Y. (2022). The impact of COVID-19 and control measures on public health in Thailand, 2020. *PeerJ*, *10*, e12960. https://doi.org/10.7717/peerj.12960

Yusuf, S., Joseph, P., Rangarajan, S., Islam, S., Mente, A., Hystad, P., Brauer, M., Kutty, V. R., Gupta, R., Wielgosz, A., AlHabib, K. F., Dans, A., Lopez-Jaramillo, P., Avezum, A., Lanas, F., Oguz, A., Kruger, I. M., Diaz, R., Yusoff, K., ... Dagenais, G. (2020). Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. *Lancet (London, England)*, *395*(10226), 795–808. https://doi.org/10.1016/S0140-6736(19)32008-2

Zakaria, M., Karim, R., Rahman, M., Cheng, F., & Xu, J. (2021). Disparity in physician-patient communication by ethnicity: evidence from Bangladesh. *International Journal for Equity in Health*, *20*(1), 65. https://doi.org/10.1186/s12939-021-01405-6

Zhang, M., Htun, N. S. N., Islam, S., Sen, A., Islam, A., Neogi, A. K., Tripura, R., Dysoley, L., Perrone, C., Chew, R., Batty, E. M., Thongpiam, W., Wongsantichon, J., Menggred, C., Zaman, S. I., Waithira, N., Blacksell, S., Liverani, M., Lee, S., ... Peto, T. J. (2024). Defining the hidden burden of disease in rural communities in Bangladesh, Cambodia and Thailand: a cross-sectional household health survey protocol. *BMJ Open*, *14*(3), e081079. https://doi.org/10.1136/bmjopen-2023-081079

Zhang, M., Kozlowski, H., Chew, R., Htun, N. S. N., Morris, S. K., Akladious, C., Sarker, A. R., Lubell, Y., & Peto, T. J. (2024). The spectrum of health conditions in community-based cross-sectional surveys in Southeast Asia 2010-21: A scoping review. *BMC Public Health*, *24*(1), 1853. https://doi.org/10.1186/s12889-024-19347-3

Zhang, M., O'Keefe, D., Craig, J., Samley, K., Bunreth, V., Jolivet, P., Balkan, S., Marquardt, T., Dousset, J.-P., & Le Paih, M. (2021). Decentralised hepatitis c testing and treatment in rural cambodia: Evaluation of a simplified service model integrated in an existing public health system. *The Lancet Gastroenterology & Hepatology*, *6*(5), 371–380.

Zouwen, J. van der, & Smit, J. H. (2004). *Evaluating Survey Questions by Analyzing Patterns of Behavior Codes and Question–Answer Sequences: A Diagnostic Approach* (pp. 109–130). John Wiley & Sons, Ltd. https://doi.org/10.1002/0471654728.ch6