Evaluating the effects of a health workforce intervention on indicators of quality of newborn care in Kenyan neonatal units

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Dedication

This thesis is dedicated to my mother, Professor Hauwa Imam, an academic I admire and aspire to be like.

Abstract

In Kenya and many resource-constrained low and middle-income countries (LMICs), there is a drive to make Level 2 neonatal unit services more accessible to the populace to reduce neonatal mortality. This has led national governments and development partners to equip such units with the necessary technology. However, inadequate investment in commensurate human resources for health in Kenya and other LMICs may limit any benefits of upgrading neonatal units. It is, therefore, timely to evaluate if improving nurse staffing numbers by a modest amount in contexts supported to provide Level 2 neonatal care results in improved quality of care. I used literature reviews and quantitative research methods to answer this question. Using cross-sectional data and a before and after design, I collect data on care provision in eight Level 2 neonatal units in Kenya and prospectively explore changes in nursing time and care provision following adding extra nurses in four of them.

I found that nurse staffing was extremely poor in the eight Level 2 neonatal units in Kenyan public hospitals. On average, using one measure of nurse input, nurses had 30 minutes per patient per 12-hour shift. As a result, they could only manage a third of all measured nursing tasks. A third of tasks were missed, and another third were informally delegated to nursing students and caregivers, including technical nursing care items, which raises possible patient safety concerns. The nurse staffing intervention resulted in a 4.2% change in measured bedside nurse-delivered care but no change in total measured neonatal care. This, in part, was linked to challenges in achieving full fidelity of the workforce intervention, which resulted from many nurses going on leave and nurse transfers out of the neonatal unit.

The findings suggest that for Kenya to meet the Sustainable Development Goal of reducing neonatal mortality to 12 per 1000 live births, more significant investments must be made in the nursing

workforce and other human resources for health. Such investments must be holistic across the public health system, not just for neonatal services alone.

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Declaration and publications

I declare that this thesis is my original research and has not been submitted for a degree at any other university. The following peer-reviewed papers that I first authored contain some contents from this thesis:

- Imam A, Obiesie S, Gathara D, Aluvaala J, Maina M, English M. Missed nursing care in acute care hospital settings in low-income and middle-income countries: a systematic review. Human resources for health. 2023 Mar 14;21(1):19.
- Imam A, Obiesie S, Aluvaala J, Maina JM, Gathara D, English M. Identifying gaps in global evidence for nurse staffing and patient care outcomes research in low/middle-income countries: an umbrella review. BMJ open. 2022 Oct 1;12(10):e064050.
- Imam A, Gathara D, Aluvaala J, Maina M, English M. Evaluating the effects of supplementing ward nurses on quality of newborn care in Kenyan neonatal units: protocol for a prospective workforce intervention study. BMC Health Services Research. 2022 Oct 4;22(1):1230.
- Imam A, Obiesie S, Aluvaala J, Maina M, Gathara D, English M. Nurse staffing and patient care outcomes: protocol for an umbrella review to identify evidence gaps for low and middle-income countries in global literature. Wellcome Open Research. 2021;6.
- Imam A, Obiesie S, Aluvaala J, Maina M, Gathara D, English M. Missed nursing care in acute care hospital settings in low-middle income countries: a systematic review protocol. Wellcome open research. 2021;6.

For the above papers, I conceptualised the ideas, wrote the first drafts entirely and had corrections for subsequent drafts from my supervisors and co-authors. All submitted papers also had input from reviewers on the structure and content of these papers.

I conducted all statistical analyses within my DPhil. I have an MSc in Epidemiology and Biostatistics, and my PhD funding supported me to attend methodology courses linked to the methods I employed within this DPhil. The sample size estimation for my research was however determined by the parent programme which housed my DPhil.

For my literature reviews in Chapter 3, I had the support of a university Librarian to develop the search strategies. I was also supported by a second reviewer who cross-checked my data extractions and who was involved in the selection process for papers to include within these reviews. In addition, for my primary data collection, I was supported by a team of eight data collectors and two research officers whom I trained on my data collection processes and procedures.

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List of abbreviations

AIC – Akaike's Information Criteria

AMSTAR-2 - A MeaSurement Tool to Assess systematic Reviews-2

BERNCA-R - Basel Extent of Rationing of Nursing Care

BCG - Bacillus Calmette-Guerin

BIC – Bayesian Information Criteria

CINAHL - Cumulative Index to Nursing and Allied Health Literature

CPAP – Continuous Positive Airway Pressure

ENAP – Every Newborn Action Plan

ETAT+ - Emergency Triage, Assessment, and Treatment Plus

FTE – Full-time Equivalent

HFA – Health Facility Assessment

HICs – High-income countries

HIGH-Q - Harnessing Innovations in Global Health for Quality Care

HIV – Human Immunodeficiency Virus

HRH – Human resources for health

IOM – Institute of Medicine

IQR – Interquartile range

ITS – Interrupted time series

JBI - Joanna Briggs Institute

KMC- Kangaroo Mother care

LMIC – Low and Middle-income Countries

LRT – Likelihood Ratio Test

MNCS- Missed Nursing Care Scale

MoU - memorandum of understanding

NA – Not applicable

NCI – Nursing Care Index

aNCI - Nursing care delivery by anyone

nNCI - Nurse-delivered care

pNCI – Prioritised nursing care

sNCI - Nursing student and nurse index

NCK – Nursing Council of Kenya

NEST-360° - Newborn Essential Solutions and Technologies

NHPPD - Nursing Hours Per Patient Day

NHPPS – Nursing hours per patient per shift

NHS – National Health Service

NMR – Neonatal mortality rate

NNAK - National Nurses Association of Kenya

PMTCT – Prevention of Maternal to Child Transmission

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

QoCN – Quality of Care Network

RN – Registered Nurse

SDG – Sustainable Development Goals

SOPs -Standard operating procedures

SSNC – Small and Sick Newborn Care

TIDieR - Template for Intervention Description and Replication

UHC – Universal Health Coverage

UNICEF – United Nations Children's Fund

WHO – World Health Organization

WISN - Workload Indicator Staffing Needs

Foreword – My journey to the DPhil

I grew up in Nigeria, where I also trained as a Paediatrician. I think my fascination with research started during my years of clinical training when we had visiting Professors of Nigerian descent who came from the diaspora. They had large, funded project grants with research sites in my training hospital and others. They always appeared larger than life to me, and I aspired to be like them professionally at some point in the future. Perhaps they woke up quiescent feelings in me – my paternal grandparents both had PhDs, and my mother is a Professor of Education and an academic I admire. Growing up with an academic lineage and an academic parent must have instilled some thoughts in me that were awakened by my encounters. I generally see research as an opportunity to be an international citizen and part of an international community addressing global challenges.

My journey to research started during my residency when I took a gap year to study for an MSc in Epidemiology and Biostatistics at the University of Leeds in the UK. Following my clinical training, I moved on to work as a Research Clinician at the Medical Research Council in the Gambia on vaccine clinical trials while developing my academic portfolio. I think it was at this point I realised that to make it in research, I needed a PhD. I remember applying and cold emailing a few professors, including my current first supervisor, Professor Mike English. I never thought I would eventually be doing a DPhil at the University of Oxford.

Fast-forward to the present moment, I am grateful for the growth the DPhil has brought me academically and professionally. I am hopeful for the next chapter of my career as an academic clinician. I hope you enjoy reading this thesis; it is the culmination of just over three and half years of hard work and sticking with it through thick and thin.

Reflection on my position, background and research role

I came into this DPhil after having previously trained and practised as a paediatrician in newborn units in Nigeria and having conducted research in another resource-limited setting (The Gambia). Although these are different environments from Kenya, they share many similarities, including the everyday struggle and challenge for human and material resources and the constant stretch of the health systems.

This thesis has allowed me to apply two lenses—the first as an 'insider' who has experienced similar settings due to my unique experiences and clinical training, and the second as a researcher attempting to maintain ambivalence despite my background. I also recognise that although I am a clinician with experience in resource-limited settings, I have only seen nursing from the outside, either in my interactions with nurses around patient care or as colleagues. I have never experienced what it means to be a nurse in a resource-challenged environment.

In addition, since January 2021, I have come into this research as a DPhil student on an existing project attempting to answer a broad research question but not having the specifics on how to tackle this question. While I was 'presented with a research question', this DPhil has allowed me to break down the research question into answerable objectives. It has also allowed me to systematically engage with the literature and chart my unique course to answer my research question. I have conducted systemic literature reviews to identify evidence, developed a unique logic model to guide my data analysis, adapted existing methods to answer my research question and developed novel ways to answer some aspects of my central research question.

Chapter 1- Introduction

In my introductory chapter, I examine nursing at three levels of health systems: macro (global or national level), meso (health facility level), and micro (individual level) (1). I initially focused on the global research evidence and then the evidence from Kenya (where my research is situated). Following this, I discuss 'quality of care,' briefly summarising the current landscape and then examining the literature that links nurse staffing and quality of care. I conclude this chapter by summarising my research aims and objectives.

1.1 Nursing as a profession.

Nurses and midwives represent the largest health workforce group globally, accounting for almost three-fifths of all healthcare professionals (1). They form the backbone of primary healthcare delivery, pandemic preparedness, and the provision of preventative and curative healthcare services for all persons – old and young, and also within families, groups and communities (2). Their role varies from setting to setting but at the core of nursing is the provision of safe, quality and person-centred care to support and achieve optimal health and well-being (2).

In general, the word 'nurse' covers a broad range of individuals with diverse skill sets. This can include specialised nurses such as advanced nursing practitioner or nurse specialist, who possess advanced skills in a particular area of medicine and can offer specialised services and who are present in developed health care settings (3). They also include top level nurses, commonly referred to as registered nurses, who have degrees or advanced diplomas, and intermediate level nurses referred to commonly as enrolled nurses who frequently complete certificate courses or ordinary diplomas (3). A lower level also exists which go by different names in different climes, for example, auxiliary nurses, assistants in nursing, licensed professional nurse (3). Whatever the nomenclature used, globally this group represent a tightly regulated profession, and they are governed by a code of practice usually underpinned by positive professional attributes and provided by regulatory bodies that guide and streamline the practice of nursing (4).

1.2 Nursing at a global level – the problem of nurse shortages.

1.2.1 Background

In the 21st century, one pervasive problem has been shortages of nurses globally, with the worst shortages seen in low and middle-income countries (LMICs), spanning countries in four regions of the world – Africa, Southeast Asia, Eastern Mediterranean, and Latin America (Figure 1.1) (2)**.** It is estimated that 89% of all global nursing shortages occur in low and middle-income settings, with complex root causes varying across countries (2). In some low-resource settings, there is a problem of underproduction (5), while in others, there is a dissonance between production and the ability to absorb graduate nurses locally (5). Within countries, there is also some evidence of unequal nursing workforce distribution across rural-urban and public-private divisions (6) and a perennial problem of out-migration of nurses from resource-constrained LMICs to high-income countries (7,8).

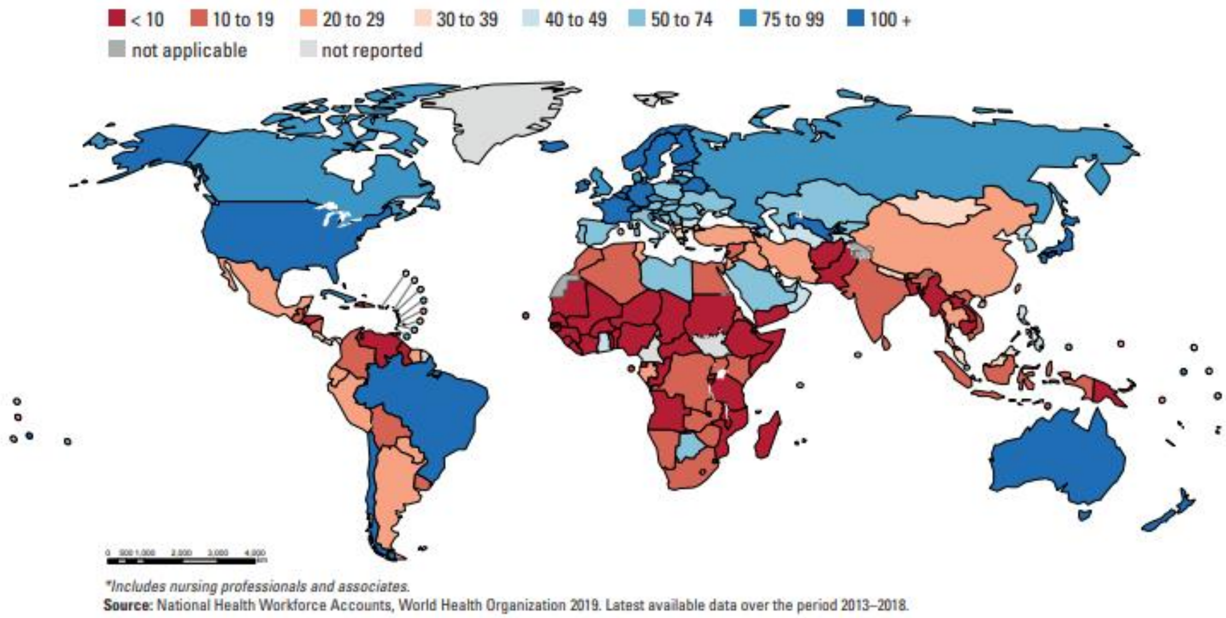

Figure 1.1– Global density of nursing personnel per 10,000 population in 2018 (source – State of the World's Nursing 2020 (2)

Shortages also occur in high-income countries. In many of these countries, nursing shortages are linked to an incapacity to produce an adequate number of nurses to meet surging population demands, driven by an increasingly ageing population with more significant social care needs, improvements in healthcare leading to increased survival of patients with complex care needs and a rise in non-communicable diseases (9). Workforce shortages also arise within countries, across rural-urban divides, or different departments (10). An added problem to shortages in high-income settings is workforce retention rates, with an increasing number of nurses leaving the profession or migrating to other high-income countries (10). These countries have coped with nursing shortages by creating other cadres to support nurses; for example, in the UK and other European countries, newly created nursing cadres such as nursing associates bridge the gap between nurses and non-professional health care assistants (11,12). Limited production has also been tackled by finding alternative ways to train nurses, including introducing nursing apprenticeship programs outside the formal nurse training pathways or employing migrant nurses from other parts of the world (13). The NHS, for example, has 17% of the nursing workforce who graduated from foreign universities (10).

1.2.2 Macro level: global policy direction for nursing.

The World Health Organization (WHO) State of the World Nursing Report specifically states that - "The world does not have a global nursing workforce commensurate with the universal health coverage and SDG targets" and estimates a global shortfall of about 5.9 million nurses globally (2). Specifically, one of the SDG targets, SDG 3c, focuses on the health workforce and sets a target to "substantially increase health financing and the recruitment, development, training, and retention of the health workforce in developing countries, especially in the least developed countries and small island developing States." (14). Approximately 18 million additional healthcare workers are needed globally for the health-related SDGs (15).

Recognising the current challenges in nursing, the 74th World Health Assembly adopted the Global Strategic Directions for Nursing and Midwifery 2021 – 2025, which has four key pillars focusing on nursing education, jobs, leadership, and service delivery (15). Each of these pillars has prioritised policy actions that need to be achieved to fulfil them; for example, the policy priorities for service delivery include reviewing and strengthening professional regulatory systems and adapting workplaces to enable maximal service delivery contributions by nurses and midwives (Table 1.1). Individual countries and global partnerships have also developed specific strategies to build their nursing workforce, keying into global policy (10,16–20). However, despite their pivotal roles and the international drive to promote nurses and the nursing profession, challenges persist in ensuring the correct number of nurses with the right skills in the right place (2).

Table 1.1 – World Health Organization Strategic directions and policy priorities 2021- 2025 (15).

Pillars	Strategic direction	Policy priority
Education	Midwife and nurse graduates match or surpass health system demands and have the requisite knowledge, competencies, and attitudes to meet national health priorities.	Align nursing and midwifery education levels with optimised roles within the health and academic systems.
		Optimise the domestic production of midwives and nurses to meet or surpass health system demand.
		Design education programmes to be competency-based, apply effective learning design, meet quality standards, and align with population health needs.
		Ensure faculty are adequately trained in the best pedagogical methods and technologies and have demonstrated clinical expertise in content areas.
Jobs	Increase the availability of health workers by sustainably creating nursing and midwifery jobs, effectively recruiting and retaining midwives and nurses, and ethically managing international mobility and migration.	Conduct nursing and midwifery workforce planning and forecasting through a health labour market lens.
		Ensure adequate demand (jobs) concerning health service delivery for primary health care and other population health priorities.
		Reinforce the implementation of the WHO Global Code of Practice on the International Recruitment of Health Personnel.
		Attract, recruit, and retain midwives and nurses where they are most needed.
Leadership	Increase the proportion and authority of midwives and nurses in senior health and academic positions and continually develop the next generation of nursing and midwifery leaders.	Establish and strengthen senior leadership positions for nursing and midwifery workforce governance, management, and input into health policy.
		Invest in leadership skills development for midwives and nurses.
Service delivery	Midwives and nurses work to the full extent of their education and training in safe and supportive service delivery environments.	Review and strengthen professional regulatory systems and support capacity building of regulators, where needed.
		Adapt workplaces to enable midwives and nurses to contribute to service delivery in interdisciplinary healthcare teams maximally.

1.2.3 Meso-level: Nursing at the ward level

In this subsection, I examine how nursing care is organised at ward level and how the ideal nursing numbers are determined and the global evidence for ward-level nursing.

1.2.3.1 How is nursing care organised (Models of nursing care)

Models of nursing care describe different approaches to providing nursing care for patients. These are mainly centred around the organisation of nurses for service delivery (21). Typically, there are three classic models of nursing care are recognised in acute hospital settings, and this include (21):

1. Primary nursing care – In this model a nurse takes care of a limited number of patients and is responsible for the totality of their care throughout their hospital stay period (21).
2. Functional nursing – This is essentially a task-based model of care provision. Tasks are usually assigned based on qualifications and a single nurse might be in charge of the same task for more than one patient (21). In practice this allows the involvement of less skilled nursing staff to participate in patient care. An example might be a nurse assistant saddled with monitoring vital signs for a group of patients while a senior nurse administers medication to a group of patients.
3. Team nursing – In this model, a group of nurses work collaboratively towards providing treatment and care to patients who are in care (21). The emphasis in this model is on shared patient responsibility for patient care,

Newer models of care represent combinations or variants of the primary nursing models (21).

1.2.3.2 How many nurses are needed at the ward level?

Globally, there is no consensus on what an adequate number of nurses should be at the ward level or how to determine such numbers (22) . The science behind determining a safe number of ward nurses has evolved around the central theme of nursing workload (22). In practice, nursing numbers are guided by expert opinion on acceptable staff-to-patient ratios or calculations based on individual patient care needs or sometimes time to perform patient care activities by the average skilled nurse (23,24). Ideally, the total hired nursing workforce would consider an uplift in calculated numbers to cover events such as annual leave, sick leave, maternity leave, and other considerations such as days off or flexible working (22). It is also common to have nursing staffing thresholds below which temporary staff are called in to support the existing staff in high-resource settings (18). Table 1.2 summarises various methods used to determine ward-level nursing.

Table 1.2 - Approaches to plan nurse staffing (23–25).

Nurse staffing approach	Derivation	Examples
Professional judgement	Shift-level nursing staffing is guided by professional judgment or expert opinion, such as that of senior nurses. Such shift-level plans are then converted into staff hiring recommendations sufficient for the daily rota to function.	Telford method
Benchmarking	A fixed number of nurses is assigned to patients or a proxy measure for patients. Little or no formal assessment of the individual patient requirements for nursing care is conducted. Determining staffing requirements is guided by expert opinion or consensus about the staffing needs of a particular type of ward. For example, ratios in intensive patient care differ from those in general wards. This assumes prototypical patients for similar ward types, which can be managed using a fixed rota.	Nurse-to-patient ratios, nursing hours per patient or nurse staff per occupied bed.
Volume based approaches	Employ benchmarking above but consider changes in nursing workload, such as increased patient admissions.	Patient-to-nurse ratios
Patient classification system	The acuity or dependency of a patient determines the required staffing levels. A patient's diagnosis-related group can also be used to determine staffing needs. Each patient group has a weight (multiplier) dependent on its acuity level, which indicates the average nursing time required to provide nursing care for this patient.	Safer Nursing Care Tool in the UK
Timed-task approach	Staffing levels are determined using timed estimates of a list of tasks for each patient. The sum of all timed tasks for individual patients determines the total staffing requirements. A second variant uses the time skilled workers take to perform major activities linked to their specific roles within the local context.	GRASP commercial system USA. Variant example - Workload Indicator Staffing Needs.
Regression-based approach	Use data from quality assured wards to model the relationship between staffing levels and variables at three levels of patient care – patient, ward, and hospital. Coefficients from this analysis are projected to other wards to determine the required staffing for other wards.	RAFAELA system in Nordic countries

1.2.3.3 Ward-level nurse staffing in high-income countries.

Human resources for health (HRH), particularly nursing, constitute a large proportion of health system expenditure in high-income settings, where cost has been an essential consideration for health policymakers (26). For example, expenditure on nursing is the most significant single expenditure of the UK's National Health Service (NHS) (20). Task shifting/ sharing involving the transfer of roles of highly skilled professionals to less experienced workers is featured prominently as a health workforce strategy aimed at decreasing healthcare costs in many high-income settings (12). This has led to a proliferation of nurse-supporting roles at the ward level, such as nursing associates, auxiliary nurses, and healthcare assistants in various settings (11,12). Notable differences thus exist in ward-level nurse staffing to patient ratios and the proportion of registered nurses at the ward level in the nursing workforce (a concept referred to as nursing skill mix) across high-income countries (27). One study of 33,659 nurses working in medical and surgical hospitals across 12 European countries found that skill mix, measured as the proportion of registered nurses on the nursing team, varied across countries and ranged between 57 and 82% (12). In the same study, the patient-to-registered nurse (RN) ratio also varied between 3.7 patients per RN to 9.9 patients per RN (12).

1.2.3.4 Ward-level nurse staffing in resource-constrained low and middle-income countries (LMICs) settings.

Resource-constrained LMICs experience perennial challenges in resource limitations that affect health expenditure, including human resources for health and the purchasing of technologies linked to quality care provision. Although ward-level nursing shortages are a global problem, the challenge in many resource-constrained LMICs is that such shortages can be extreme (28,29). For example, some studies from such contexts have described extreme nurse staffing-to-patient ratios where one nurse on the ward might provide care for as many as 25 patients on a shift (28,29). In such instances, low nursing staff-to-patient ratios appear to be seen as a norm by policymakers, and current staffing levels are not challenged by research evidence.

Recognising the challenges related to poor hospital staffing, the World Health Organization (WHO) has promoted the Workload Indicator Staffing Needs (WISN) planning tool as a solution to determining staffing needs in such contexts (25). The WISN determines local workforce requirements based on an assessment of workload pressures measured using activity standards (time taken for a skilled worker to perform a particular activity) tailored to local standards and which cover all aspects of work routinely conducted by the staff (25). One challenge with this is that the WISN approach frequently results in estimations of such significant workforce needs that they might not be feasible to address in the immediate or medium term and require long-term policy planning (30–32). A second challenge is that the currently available data does not demonstrate the impact on quality of care or patient care outcomes when policymakers do not achieve estimated staffing. Convincing governments to invest in staffing will need evidence that shows the effects on quality associated with the current status quo and the effect associated with staffing increases.

1.3 Micro level: What do nurses do? – a focus on neonatal nursing in low-resource settings

Nurses play a significant role across all health system levels, including primary, secondary, and tertiary services. In the neonatal unit, they are involved in various activities, including patient-facing and non-patient-facing tasks. Table 1.3 summarises a list of nurse tasks in neonatal units in low-resource settings.

Table 1.3 – Neonatal nursing tasks (Adapted from Murphy *et al.*: Expectations for nursing care in newborn units in Kenya: moving from implicit to explicit standards (33).

Patient-facing tasks*	Non-patient facing tasks#
Admissions – taking nursing history and physical examination	Drug and vaccines – drug preparation, dilutions
Routine vital signs and patient monitoring	Expressed breast milk and formula feed preparation
Regular patient care – Diaper change, cleaning babies, changing bed linens, incubator monitoring, wound care	Documentation – Discharge and admission registration, patient labels, birth notification, treatment sheet review, updating child health book, recording in drug books, billing, recording stock and managing medical records
Administering interventions/ carrying out investigations – venous sampling, heel prick tests, collecting urine/stool and neonatal resuscitation	Infection control – visitors education/ practice, cleaning, sterilisation of equipment
Drug and vaccines – oral and IV drug administration, cannula patency check, cannula site check, vitamin K administration, cord and eye care, BCG and oral polio vaccination	Accompanying patients to the lab/x-ray/theatre for procedures or on outward referrals to other facilities or wards
Oxygen therapy and oxygen therapy management	Equipment checking
Continuous Positive Airway Pressure (CPAP) management	Equipment handover
Phototherapy and phototherapy care	Nursing student supervision
Feeding – cup feeding, nasogastric tube insertion, nasogastric tube feeding.	
Blood transfusion and exchange transfusion	
Counselling/ support/ health education	
Providing input to medical ward rounds	
Pre-operative and post-operative care	
Assistance with portable chest x-ray	

*-patient-facing tasks are tasks that occur around the patient's bedside, while non-patient-facing tasks are activities that occur away from the bedside

BCG – Bacillus Calmette-Guerin

1.4 Nurses and Nursing in Kenya

1.4.1 Background

Kenya is a low-middle-income country with a population of about 55.1 million. The under-five mortality rate stands at 41.1 per 1000 live births, while its neonatal mortality rate stands at 20 per 1000 live births, far above the SDG targets of 25 per 1000 live births for under-five mortality and 12 per 1000 live births for neonatal mortality (34).

The public healthcare system, comprised of government-owned health facilities, is the primary healthcare provider in Kenya (35). The organisation of the modern-day public health care system in Kenya has evolved following a change in the Kenyan constitution in 2010, which pushed forward a devolved governance structure, moving from eight administrative provinces to placing administrative powers in the hands of each of the 47 Kenyan counties (35). This gave the counties greater independence and autonomy in managing their affairs. It also meant the Kenyan public healthcare services underwent significant restructuring, with each county managing its health service delivery and human resources for health (36). Following devolution, the national government's focus changed to creating an enabling environment for health service delivery through health policy formulation, financing, quality assurance, standards creation and health services monitoring and evaluation (37).

Regarding the nursing workforce, Kenya has a nursing and midwifery personnel density of 11.99 per 10,000 population, far below the global average density of 36.9 per 10,000 (2). In comparison, there are eight to ten times the number of nurses per population in more developed countries, for example, the US and UK (Table 1.4) (38). Despite a significant unmet need for nursing services, there are paradoxically still many unemployed nurses in Kenya (39).

Nurses and midwives represent roughly 70% of the current Kenyan health workforce (40), and they are unequally distributed in-country, with the highest percentage employed in Nairobi, the Kenyan capital and other major Kenyan cities (41,42). The public sector provides the bulk of employment for nurses, with 8 in 10 nurses employed by the public sector (41). Although nursing shortages are pervasive in Kenya, a more significant shortage exists for nurses with specialised or advanced skills (43).

Table 1.4– Nursing and midwife personnel numbers and density per 10,000 population in Kenya compared with other East African countries, the US and the UK (source – World Health Organization National Health Workforce Accounts Database (38)).

Country	Nursing and midwife personnel number	Nursing and midwifery personnel per 10,000 population
Burundi	9515	7.581
Comoros	1234	15.896
Djibouti	No data	No data
Ethiopia	90179	7.695
Eritrea	4971	14.428
Kenya	**59901**	**11.991**
Madagascar	7827	2.915
Malawi	13564	7
Mauritius	4986	38.49
Mozambique	18206	5.676
Rwanda	11970	9.326
Seychelles	951	92.241
Somalia	No data	No data
South Sudan	3726	3.584
Tanzania	31940	5.498
Uganda	74873	16.862
Zambia	36288	18.635
Zimbabwe	31792	20.289
United Kingdom	616769	91.671
United States of America	4188638	124.683

1.4.2 Nursing in Kenya at the macro level –

In the following few subsections, I discuss nursing in Kenya at the macro level, focusing on nursing administration, regulation of nursing and the training of nurses. I also discuss Kenya's health and nursing workforce strategy.

1.4.2.1 The public healthcare system with a focus on nursing administration.

Before 2013, Kenya operated a centralised national public health care system managed centrally by the Kenyan Ministry of Health (35). Public health facilities were organised hierarchically in a 6-tier system where level 6 health facilities (the highest level) represented national-level referral hospitals which provided tertiary services, and level 1 (the lowest level) were community-level services (Figure 1.2). In between levels 1 and 6, at the sub-national level (level 5), there were eight secondary level hospitals, referred to as provincial hospitals (their location was based on Kenya's eight administrative provinces), and an additional seven referral regional hospitals, which operated at level 5 (35). District and subdistrict hospitals served to provide primary health services, while community-level services, health centres and local dispensaries essentially served a rural population (44).

Nursing administration mirrored the hierarchical organisation of the health system. National nursing services were headed by a Chief Nursing Officer (a position later referred to as Director of Nursing Services) who, supported by a team of senior nurses, oversaw all national policies for nursing and advised the national government on nursing matters (44). At the sub-national level, health administration was split into eight nationwide provincial offices, each headed by a Provincial Nursing Officer (44). A district public health nurse headed the rural health community health services at the lower district level, while a nursing service manager oversaw each hospital (44). The nursing chain of command thus flowed from the Director of Nursing Services to Provincial Nursing Officers, who ultimately provided instruction to nursing service managers and the district public health nurse (44).

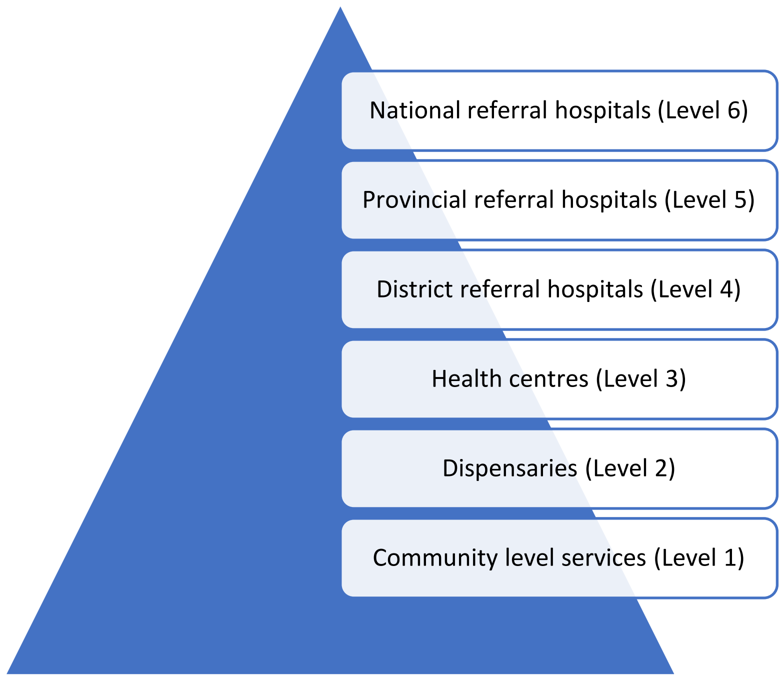

Figure 1.2– Pyramid showing levels of the hierarchy of the public health system before devolution.

Following devolution, the public health care system moved from a six-tier to a four-tier system (35). This change was linked to a health system restructuring framework under the third Kenyan Health Sector strategic plan (2012 – 2017) (45). In the four-tier system, the highest tier, tier 4, combined national and provincial referral hospitals into a single tier, while the district-level hospitals became known as county referral hospitals (Figure 1.3) (37).

With devolution and a shift of administrative powers to counties, the County Nursing Officer position was created. This individual oversees nursing affairs in the county. They report to the County Director of Health, who reports to the County Executive Committee Member for Health, who is accountable to the county governor (44). Post-devolution, the national government now focuses on creating enabling policies for nursing (44)

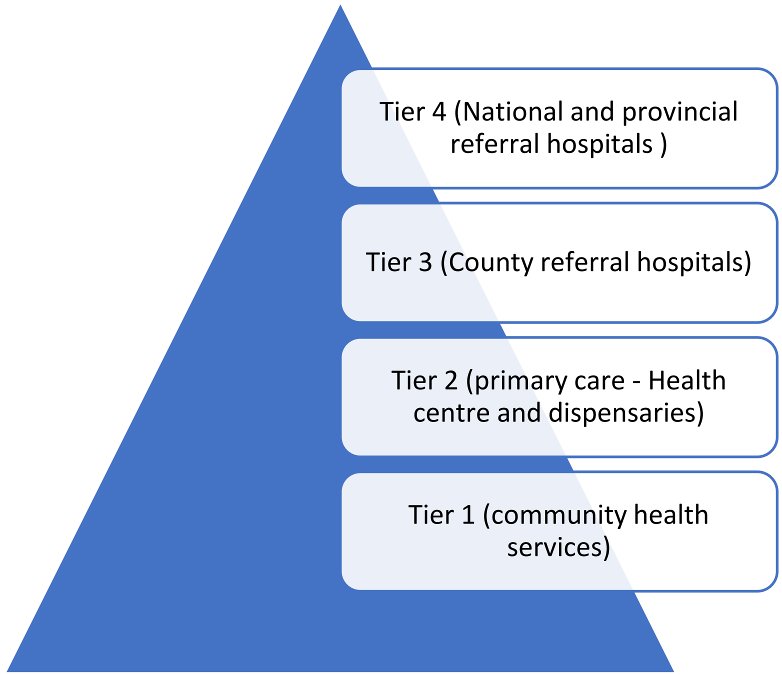

Figure 1.3– Pyramid showing levels of the hierarchy of the public health system after devolution.

1.4.2.2 Regulation of nursing in Kenya

Nursing is regulated by The Nursing Council of Kenya (NCK), a statutory body established in 1983 and backed by an act of parliament (Nurses Act Cap 257) to regulate the safe delivery of nursing and midwifery care to the public (46). This agency has broad oversight of nursing in Kenya, providing functions such as the accreditation of nursing training schools, regular inspection of nursing training institutions, regulation of the nurse training curriculum, indexing of new nursing students to track pre-service nursing education, licensing of new nurses, maintaining a register of all nurses and midwives in Kenya and a role in document verification for nurses planning to immigrate (46). It also upholds nursing standards, including disciplinary action against nurses and midwives for unprofessional conduct (46).

1.4.2.3 Nurse training in Kenya

Nurses are trained at three entry-level programmes in Kenya under the Nursing Council of Kenya (NCK) regulation. These levels are the certificate (enrolled) level, the diploma (registered) level and degree-level programmes (44). Degree-level nursing programs earn a Bachelor of Nursing following their courses, and they usually have one-year post-graduation internships in which they are exposed to clinical practice (44). For diploma and certificate nurses, clinical exposure is fitted into their training curricula with blocks of classroom lectures interspersed by periods of clinical attachment, ideally under the supervision of qualified nurses in training hospitals (44). The NCK has also introduced an upgrading programme where enrolled nurses could apply to upgrade their skills to the registered nursing level by undertaking a diploma (47). Post-basic training is available for nurses, which differs from entry-level training, where nurses can gain higher diplomas in speciality areas, for example, Paediatric or neonatal nursing, or where they can develop academically by studying for a master's or PhD programmes in the major disciplines (48). This is, however, a less followed route.

1.4.2.4 The Kenyan health workforce and nursing workforce strategy

Strengthening the capacities of human resources for health is a key strategy of the Kenyan government. This is prominent in key policy documents, including the Kenyan Health Policy (2014 - 2030), which directs the country's long-term health policy (49), and the Kenyan Health Sector Strategic Plan, which dictates medium-term national health priority (35).

In recognition of the critical role of nurses as instrumental in achieving the national health policy goal, the Kenyan government recently published its first-ever national nursing and midwifery policy for ten years from 2022 to 2032 (40). This provides the government with a focused nursing policy strategy and a framework linked to key global nursing policy directions, such as the World Health Assembly Global Strategic Directions for Nursing and Midwifery 2021 – 2025 (15). The Kenyan National Nursing and

Midwifery Policy focuses on enhancing and strengthening six key areas: education and research, workforce planning and management, access to quality nursing, regulation of activities, governance and leadership capacity and financing and strategic partnerships (40).

Despite well-meaning policies to provide overall strategic direction for human resources for health and nursing, there are significant challenges with policy implementation linked in part to the availability and management of public funds. The current public health system is plagued by a recurrent freeze on public service recruitment, including hiring nurses, budget ceilings on the health workforce, recurrent expenditure constraining the fiscal space for additional recruitment and an old workforce resulting from increased retirement age and freeze in new hires (50). High rates of industrial action among nurses and other health workers are also pervasive, along with high out-migration rates (51,52).

1.4.2.5 Meso and micro-level: The evidence for day-to-day ward nursing in Kenya focusing on neonatal units.

The macro-level problems in the Kenyan public health system are reflected in day-to-day nursing, including neonatal unit nursing in Kenya. Evidence suggests that neonatal nurses have high workloads, with studies reporting that one neonatal nurse might care for as many as 25 babies on a single nursing shift, with heavier workloads seen in the public health sector (28). In smaller hospitals, nurses also share their time between caring for sick newborns and caring for their mothers in the maternity (53).

Such severe shortages are reflected in the everyday struggle of neonatal nurses to provide care and develop coping strategies for their day-to-day work (54). Qualitative research, primarily from ethnography, has suggested that neonatal nurses develop coping strategies by building some predictability into their roles by categorising patients and routinising nursing activities (54). Typically, neonatal units have scheduled times for various activities; for example, medication, feeding and care for individual babies fit into such times. Babies are also categorised into three categories (A, B and C).

Category A babies, viewed as the sickest of babies, receive the most care, as opposed to B (stable but unwell) and C (stable), and this is considered a form of 'subconscious triage' (55). There is also qualitative evidence to suggest that nurses prioritise technical over routine bedside tasks (55,56). Quantifying such practices would be invaluable to providing evidence for needed improvements in staffing.

1.5 Quality of care

The Institute of Medicine defines quality of care as "the extent to which health care services provided to individuals and patient populations improve desired health outcomes" (57). Quality care is also viewed as a multidimensional concept encompassing the provision of care that is evidence-based, safe, efficient, patient-centred, timely, equitable and integrated (58). In practice, it is difficult to measure and is assessed by measuring indicators that provide 'signals' of quality (59). Broadly speaking, quality indicators can be structural (reflecting physical components of care- staffing, equipment), process (appropriateness of care delivery) and outcome-based (reflecting patient health status) (59).

In the following few subsections, I examine the global agenda for quality of care and review the evidence linking ward-level nursing staff to quality of care. I also explain why neonatal units are good settings for examining the relationship between nurse staffing and quality of care.

1.5.1 The global agenda for quality of care

In recent times, there has been a renewed global focus on healthcare quality by policymakers and development partners (60). This is linked to a few reasons, including the recognition of significant inequalities in global healthcare standards, increasing public expectations for quality, a recent move towards attaining universal health coverage (UHC) and a recognition that millions of preventable deaths and patient harm are attributable to poor quality care (61). The global refocus on quality of care is also linked to recognising the critical nexus between healthcare quality and pandemic preparedness and an understanding that access to care alone does not guarantee positive public health outcomes (61). This refocus on quality of care is evident in international declarations and global policy directions. For example, the Sustainable Development Goals in target 3.8 specifically calls on countries to “achieve UHC, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all” (62). The World Health Organization (WHO) has also developed policy documents to guide strategies for setting national policies on quality and planning the delivery of quality health services (63–65). It has developed a quality framework specifically for maternal and newborn health, which underscores the critical role of human resources for health (including nurses) as one of its eight domains to ensure positive health outcomes (Figure 1.4) (66).

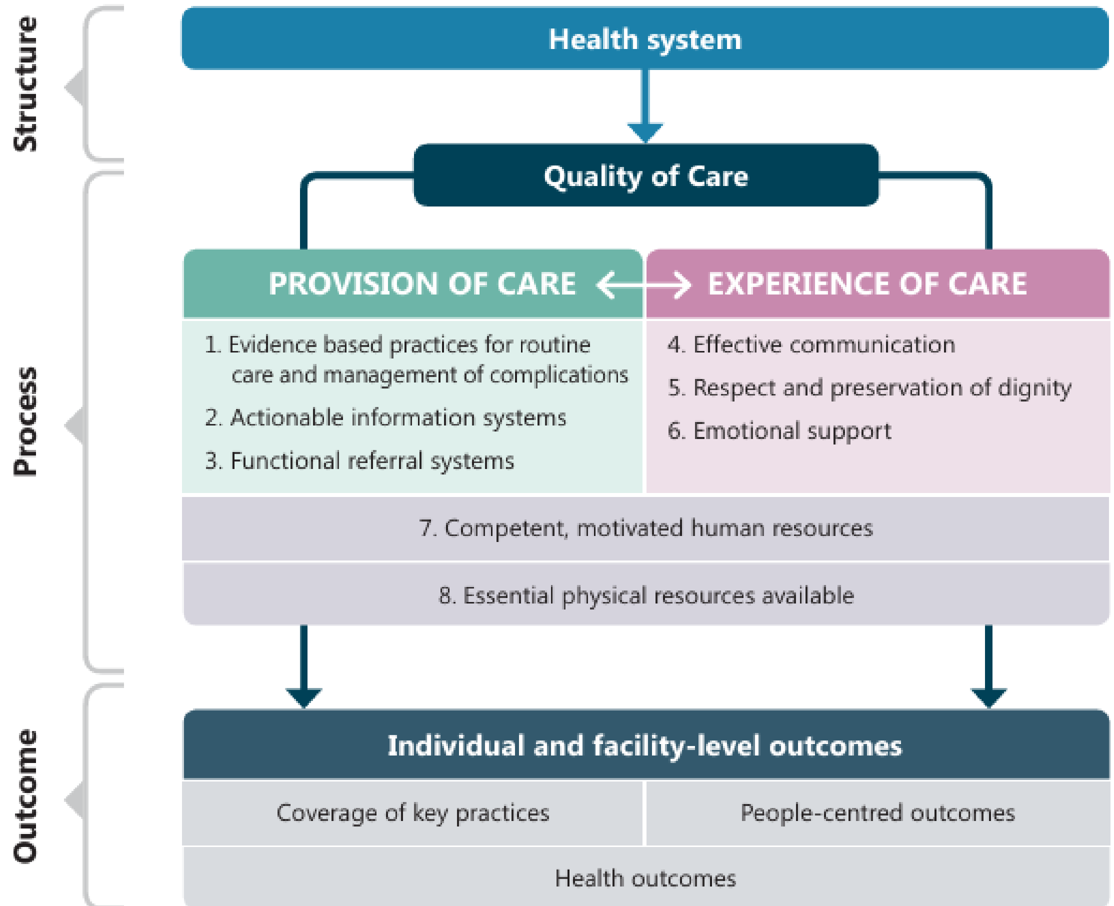

Figure 1.4– WHO framework for the quality of maternal and newborn health care (66).

Quality of care is also taking centre stage in the global agenda to improve care in low- and middle-income countries, particularly in maternal, newborn, and child health. There is a worldwide move towards funding networks of care. This comprises groups of health facilities and or healthcare-affiliated stakeholders (governments, non-governmental organisations, donors, academia) coming together to deliberately improve care quality through a process of collaborative learning and multidisciplinary teamwork (67,68). Examples of such networks include the Quality-of-Care Network (QoCN), which was a partnership between national country governments, implementation partners and funding agencies which aimed to halve facility deaths of mothers, newborns and stillbirth rates by the year 2022 (69). Another example is the Newborn Essential Solutions and Technologies (NEST-360°) collaboration, which has a similar partnership to the QoCN and is present in four African countries, including Kenya, with a goal of halving neonatal mortality (I go into greater detail about this collaboration in Chapter 2 where I describe my research context) (70).

Using indicators to measure quality of care has also been at the forefront of the global quality agenda (71). There are a plethora of indicators for quality of care (59). One recent systematic review found 144 indicators; most were, however, not linked to nurse staffing (59). The WHO has also developed 25 Paediatric and newborn care core indicators spanning the eight care domains described in Figure 1.4 (72). Indicators on their own only identify challenges with quality, and it has been suggested that measurements be paired with quality improvement when deficits are observed (71).

1.5.2 The evidence linking ward-level nurse staffing and quality of patient care

The health workforce is recognised as one of the six cardinal building blocks of the health system and is a critical input that affects health service readiness, quality, and safety (66). A large body of research, mainly from high-income countries (HICs), has demonstrated the effect of understaffing on poor patient outcomes (11,73–77).

The evidence base has shown that lower nurse-to-patient ratios are associated with poor patient outcomes, such as increased patient mortality. Griffiths *et al.*, using a retrospective longitudinal cohort design employing routinely collected administrative data from the National Health Service in the UK, showed that the average hazard of death increased by 3% for every day a patient experienced nurse staffing levels below the average ward level nurse staffing (11). Aiken *et al.* also used a similar methodology combining hospital administrative data on patient mortality statistics and nurse surveys on workload to demonstrate a relationship between nurse staffing and mortality risk (26). Both studies employed large administrative data sets from multiple hospitals and, in the case of Aiken et al., data from multiple countries to demonstrate an association with mortality (11,26). Low nurse-to-patient ratios have also affected some nurse outcomes; for example, greater dissatisfaction, burn-out and higher rates of intention to leave using similar secondary data (27). Other studies have also been conducted on outcomes such as poor patient satisfaction, nurses' perceptions and reports of poor-quality care, length of stay, hospital-acquired infection and complications related to in-hospital stay (27,78). While existing data have employed large datasets providing causal links for poor nurse staffing and patient care outcomes, this evidence has largely been observational and ecological; critics of the evidence have suggested the need for interventional research and greater patient-level data to allow for case-mix adjustment to strengthen the causal arguments (79)

In addition, research focusing on nursing skill mix, i.e. the proportion of the nursing workforce that are registered nurses and the quality of care, has provided evidence that substitution of ward nurses using nurse support workers in HICs leads to a dilution of skill mix and poorer quality of care using observational data (80). Aiken *et al*. used cross-sectional patient discharge data and nurse and patient survey data to demonstrate that a higher proportion of registered nurses in the nursing team is associated with improved patient care outcomes (81).

The situation in low- and middle-income countries is characterised by a dearth of evidence for nurse staffing and quality of patient care. A few reviews investigating this have documented limited evidence of relatively poor quality (9,82)**.** Assaye *et al.,* in their review, documented only six papers from LMIC settings that documented this relationship (29). There thus exists an evidence gap in such settings.

In general, the quality of patient care has been measured using outcome-based measures of care or process-based ones, such as missed nursing care (83,84). Missed nursing care is an umbrella term for nursing processes of care that are either partially or wholly omitted or delayed by nurses during their duties (85,86). Multiple synonyms in the literature often refer to it, including care left undone, implicit rationing of care, task incompletion, and unmet needs (87). Rather than reporting what was not done, some studies have reported more positive measures (nurse-delivered care or nursing care provided), which still reflect the concept (28). Whatever the term used in literature, the theory behind missed nursing care is that nurses have to prioritise aspects of care over others due to competing demands for nursing time, so they either completely miss, delay or deprioritise tasks (85). Studies of nurse staffing and missed nursing care have shown that poorer nurse staffing is associated with greater missed nursing care (83,84). They have also demonstrated that increasing nurse staffing decreases missed nursing care (76). Research on missed nursing care has also shown that missed nursing care mediates between staffing levels and adverse patient care outcomes, such as mortality and decreased patient satisfaction (87,88)**.** There is, thus, significant scientific evidence that a reduction in missed nursing care (or an increase in nurse-delivered care) is related to better patient care outcomes.

1.5.3 Why neonatal units are good settings to study the effect of nursing on quality of care in resource-constrained LMICs at this time.

There is increasing recognition that many newborn deaths are preventable, and it is estimated that at least three million lives might be saved annually by improving the quality of care in the newborn period and the immediate postnatal period (89). The SDGs in target 3.2 focus on ending preventable deaths of newborns and children under five by 2030 and specifically set a target to reduce neonatal mortality rate (NMR) to under 12 per 1000 live births (90). A global policy linked to the NMR target is the Every Newborn Action Plan (ENAP), launched by the WHO in 2014 and implemented by 106 countries (91). The ENAP has five key strategic objectives for ending preventable newborn deaths and stillbirths, including investing in peripartum care, improving the quality of maternal and newborn care, improving access to care, leveraging the power of parents, families and community and measuring and tracking birth outcomes and quality of care around birth (91). Specifically linked to improving the quality care of newborns is the recognition that providing quality care for small and sick newborns is a crucial strategy, and this is highlighted in two key policy documents - standards for improving the quality of care for small and sick newborns in health facilities (89), and the Survive and Thrive report (92), both of which highlight the critical importance of human resources for health.

Recently, new indicators have been added to the ENAP to hasten the progress towards the 2030 SDG neonatal targets (93). This includes increased access to Level 2 neonatal care (defined in Table 1.5) at the district (subnational) level (93). In Kenya, there has been a large-scale newborn technology introduction and re-design of newborn units under a collaboration between the government and the NEST-360° alliance (discussed in detail in Chapter 2) to increase access to Level 2 newborn care (70). These investments are not simultaneously ensuring health workforce or nursing workforce expansions. This is despite the pivotal role that a sufficient multidisciplinary workforce with requisite skill plays in ensuring neonatal survival and utilising technology for care provision (94). The recent upgrade in life-saving technologies in neonatal units in Kenya provides an opportunity to examine the effect of health workforce numbers and specific interventions to increase this on the quality of newborn care.

Table 1.5 – World Health Organization levels of newborn care with interventions they can provide (93).

Level 1 (Immediate and essential newborn care)	Level 2@ (Special newborn care)	Level 3* (Intensive newborn care)
Immediate newborn care (delayed cord clamping, drying, skin-to-skin, etc.)	Thermal care, including KMC for all stable neonates <2000g	Mechanical/assisted ventilation
Neonatal resuscitation for those who need it	Assisted feeding and intravenous fluids	Advanced feeding support (e.g. parenteral nutrition)
Breastfeeding early initiation and support	Safe administration of oxygen	Investigation and treatment for congenital conditions
Essential newborn care Identification and referral of complications	Detection and management of neonatal sepsis with injection antibiotics	Screening and treatment for Retinopathy of Prematurity
Targeted care as needed, e.g. PMTCT of HIV	Detection and management of neonatal jaundice with phototherapy	
	Detection and management of neonatal encephalopathy	
	Detection and referral/management of congenital abnormalities	
	Management of preterm respiratory distress with CPAP	
	Follow-up of at-risk newborns	
	Exchange blood transfusion	

@ - Level 2 neonatal units can provide all interventions at Level 1 and interventions listed under Level 2

*-Level 3 neonatal units can provide all interventions at Level 1 and Level 2, and all interventions listed under Level 3

CPAP – Continuous Positive Airway Pressure, HIV – Human Immunodeficiency Virus, KMC- Kangaroo Mother Care, PMTCT – Prevention of Maternal to Child Transmission

1.6 Thesis justification and aims.

Nurses are integral in achieving the global health agenda, and there has been an increased focus on nurses and nursing policy at the national and international levels. These policies have yet to translate into increased nursing numbers on the frontline. This is particularly so in resource-constrained low-income settings where extremely low nurse-to-patient ratios are largely viewed as a norm. In such settings, there exists a dearth of evidence on the relationship between nurse staffing and quality of patient care (9,29). The extent and nature of this gap in evidence has been poorly studied. Also, most data on nurse staffing and quality of patient care comes from high-income settings, which have distinctively different patient care and organisational contexts from under-resourced settings (29,78).

Another challenge has also been the methodology employed in this area of research, which has exclusively involved non-interventional study designs (79). Although these methods establish strong associations between nurse staffing and quality of care, there is room for interventional studies to strengthen the causal argument for an adequate number of ward nurses and their role in improving the quality of care (79).

The current thesis examines nurse staffing levels and nursing care provision in a set of Kenyan newborn units with resource constraints and evaluates the relationship between the two and the impact of adding extra nurses on the provision and quality of newborn care using a prospective intervention study design. In this thesis, quality of care is primarily measured using changes in nurse-delivered care (the proportion of care nurses in the neonatal units can deliver to babies who are resident for care). Care delivered by nurses in neonatal units can be viewed as a process measure of the quality of care, assessing key quality dimensions, including safety and delivery of evidence-based practices.

My specific objectives for this thesis were to:

1. Examine the existing evidence for nurse staffing and quality of patient care in low and middle-income countries and identify a set of nurse staffing and quality of care metrics.
2. Examine nursing care provision and missed nursing care in a set of Kenyan newborn units and determine the relationship between nurse staffing and nursing care provision.
3. Determine the effect of enhancing nurse staffing on nurse-delivered care measured using the nursing care index (NCI) tool in a before and after design study of four hospitals.
4. Examine how introducing additional staff affects nurse staffing metrics as a measure of intervention fidelity to help explain any observed effect on nursing care delivered.

Chapter 2- Methods[1]

2.1 Introduction

In the previous chapter, I explored the global nursing workforce shortages and specifically focused on the evidence linking nurse staffing levels and quality of care. I also provided broad details of the Kenyan context, where my research is based. In the current chapter, I describe my research context and broadly discuss my study methods. In subsequent chapters, I will provide greater details of the methods I employed for each results chapter. My study methods include systematic literature reviews and quantitative research methods.

2.2 Research context

My DPhil project is nested within a larger parent project, Harnessing Innovations in Global Health for Quality Care (HIGH-Q). I initially provide broad details of this parent project (HIGH-Q) and then give an overview of specific methods I employed to answer my DPhil research questions.

2.3 The Harnessing Innovations in Global Health for Quality Care (HIGH-Q) programme

The HIGH-Q programme was introduced on the background of an existing collaboration, the NEST-360° alliance, which conducted a large-scale introduction of new neonatal technologies and neonatal staff capacity building across newborn units in Kenya and three other African countries (Tanzania, Malawi,

[1] This Chapter contains content from the following publication - *Imam A, Gathara D, Aluvaala J, Maina M, English M. Evaluating the effects of supplementing ward nurses on quality of newborn care in Kenyan neonatal units: protocol for a prospective workforce intervention study. BMC Health Services Research. 2022 Oct 4;22(1):1230.*

and Nigeria) (70). NEST-360° is an international alliance of researchers from 22 organisations and institutions collaborating with the national governments of the four aforementioned African countries (70). It has the broad aim to tackle preventable newborn deaths across Kenya and other African countries through implementing a package of equipment and training in the use of life-saving neonatal devices such as blood glucose monitors, radiant warmers, oxygen delivery units, phototherapy, Continuous Positive Airway Pressure (CPAP) machines, and a few other newborn technologies (70). NEST-360° is also creating an ecosystem for using and sustaining these technologies through capacity building for neonatal unit staff and other staff involved in equipment management, such as biomedical engineers (70)However, implementing the NEST-360° bundle together with all-around neonatal care is reliant on existing hospital staff, including nurses.

Building on the existing NEST-360° alliance, the HIGH-Q programme sought to evaluate how technological implementation can be better designed for improved quality of newborn care. In addition, the HIGH-Q programme recognised that newborn technologies were being introduced in poorly staffed neonatal units and sought to examine how a staffing intervention to increase the number of staff available for nursing care on a background of increased neonatal technologic capacity might affect the quality of newborn care in these units (78).

2.3.1.1 Architecture of the HIGH-Q programme and how my research feeds into this

The HIGH-Q programme has five broad objectives - evaluate how the introduction of new technologies affected the quality and outcomes of neonatal care, evaluate how the introduction of the staffing intervention affected quality of newborn care and staff and family experiences and examine how post-discharge pathways might be strengthened for newborns. It also examined the governance processes around technologies and costs associated with the implementation of the workforce intervention (Figure 2.1). Within the broad objective of evaluating the effects of the workforce intervention on quality of care, my DPhil was distinct and specifically focused on if adding extra nurses to newborn units improved the quality of care. There were ancillary studies within this broad objective which were led by research assistants and post-doctoral fellows. These complemented my research but focused on other specific aspects of the workforce intervention, for example, the effect of the intervention on staff and family experiences, a process evaluation to understand how the workforce intervention resulted in the observed effects, a time in motion study to understand how nurses used their time in the neonatal units and another study to examine how the addition of ward assistant to supplemental nurses affected care quality and the roles undertaken by nurses (Figure 2.1). The work by other DPhil students within the programme is also summarised in Figure 2.1. In the next subsection, I focus primarily on my aspect of HIGH-Q, the HIGH-Q workforce intervention.

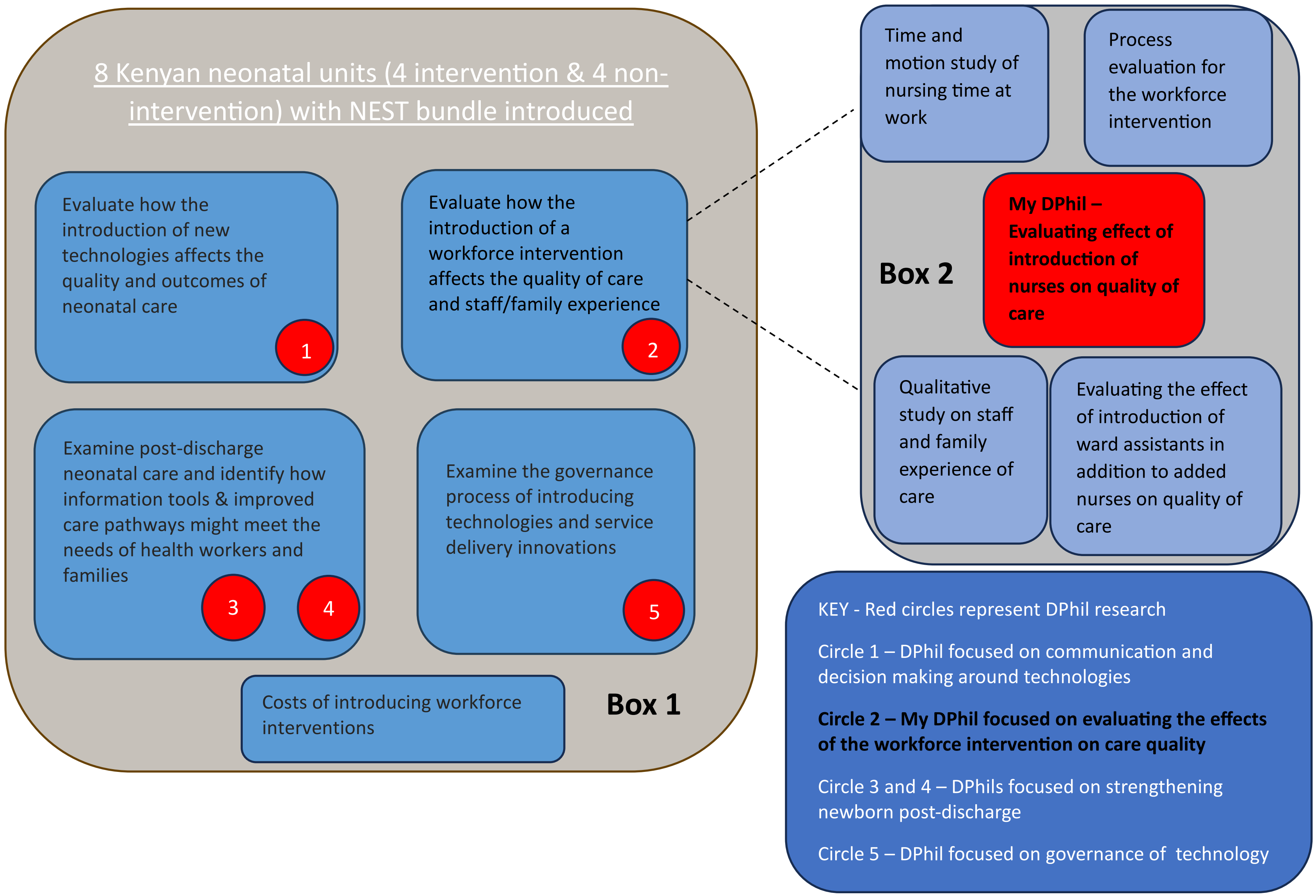

Figure 2.1 - Architecture of the Harnessing Innovations in Global Health for Quality Care (HIGH) programme showing broad study objectives in Box 1 and my DPhil in focus and how it relates to complementary research in Box 2

2.3.1.2 The HIGH-Q programme workforce intervention

A central element of the HIGH-Q programme was the addition of three extra nurses to supplement existing nurse staffing numbers in four neonatal units, termed intervention newborn units. These nurses were added for 15 months. Mid-way through the nurse staffing intervention at six months, three neonatal ward assistants were added to each of these settings to complement the work of the nursing staff. The programme considered adding this number of extra nursing staff as potentially feasible for policymakers to make in a resource-limited units such as Kenya. It was also within budget for the programme. The programme involved the Nursing Council of Kenya (NCK) and the National Nurses Association of Kenya (NNAK) in discussing the need for an intervention study but the selection of three nurses was based on affordability and the sample size calculation (as previously mentioned). The NCK and NNAK were also involved in the design of the job description for the neonatal ward assistants who were added to the neonatal units. My DPhil focused on evaluating the effect of the addition of nurses alone on the quality of newborn care provided in these units.

2.3.1.3 HIGH-Q study site selection

The HIGH-Q programme was conducted across eight newborn units. These comprised four intervention neonatal units mentioned in the preceding subsection and an additional four units with no staffing intervention in place (Figure 2.1). This second group of neonatal units, referred to as non-intervention units, provided additional data as an external reference to help understand typical nurse staffing patterns and care provision. All HIGH-Q selected neonatal units were government-owned facilities, and they provided intermediate-level (Level 2) neonatal care, for example, non-invasive ventilation support such as CPAP, feeding support of critically ill babies using tube feeding and support of small and sick newborns who do not require intensive care or neonatal ventilation (95). They also served as referral neonatal units for primary care and were situated in level 5 hospitals, representing the highest tier (Tier

4) of the Kenyan health system (See Figure 1.2 and Figure 1.3). In HIGH-Q, the neonatal unit selection was a pragmatic process as sites were selected with consideration for proximity (between 1-to-4-hour travel distance) to Nairobi, the Kenyan capital, due to the travel constraints related to the COVID-19 pandemic, and to allow for easy movement across the sites. Pragmatic study site selection was also important because it was crucial to work in neonatal units where the programme had administrative support and settings with varied nursing workloads to allow for staffing variability.

2.4 DPhil research approach

2.4.1 Background

My DPhil addresses the central research question: In neonatal units with very low nurse staffing levels and wider resource constraints, does a workforce intervention that increases nurse staffing levels on neonatal wards improve the quality of care received?

To address my central research question, I initially conducted systematic literature reviews on nurse staffing and quality of care, which informed the development of a logic model to guide my overall analytic strategy. In the next few subsections, I give a broad overview of each component of my research approach and then go into more specific detail within subsequent results' chapters.

2.4.2 Systematic review of literature

An early step in my DPhil was conducting two literature reviews. The first was an overview of existing systematic reviews on nurse staffing and patient care outcomes, a measure of the quality of patient care (82). The second was a more specific systematic review on missed nursing care (patient care that is wholly or partially missed by nurses when they carry out their duties) in acute hospital settings in low and middle-income countries (LMICs) (96). Both reviews influenced the contents of my logic model (discussed later in the next subsection).

2.4.2.1 *Overview of systematic reviews*

I selected this review type as it allows for greater efficiency when synthesising literature in an area with a large volume of research (97). Using this review methodology, I synthesised the information from published systematic reviews to examine how nurse staffing had previously been measured in published research and appraise patient care outcome metrics that had previously been studied concerning nurse staffing. Following this review, I identified missed nursing care, a process measure of quality care, as my preferred outcome measure to evaluate the effect of the nursing workforce intervention on the quality of newborn care. I preferred this metric as it is likely proximal in the causal pathway of how an intervention might elicit its effect compared to traditional outcome-based measures of quality of care, for example, patient mortality or length of stay.

2.4.2.2 *Systematic review on missed nursing care.*

Following the overview of reviews described above, I conducted a systematic review specifically on missed nursing care. Through this review, I appraised existing measurement tools for missed nursing care and developed my analytic strategy on missed nursing care (These are described in Chapters 4 and 5, which focus on missed nursing care).

2.4.3 Logic model

Based on literature from my systematic review of the literature, I developed a logic model to guide my conceptual thinking on how the nurse staffing intervention might be deployed and how it might lead to a change in my indicator for the quality of newborn care (missed nursing care). This process involved defining key mediators along the causal pathway from intervention to outcome and underlying pathway causal assumptions (Figure 2.2). I addressed some of these causal assumptions through key adaptations (tailoring) of the nurse staffing intervention. I considered other potential methods to guide my thinking, such as a theory of change or conceptual framework. My logic model was built around a structure-process-outcome framework proposed by Donabedian (I go into this in a subsequent subsection). A theory of change, although providing more details about mechanisms and assumptions, is a more laborious process involving multiple stakeholders and requiring multiple iterations (98). It might conveniently stand alone as a DPhil objective. Also, the HIGH-Q project was developing a theory of change for the overall study and using this method might have duplicated the process.

2.4.3.1 Tailoring the intervention

Tailoring refers to the planned personalisation, titration, or adaptation of an intervention and is often carried out to improve its uptake (97). This section addresses how I modified the HIGH-Q intervention using my logic model for this purpose.

In my logic model, I identified key assumptions along the pathway to effect. This included buy-in from existing neonatal nurses to the programme, supplemental nurses possessing the requisite skill to function as neonatal unit nurses and the absence of resource diversion, for example, transfer of existing nursing staff or increased leave or absenteeism (Figure 2.2). To address some of these assumptions, I suggested critical modifications to the nurse staffing intervention implemented by the HIGH-Q programme before deploying the nurse staffing intervention. This included signing a memorandum of understanding with county governments and hospital management to minimise staff transfers and maintain existing nurse staffing ratios during the intervention and providing the additional nurses with structured neonatal care training before their introduction.

2.4.3.2 Framework for the logic model

I structured my logic model using Donabedian's structure process and outcome framework (Figure 2.2) (99) (100). Briefly, Donabedian's framework describes how changes in health service structures influence critical processes of care, which in turn can affect care outcomes (99). Using this framework, I identified that the nurse staffing intervention would likely change a key structure in neonatal units -

nurse staffing levels. I then identified vital processes that were likely to change because of the intervention, including an increase in time available for nursing care, ultimately leading to an increase in nurse-delivered care/ reduction in missed nursing care. The measures of nursing care time were derived from the literature in my overview of systematic reviews.

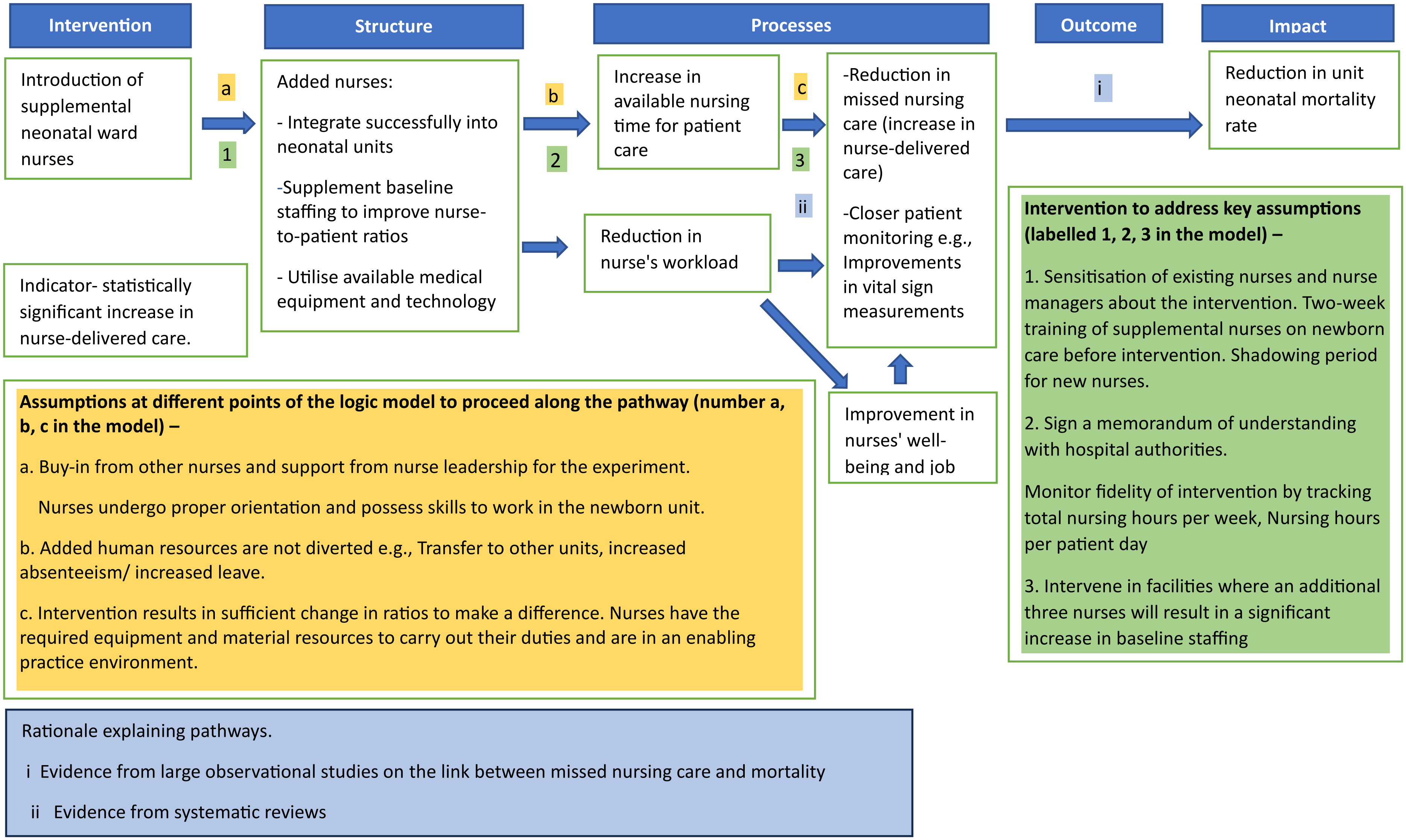

Figure 2.2 - Logic Model – Adapted from Imam A, Gathara D, Aluvaala J, Maina M, English M. Evaluating the effects of supplementing ward nurses on quality of newborn care in Kenyan neonatal units: protocol for a prospective workforce intervention study. BMC Health Services Research. 2022 Dec;22(1):1-9 (78).

- Mortality is classed as an impact, as it is likely affected by other exposures and is significantly downstream of the intervention

2.4.4 Research methods

In this section, I provide an overview of the methods used for my systematic literature reviews and primary data collection. Subsequent chapters explore each method in greater depth.

2.4.4.1 Systematic literature review

Overview of systematic reviews

To conduct my overview of reviews, I used the Joanna Briggs Institute guidelines, which guide all aspects of performing this form of review (101). I used the A MeaSurement Tool to Assess systematic Reviews-2 (AMSTAR-2) criteria to assess the quality of the individually included systematic reviews (102). Before conducting my review, I registered the review protocol on the International Prospective Register of Systematic Reviews (PROSPERO), which can be accessed at https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021286908. I also published my review protocol (9).

Systematic review

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidance, the standard reporting tool for a systematic review, guided the conduct and reporting of my systematic review (103). I conducted quality assessments of individual studies using the Newcastle-Ottawa Scale (93). I registered my review protocol on the International Prospective Register of Systematic Reviews (PROSPERO), which can be accessed at https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021286908 and I published my review protocol (104).

2.4.4.2 Primary data

Data collection

Using a structured observational checklist, I collected nursing care provision data across the eight HIGH-Q neonatal units (Appendix 1). In the four intervention units, I collected this data at baseline (before extra nurses were added) and then six months after their introduction (post-intervention period). I collected the same nursing care data in four non-intervention neonatal units on one occasion coincident with the post-intervention data collection period. The ideal might have been to do a before and after in both non-intervention and intervention sites, but cost considerations allowed only for a single time point data collection.

Data collection from the non-intervention sites in addition to providing broader information on context, also served to provide reference data to indicate that what was observed in the four purposefully selected intervention sites was not completely atypical in terms of nursing workloads and patterns of working. Additionally, taking this data at the time of the intervention was in part linked to contingency planning. It allowed the programme to have some contemporaneous information in case there was a major change over time in staffing patterns, for example, a new hiring programme everywhere or an industrial strike (common in the Kenyan setting) or a resurgence of COVID so that the reference information might provide contextual information at the time of the intervention. I discuss the limitations of this in my discussion chapter.

I chose structured observations over other potential methods such as surveys, as surveys might be affected by social desirability bias or recall bias (particularly when asking nurses to comment on care they had done or not done) which are not evident when using structured observations. I also preferred this method over other methods such as time in motion studies, as a time in motion study would have examined how much time nurses spent on individual patient care rather than detect a change in actual volume of care delivered (which was the focus of my study).

Data collection tools

I adapted an existing structured observational tool previously used to collect data on nursing care delivery in newborn units in Kenya (28). I also designed a health facility assessment tool to collect specific contextual data in each of the eight neonatal units (Appendix 2).

Adapted structured observation checklist

I used a structured observation checklist (Appendix 1) to collect data on nursing care provision and care processes performed around newborns admitted for neonatal care. The development of this tool was linked to earlier work to develop draft minimum standards for nursing care in Kenya through stakeholder engagements involving a broad group of nursing experts from the Kenyan Ministry of Health, nurse training institutions and development partners working in newborn health in Kenya (33). In earlier research in Kenya, this tool had been used to measure nursing care delivery across select neonatal units using the standards proposed (28). The content and face validity of the structured observational tool had previously been evaluated in Kenya (28).

The tool was developed to collect care processes around a newborn infant, i.e., patient-facing nursing tasks (Appendix 1), through non-participatory observations by an observer at the infant's bedside. The tool has three sections –Parts A, B, and C. Part A collects data on nursing shift information, for example, the type of shift (weekday, weekend, night, or day), the shift length, the number of babies on the ward and data on shift processes such as discharges and admissions and data on shift staffing. Part B collects general data on the specific baby being observed, for example, the acuity of the baby, the current diagnosis, and other clinical characteristics such as birth weight. Part C collects patient-facing nursing care data divided across 14 domains of care, which comprise routine nursing care, vital sign monitoring, routine newborn care, feeding, nasogastric tube feeding process, oral and intravenous medication, intravenous medication delivery processes, Kangaroo mother care supervision, phototherapy, continuous positive airway pressure ventilation, oxygen therapy and patient documentation. Each of these care domains also includes specific indicators (or nursing tasks); for example, the domain of vital sign monitoring is divided into data for temperature, pulse rate, respiratory rate, and pulse oximetry monitoring (Appendix 1). Observers were trained to identify each nursing task. A glossary of nursing tasks is available in Appendix 3**.** These descriptions are based on a standard operating procedure (Appendix 4) developed to train the observers to ensure consistent data collection across the eight neonatal units.

With the permission of the previous researchers, I adapted this tool to include other aspects of data that were important for my research. I describe these adaptations in the following subsection.

Specific adaptations to the structured observation checklist for my DPhil

I adapted the structured observation checklist tool for my data collection. The original tool needed to be adapted as it did not delineate persons conducting care in the neonatal unit and considered care as carried out irrespective of who performed care. Because my intervention added extra nurses to neonatal units, it was essential to determine how improving nursing numbers affected the nurses' work. My adaptations to the tool are highlighted in yellow in Appendix 1**.** I also revised the tool to contain data on potential confounders for the intervention effect, for example, proxy data to estimate nursing workload on shifts (number of high acuity babies, babies on interventions such as those on nasogastric tube feeding), and presence of the necessary medical equipment to perform nursing duties such as thermometers, pulse oximeters and stethoscopes for vital sign monitoring.

Health facility assessment tool

To characterise each of the eight study neonatal units, I collected contextual data using a health facility assessment tool I designed for this study (Appendix 2). Before designing my HFA tool, I reviewed data from the NEST-360 HFA, which I considered dated by the time of conduct of my study, and it also did not address contextual information I needed, for example, the pattern of nursing care provision in each of the individual units. My HFA tool included data on neonatal unit staffing, such as nurse staffing numbers and skill mix, in terms of the educational levels of each nurse within the unit. It also included data on other staff who worked in the unit, including consultant Paediatricians, medical officers and medical officer interns who are junior doctors and ward assistants. The tool also collected data on specific unit procedures, such as neonatal unit shift lengths and types (this was not standard across all neonatal units), timing and frequency of various nursing care tasks such as vital sign monitoring and intravenous medication administration. This tool provided data for neonatal unit comparisons and contextual understanding to interpret and analyse the observation of care data.

Data collection processes

In this subsection, I describe the data collection processes and some of my key considerations. I sequentially describe the process from piloting the adapted structured checklist and health facility assessment tools to field staff recruitment considerations and actual data collection.

Piloting the structured observation checklist tool

Before conducting observations with the adapted tool, I carried out pilot tool testing at another newborn unit that was a non-study site. This was performed with two research officers employed to support the programme, whom I had previously trained in all aspects of data collection, including using the observation tool**.** This pilot process aimed to determine the feasibility of using the adapted version of the tool and the practicality of conducting observations. These research officers were later instrumental in supporting the training and supervision of field staff.

Recruitment considerations for field staff

To assist with conducting observations in the eight newborn units, the HIGH-Q programme recruited four field staff (hereafter referred to as observers) for data collection at baseline in the four intervention hospitals. In the post-intervention period, the programme recruited eight observers, comprising the initial four who had previously worked during baseline data collection in the intervention hospitals and an additional four to collect data in the non-intervention hospitals.

The programme recruited nutritionists for the observer role. The rationale behind this was that they were individuals who understood the hospital context and medical jargon. Unlike nurses or doctors, nutritionists would be less likely to be influenced by professional standards and loyalties and might also be better at retaining non-participant status during observations of care.

Field staff (Observer) training

To streamline the data collection process and ensure that the data was being collected in a standard format across all hospitals, I developed and adapted existing standard operating procedures (SOPs) to guide all aspects of data collection (Appendix 4)**.** These SOPs covered key data collection processes such as participant consenting, observations of care, what processes to observe, and a description of each process. They also covered hospital entry, data quality and data entry (Appendix 4). The two trained research officers worked closely with me and supported the training of the observers for data collection alongside other members of the HIGH-Q programme. The programme also conducted communication and skills training for observers, and they also underwent Good Clinical Practice research training. The training for the observers was split into classroom teaching and demonstration and in-hospital pilot training.

Group Pilot training of the observers.

I conducted group pilot training with the observers in a second newborn unit that was not one of our study sites. This training focused on the practical use of the structured observation checklist. I determined the feasibility of key data collection processes such as identifying the babies for observation, staff and caregiver consenting, recognising different sources for data extraction, and ensuring internal consistency of observations among the observers. For the latter, I paired the observers with myself or any of the two research officers for pilot data collection. At the end of these sessions, we revisited discrepancies in observations, and I made any corrections. This process was repeated along with the classroom training before the onset of the post-intervention data collection. Following this initial pilot training, each observer had further in-neonatal unit training in their respective hospitals.

In-hospital piloting of the structured observation tool and data collection processes

Before data collection, each recruited observer had a week of pilot-testing the observation tools and data collection processes in their respective newborn units. The two research officers and I travelled to each site to support and supervise the pilot testing across sites. We repeated this process before the conduct of post-intervention data collection. During these visits, we reviewed observation practices and specific data that were being collected and addressed any challenges and difficulties associated with observations. In addition to being supervisory, our visits also served the dual purpose of conducting health facility assessments in each neonatal unit.

Individual pilot testing by the resident observer within each neonatal unit allowed them greater practice with the tool. It allowed them to familiarise themselves with their respective unit layouts and specific processes to make their data collection as seamless as possible. It also permitted nurses providing care within these units to become comfortable with being observed, and this might have thus minimised the impact of the Hawthorne effect on actual data collection (105). To further minimise the Hawthorne effect, data collection was spread over six weeks and randomly selected 12-hour nursing shifts were observed. In this way, nursing staff could not predict shifts that would be observed. There is data to suggest that the impact of the Hawthorne effect decreases over time (106).

Observers debrief sessions.

During data collection, I led the research team in weekly debrief sessions, which were occasionally supported by a senior HIGH-Q programme member. These sessions served to troubleshoot issues arising in the field and were also an avenue to give feedback on lessons learned in one neonatal unit to the other observers.

2.4.4.3 Secondary data

As part of my data collection, I retrieved nursing rotas (which spell out nurse staffing for each intervention neonatal unit) from six months before the pre-intervention data collection to six months after the intervention. I also retrieved daily bed returns (daily patient volume in each unit) for the same period. I use this data to measure the intervention uptake across neonatal units. I will discuss this concept in greater detail in Chapter 6.

2.4.5 Study participants

To provide much broader details of nursing care provision, recruited participants (newborns) were from the patient care categories: unstable, stable but still ill, and stable babies. For explicit definition of these categories, I used previously defined and published criteria used routinely in Kenyan neonatal units; these classify babies into categories A (unstable), B (stable but ill) and C (stable) (33). Briefly, category A (unstable) babies require support with vital functioning, for example, babies on breathing support or who require incubator care, Category B (stable but ill) babies do not need support but are on interventions, for example, intravenous medication and nasogastric tube feeding, while category C babies are otherwise stable babies who are on the unit for kangaroo mother care, catch-up growth or due to maternal ill health.

Table 2.1 – Patient categorisation used to classify recruited babies into A, B and C*

<table>
<tr><th>Criteria</th><th>Category A (Unstable baby)</th><th>Category B (Stable but still ill)</th><th>Category C
(Stable baby)</th></tr>
<tr><td>Criteria 1</td><td>Baby is on at least one or any combination of the following interventions:
Continuous Positive Airway Pressure Ventilation.
Oxygen
Intravenous fluids
Blood transfusion
Under radiant warmer
Incubator care</td><td>Should not have any of the interventions listed in patient category A</td><td>Should not have any of the interventions listed in patient categories A and B</td></tr>
<tr><td>Criteria 2</td><td></td><td>Baby is on any combination of the following interventions.
Intravenous medication
nasogastric tube feeding
Double phototherapy</td><td>A baby who fits into any of the following categories:
Term baby on phototherapy alone
Baby accommodated because the mother is ill.
Stable preterm on KMC
On oral medications only</td></tr>
</table>

*-Adapted from Murphy GA, Omondi GB, Gathara D, Abuya N, Mwachiro J, Kuria R, Tallam-Kimaiyo E, English M. Expectations for nursing care in newborn units in Kenya: moving from implicit to explicit standards. BMJ Global Health. 2018 Mar 1;3(2): e000645 (33).

Participant eligibility criteria

Inclusion criteria

Participants who met the following inclusion criteria were recruited for this study –

1. Babies who had been admitted for care in the neonatal unit.
2. Those whose caregivers' consent to the study
3. Babies on a shift where the nurse on duty has consented to observations.

Exclusion criteria-

I excluded the following babies from the study.

1. Babies who were so severely ill they were at risk of imminent death or transfer to critical care units during observations of care – This is because they were likely to result in truncated observations in the event of sudden death during observations. This group of patients would also have been challenging for both observers and parents.
2. Babies with congenital anomalies and surgical conditions – This group were likely to have different observation standards from regular neonatal admissions, particularly if they were post-operative.
3. Those whose parents declined consent.

2.4.6 Shift selection - Nursing shift randomisation

I used stratified random sampling to determine the nursing shifts for observation. Random nursing shift blocks were created using STATA-18. This constituted random blocks stratified into day or night in a 50:50 ratio and weekends and weekdays in a 2:4 ratio (Figure 2.3). A sequence of random nursing shift blocks was then created for each baby category (A, B and C) (Figure 2.3). Each neonatal unit thus had its unique randomisation sequence, which spelt out the category of baby to be observed and on what shift type these babies were to be observed (weekday day, weekday night, weekend day, and weekend night). For example, the first sequence of the randomisation code might state that category B babies would need to be observed on the subsequent weekend day shift. This was done to provide valid inference for varying nursing shifts and patient care categories as care provision and nurse-delivered care are known to vary based on shift type and patient care category (96,107,108).

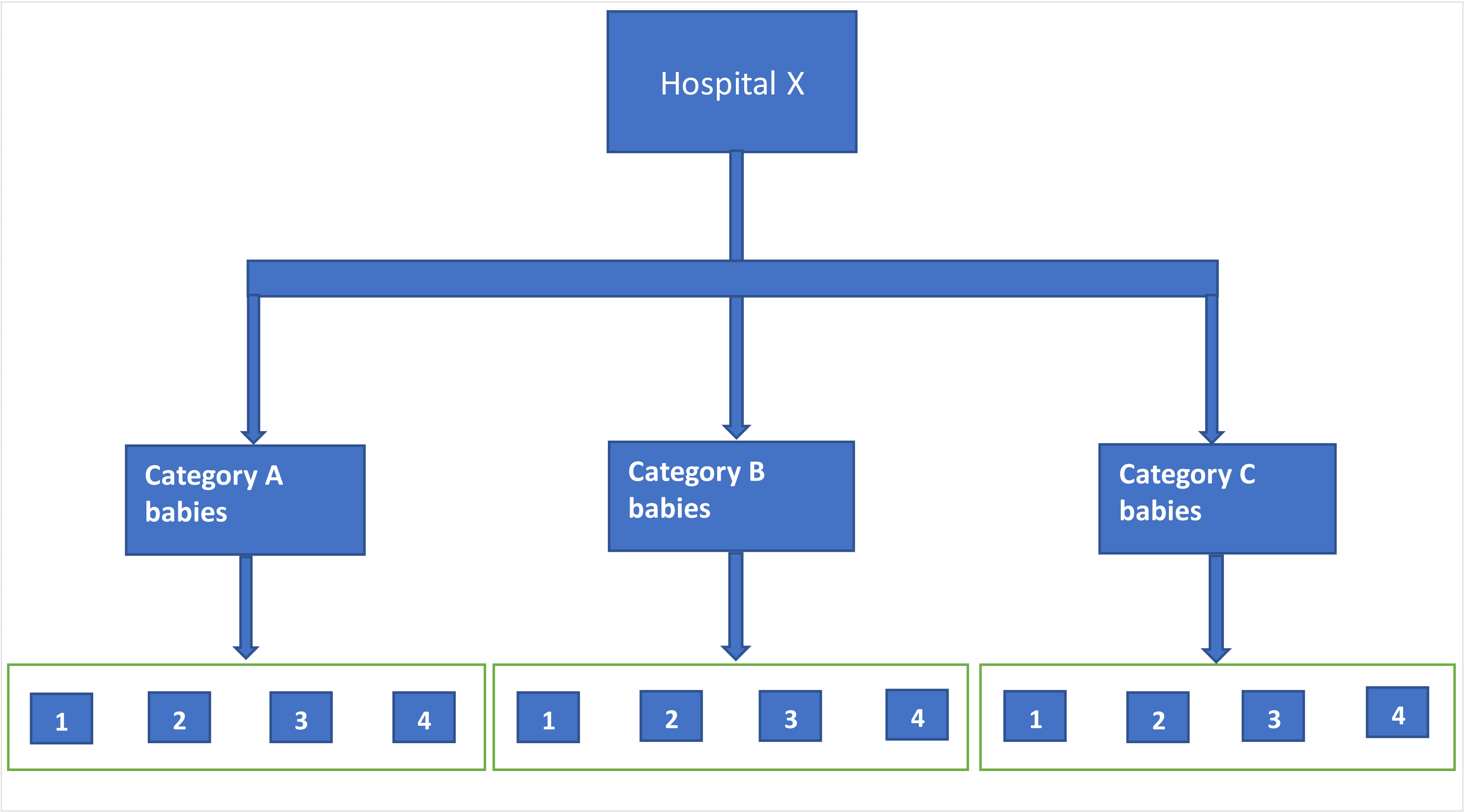

Figure 2.3– Stratified sampling approach across hospitals (neonatal units).

1 – Random Weekend Day 12-hour shift, 2 - Random Weekend night 12-hour shift, 3- Random Weekday Day 12-hour shift, 4- Random Weekday night 12-hour shift. Weekday and weekend shifts are in a 4:2 ratio.

2.4.7 Participant selection process by an observer

Following the randomisation process, each observer was provided with information on data collection a fortnight before an observation week. So, an observer knew the baby category to recruit, shift types and the dates for observations. In cases where it was impossible to recruit four babies of the same category, either because of low ward admissions or the absence of a particular category of babies on the ward, the observers informed me or the two research officers employed by the programme. Sometimes, we asked the observer to observe fewer babies or change the categories for observations based on availability. The remaining babies were then usually replaced in an additional shift.

Before starting a randomly selected shift, the observers approached caregivers of potential participants of similar illness categories (A, B or C) for consenting until they had four co-located babies for observation. They had previously been trained on participant selection, and each observer had a one-page reminder similar to Table 2.1 on the different patient categories to refer to. Observing four co-located babies within the units was feasible from both the pilot and preparatory weeks as babies of similar illness severity are frequently cohorted in the same section of the neonatal unit. Together with the two research officers, we had random supervisory visits where we offered continuous support to each observer, including cross-checking patient category selections by observers during these visits.

2.4.8 Sample size considerations.

The study sample size determination was based on a 5% improvement in mean nurse-delivered care (my primary outcome) between pre- and post-intervention data collection periods and a standard deviation of 15%. The standard deviation was derived from a previous cross-sectional study conducted in Kenya that employed the structured observational tool to measure nurse-delivered care and showed a variability of 15% across neonatal units (28). As there was no previous before and after study that had done similar work, the HIGH-Q programme considered a 5% improvement as the minimum clinically relevant improvement in nurse delivered care. Additionally, based on earlier the earlier Kenyan study which showed a largely linear relationship between nurse to patient ratio, the programme estimated what staffing intervention would be needed to improve nurse-delivered care by at least 5% and this equated to a 20-30% increase in nurse staffing which was deemed affordable by programme.

The sample size was also adjusted for clustering using a design effect of 1.5 as data on multiple (3 to 4) babies were usually collected during each observation. The study α and β to 5% and 80%, respectively. The resulting minimum sample size across each data collection period was 213. Therefore, I recruited at least 213 patients in each data collection period (213 babies from the four intervention hospitals combined, during the pre-and post-intervention period and at a single time in the non-intervention hospitals. The minimum sample size across all data collection points was thus 639. i.e. 213 multiplied by 3.

I split this sample size equally across patient illness severity categories (unstable, stable, but still ill and stable) and in a 4:2 split across the weekdays and weekends. These were some of the key factors influencing nursing care delivery identified from my literature review results presented in Chapter 3, and it was important for me to have a wide variation of data.

2.4.9 Data analysis considerations

I recognised my data was hierarchical as observed babies were nested within nursing shifts, which were nested within neonatal units (Figure 2.4). This guided my data analysis throughout the thesis, including the choice of multilevel modelling as an analytic approach. I detail my modelling strategy more in the individual results' chapters (Chapters 4 and 5). In Chapter 6, I use interrupted time series analysis to track staffing changes across time. Table 2.2 provides an overview of my specific methodology for each result chapter.

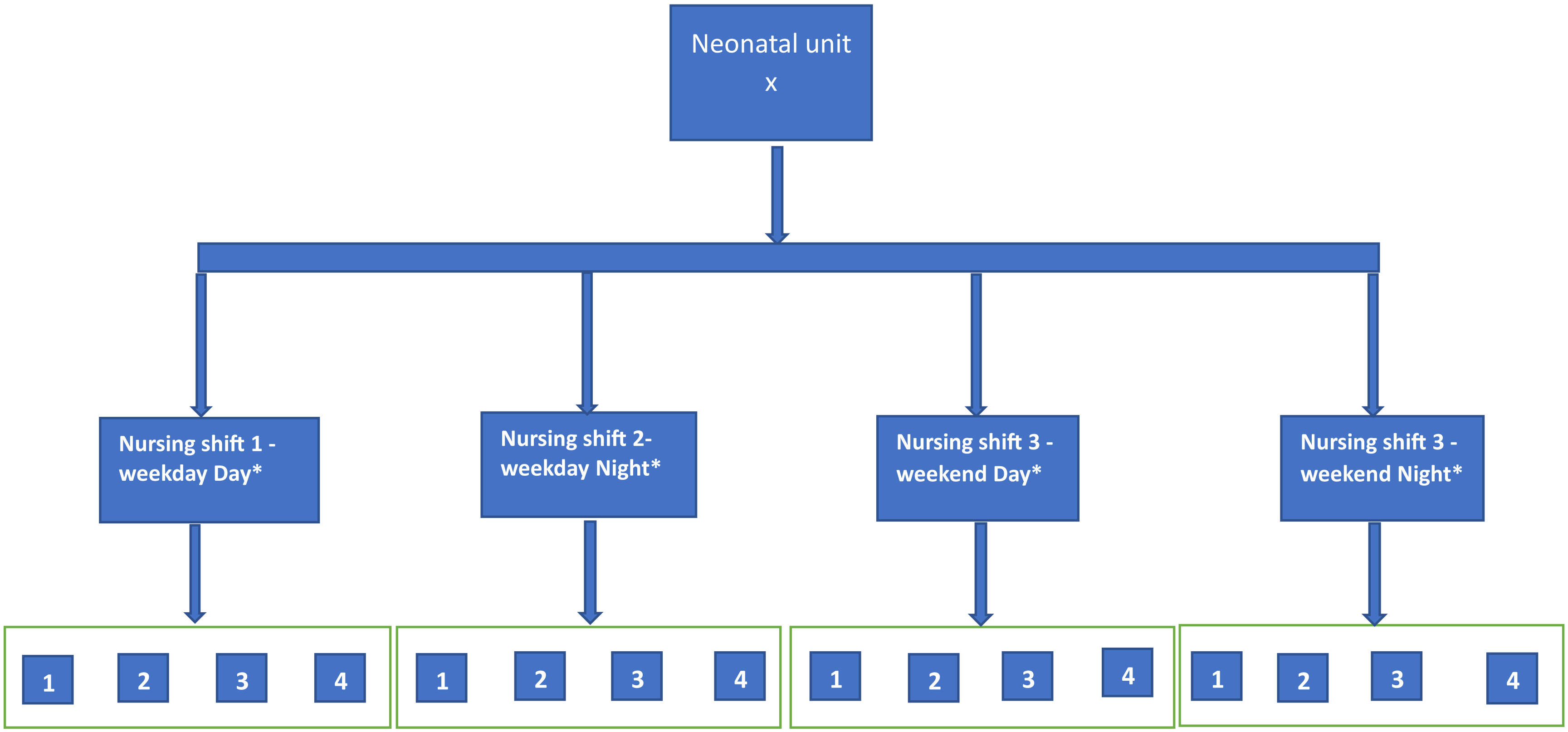

Figure 2.4– Description of hierarchical data where nursing shifts are nested in neonatal units and babies are nested in nursing shifts.

*- Random shifts were stratified into day or night in a 50:50 split and weekday and weekend in a 4:2 split

1 to 4 represent four co-located babies recruited in a shift.

Table 2.2 – Overview of specific methods for individual result chapters

Chapters	Chapter focus	Method	Data source
Chapter 3	Literature review	Umbrella review and systematic review	Secondary data sources – published papers
Chapter 4	Examining nursing care provision before the intervention	Cross-sectional analyses using multilevel modelling	Structured observational checklist from eight hospitals. Four intervention neonatal units before the intervention and an additional four non-intervention neonatal units
Chapter 5	Evaluation of the Workforce Intervention	Before and after analysis using multilevel modelling	Structured observational checklist data from four intervention neonatal units at two time points – pre-intervention and post-intervention
Chapter 6	Intervention fidelity	Interrupted time series analysis	Paper nursing rotas and daily bed returns

2.4.10 Data management

The observers collected nursing care data on paper-based structured observational checklists. Their pre-study training on the data collection SOP ensured that the data was collected consistently across each study site (Appendix 4). The two research officers and I continually visited the sites to review data collection processes throughout the data collection period.

Each structured checklist contained de-identified patient data and was only identifiable using a unique subject Identification number. The checklists were kept in a secure cabinet at the KEMRI-Wellcome Trust office in Nairobi to safely store data. Together with one of the research officers, I built a REDCap™ project to store the data collected electronically.

In the first round of data collection, information from the paper-based observational checklist was transferred to REDCap™ by data clerks who were employed for that purpose. By the 2nd round, the HIGH-Q programme provided each observer with a password-protected and encrypted electronic tablet, and they transferred data onto the REDCap™ database from their paper entries. The data collected was lodged on the KEMRI-Wellcome Trust secure server.

I continually reviewed the electronically stored data, conducting error checks and generating queries for each observer during data collection, and these were corrected from the source documents (paper-based records). Data cleaning was also continuous during my analysis, and I raised data queries that were addressed by the research officers using source documents.

2.4.11 Data quality control

It was important to ensure that the data was collected in a consistent manner and that data collected was of high quality. In addition to the standardisation of data collection methods and training of the observers (described under data collection processes), during supervisory visits, I and the two project research officers examined for completeness of the paper-based observational checklist. When there were gaps noted we discussed with the observer who was able to rectify this from source documents. Together with one of the research officers, I built data range fields into the REDCap™ database used for electronic storage and this flagged any abnormal numerical entries into the database. This were usually cross-checked from source (the paper-based checklist). I continually conducted data checks during my analysis and would continually feedback the research officers in event of missing data noted on redcap or inexplicable data noted during my examination of the data. The research officers were able to consult the original paper-based records stored at KEMRI in event of any discrepancies. Overall, the data was of high quality with minimal missingness. I handled any missing data using complete case analysis.

2.4.12 Ethical considerations

This study was covered by the ethical approval received by the HIGH-Q programme from the Oxford Tropical Research Ethics Committee (Reference- 26-21) and the Kenya Medical Research Institute Scientific and Ethics Review Unit (Reference - KEMRI/SERU/CGMR-C/229/4203). In addition, I also applied for and received a research license from the National Commission for Science, Technology and Innovation, which regulates clinical research conducted in Kenya (NACOSTI/P/22/21337). Appendix 5 contains the ethical approvals of this study. All data collection tools were designed not to include any identifiable patient information.

Before collecting data, the HIGH-Q programme received approvals from the county governments that managed these hospitals and sought permission from the hospital administrations and neonatal unit leadership. I attended multiple project meetings with local hospital management, nursing managers, nurse-in-charges, and nurses of each newborn unit, where we explained the study.

2.4.12.1 Informed consenting

Observers sought written informed consent from all neonatal unit nurses during the in-hospital pilot week. At the start of every observation, verbal approval was sought from the nurses on a shift who had all previously provided written consent before data collection. At the start of every observation, the trained observers also took consent from the caregivers of any babies for observation. If a participant's caregiver declined or needed more time to consider the information provided, another baby's caregiver was approached. Teenage mothers were considered emancipated minors, and their babies were included in this study following written informed consent. I, however, excluded abandoned babies who were being held in the unit until a suitable orphanage was found for them. This is because there was no specific legal guardian for this group.

2.4.12.2 Workforce intervention

The HIGH-Q programme had some ethical considerations around the introduction of the workforce. One was that it might be unethical to randomise a seemingly beneficial intervention such as the addition of extra staff to understaffed neonatal units, and so this in part informed the decision not to consider a randomised study design. Secondly, the programme understood that the sustainability of enhanced staffing after the intervention was important, as ethically it was crucial the neonatal unit did not go back to their former situation or become worse off after the intervention. Recognising it was impossible for the project to sustain the staff within the neonatal unit's post-intervention, the programme developed a stake holder advocacy strategy to lobby the county governments to retain the added staff, this involved regular advocacy visits and presentation of interim data to key representatives of both the hospital leadership and county leadership including Ministers of Health and other county Department of Health leadership. We also signed an MoU with the hospitals and counties committing to hire and funding the salaries for the recruited nurses following expiration of their short term project contracts The outcome of this engagement process is discussed further in Chapter 5 which presents data on the effect of the workforce intervention on quality of care.

Chapter 3- Examining the existing evidence for nurse staffing and quality of patient care in low and middle-income countries

The evidence presented in Chapter 1 suggests that data on nurse staffing and patient care outcomes primarily come from high-income country settings. This chapter examines the evidence for nurse staffing and quality of patient care in low and middle-income countries (LMICs). The chapter is divided into two sections. In the first section (Chapter 3A), I use an Umbrella review (overview of systematic reviews) method to examine the research evidence gaps for LMICs in nurse staffing and quality of care research and to identify patient care outcomes and nurse staffing measures used in previous research. In the second section (Chapter 3B), using a systematic review, I focus on my primary outcome of choice, missed nursing care, identifying various tools to measure the construct and factors that are associated with it.

3.1 Chapter 3A. Umbrella review to identify gaps in nurse staffing and patient care outcome research and to identify nurse staffing metrics.[2]

3.1.1 Background

Over the last two decades, several systematic reviews have synthesised the evidence for nurse staffing and patient care outcomes (109–113). This overview of reviews integrates data from these published systematic reviews to provide broader knowledge on the following questions:

1. Where are studies within published reviews conducted, and what proportion of these are carried out in LMICs?
2. How has nurse staffing been measured in the literature?
3. What patient care outcomes have been reported across reviews, and how do reported outcomes differ between high-income countries (HICs) and LMIC studies?

3.1.2 Methods

3.1.2.1 Overview of methods

I conducted this review using guidance from the Joanna Briggs Institute and the AMSTAR-2 criteria as a framework to assess the quality of the individual systematic reviews (101,102). Before conducting this review, I registered a protocol on the International Prospective Register of Systematic Reviews

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[2] This chapter contains content from the following publication - *Imam A, Obiesie S, Aluvaala J, Maina JM, Gathara D, English M. Identifying gaps in global evidence for nurse staffing and patient care outcomes research in low/middle-income countries: an umbrella review. BMJ open. 2022 Oct 1;12(10):e064050.*

(PROSPERO), which can be accessed at https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021286908.

3.1.2.2 Study selection.

I used the inclusion and exclusion criteria in Table 3.1 to select systematic reviews for inclusion in my umbrella review.

Table 3.1: Eligibility criteria for the umbrella review*.

Criteria	**Inclusion**	**Exclusion**
Population	Systematic reviews on patients admitted to standard hospital ward settings[#]	Systematic reviews solely on patients admitted to non-standard ward settings, for example, intensive care units. Those conducted in patients in non-hospital settings, for example, community clinics or nursing homes
Exposure	Level of nursing staffing	
Comparator	Not applicable	
Outcome	patient care outcomes, for example, patient mortality, length of stay*	nurse care outcomes, for example, nurse burnout

[#]- Reviews that included primary studies with a mix of standard and non-standard ward settings were included, but only data from the primary studies in regular ward settings was included in the synthesis

*- Reviews that included patient and nurse outcomes were included, but only data from the primary studies on patient outcomes was included in the synthesis

3.1.2.3 Information sources

I searched five electronic databases for published systematic reviews: Embase (OVID), Medline, the Cumulative Index to Nursing and Allied Health Literature (CINAHL), The Joanna Briggs Institute (JBI) database, and Cochrane Library from the databases' inception (see Appendix 6 for my search strategy and strings). Following this search, I conducted forward searches of the included systematic reviews in the Scopus bibliographic database. I then manually checked the references of each systematic review to identify any additional systematic reviews.

3.1.2.4 Screening

I exported all systematic reviews I identified from my search process to the Zotero reference manager, where I removed duplicates, and then to Rayyan (a web-based application) for screening papers (114). Together with a second independent reviewer, I screened the titles and abstracts of all included systematic reviews using the eligibility criteria specified in Table 3.1 to determine reviews potentially eligible for final inclusion into the umbrella review. We (the 2nd reviewer and I) read the full texts of all potentially eligible papers and agreed on a final set of papers. We managed disagreements during this process and any other review processes through discussion. I continue to use we in subsequent subsections to describe all processes conducted by myself and the 2nd reviewer.

3.1.2.5 Quality assessment

To evaluate each included systematic review for risk of bias, we used the A MeaSurement Tool to Assess Systematic Reviews -2 (AMSTAR-2) criteria (102). This tool comprises 16 appraisal questions on domains relevant to systematic reviews (102). Appendix 7 shows the 16 questions for the AMSTAR-2 criteria.

3.1.2.6 Data extraction

I extracted data from the final set of systematic reviews using a data abstraction tool I designed in Excel (see Appendix 8 for tool subheadings). This data included the review publication year, objectives, reported patient care outcomes, and the number and origin of review studies that reported on nurse staffing and patient outcomes in regular ward care settings. It also included summary data on nurse staffing measures (Appendix 8). My second reviewer cross-checked the extracted data.

3.1.2.7 Data synthesis

I present a narrative synthesis of my results and use tables and figures to show some of my results. To identify the origins of studies within each of the systematic reviews, I use the World Bank country and lending group classification system as of 23rd December 2021 to classify countries into LMICs or HICs (115). I then tallied all reported patient care outcomes within the systematic reviews. For each outcome, I documented the proportion of studies within the review that were conducted in either LMICs or HICs. I also identified and collated all reported nurse staffing metrics within each systematic review.

3.1.3 Results

3.1.3.1 Search results.

I identified 1365 articles from my initial search. After I removed duplicate articles, there were 843 remaining articles. Of this, 33 systematic reviews met the criteria for full-text reviews, following which 14 of these reviews were included in my final synthesis (29,110,111,113,116–125). My PRISMA diagram in Figure 3.1 summarises my article selection process. I also provide a list of excluded systematic reviews and the reasons for their exclusion in Appendix 9.

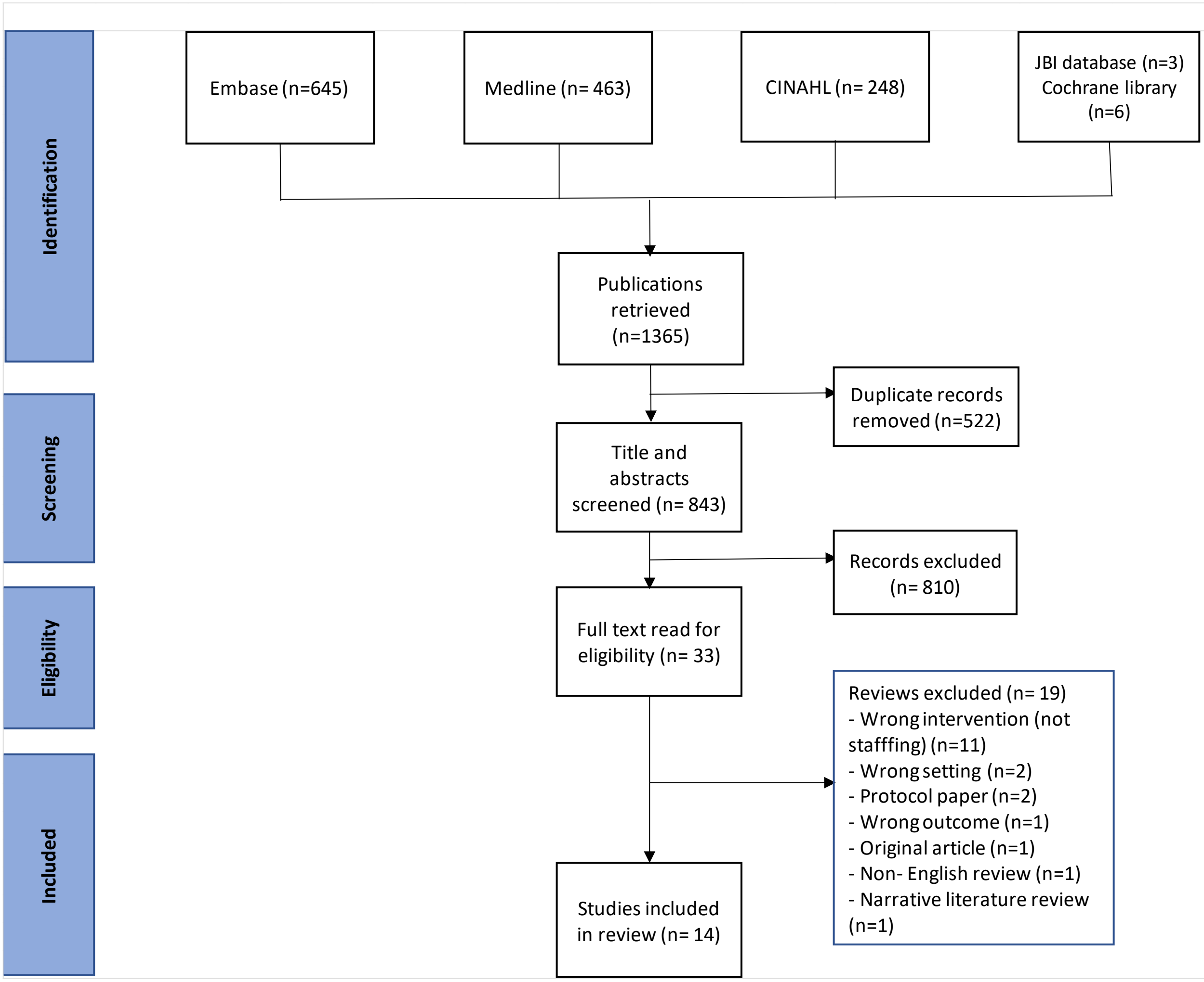


Figure 3.1– PRISMA diagram for search strategy.

3.1.3.2

3.1.3.3 Description of included systematic reviews.

I included 14 systematic reviews in my final analysis spanning between 1980 and 2020. These reviews included between 5 and 54 primary studies in their synthesis. Primary studies within the reviews were conducted in regular and non-regular ward settings, such as intensive care units. Of the primary studies within each review, between 12 and 100 percent investigated the effect of nurse staffing on patient care outcomes in regular ward settings and were included in the final synthesis. Other studies were conducted in intensive care settings, investigating the effect of nurse staffing on nurse outcomes or considering nurse skill mix as the exposure rather than nurse staffing. These were not included in the final synthesis. In Appendix 10, I provide a list of primary studies (from each review) not included in the final synthesis and the reasons for this. In total, there were 136 unique primary studies across all systematic reviews.

3.1.3.4 Origin of primary studies and proportion of studies in systematic reviews conducted in LMIC settings.

Four out of the 14 included systematic reviews reported data on studies conducted in a LMIC setting (Table 3.2). One review restricted to LMIC settings identified only six articles, while three reviews were primarily limited to HICs (Table 3.2).

Of the 136 unique studies, 94 (69.1%) were conducted in the USA. Only 9 (6.6%) of the 136 primary studies were conducted in 5 LMICs: Thailand, Brazil, Lebanon, China, and Ethiopia (Figure 3.2). Studies from HICs came from more diverse locations and were conducted in 16 other settings in addition to the USA (Figure 3.2).

Table 3.2 - An overview of the included systematic reviews showing the review objective and geographical locations where the review's primary studies were conducted.

First author (Year)	Period of review	Research setting	Number of primary studies included	Number of primary studies describing nurse staffing levels and patient outcomes in non-ICU settings[&]	Geographic locations of studies and frequency	Number of low and middle-income countries included (%)	Number of high-income countries included (%)
Griffiths (2018)	2006 - 2016	Adult hospital in-patient wards	18	17	Kuwait - 1, Europe -3, UK- 1, Sweden -1, US* - 7, Lebanon* - 1, Switzerland-1, Italy- 1, South Korea- 2	1 (5.6)	17 (95.4)
Assaye (2020)	UR - 2019	Acute care hospital settings	27	6	Brazil – 1, Thailand – 2, China – 1, Ethiopia – 1, Lebanon - 1	6 (100.0)	0 (0.0)
Thungjaroenkul (2007)	1990 - 2006	ICUs, medical and surgical units	17	5	US - 5	0 (0.0)	5 (100.0)
Twigg (2020)[$]	2000 - 2020	General medical, surgical, step-down units, emergency departments, intensive care, and nursing homes	22	7	US – 6, Australia - 1	0 (0.0)	7 (100.0)
Shin (2019)	2000 - 2018	Medical and surgical units	19	17	US – 10, South Korea – 2, Finland* - 1, Netherland* - 1, Lebanon – 1, Belgium – 1, China -1, Japan - 1	2(11.1)	16 (88.9)
Lang (2004)[$]	1980 - 2003	Acute care hospitals	43	24	US - 24	0 (0.0)	24 (100.0)

*- one study conducted across both countries, $- restricted search criteria to High income countries
&- These studies met the original review criteria, i.e., those conducted in a standard ward setting on the role of nurse staffing and patient care outcomes. UR – Unreported

Table 3.2 (continued) - An overview of the included systematic reviews showing the review objective and geographical locations where the review's primary studies were conducted.

Lankshear (2005)	1990 - 2004	Acute care hospitals	22	19	US – 18, Canada -1	0 (0.0)	19 (100.0)
Kane (2007)	1990 - 2006	Acute care hospitals	28	17	US - 17	0 (0.0)	17 (100.0)
Bourgon (2019)	1996 - 2018	Surgical units	44	28	US – 17, Europe - 2, South Korea - 1, UK – 2, New Zealand – 1, Australia – 2, Belgium – 2, Japan - 1	0 (0.0)	28 (100.0)
Wilson (2011)	1993-2010	Paediatric wards	8	5	US – 2, France – 1, Canada -1, UK - 1	0 (0.0)	5 (100.0)
Engineer (2016)$	2000-2012	Acute care hospitals	16	2	US - 2	0 (0.0)	2 (100.0)
Staplers (2015)	2004 - 2012	Acute care hospitals	29	16	US* - 12, Belgium* - 1, New Zealand – 1, Australia – 1, UK – 1, Sweden - 1	0 (0.0)	17 (100.0)
Mitchell (2018)	2000 - 2015	Hospital wards	54	19	US – 13, Thailand – 1, Australia -1, Taiwan – 1, Canada – 2, multi-country - 1	1 (4.3)	18 (95.7)
Hill (2017)	1994 - 2017	Acute care hospitals	5	5	US – 3, UK - 2	0 (0.0)	5 (100.0)

*- one study conducted across both countries, $- restricted search criteria to High income countries

&- These studies met the original review criteria, i.e., those conducted in a standard ward setting on the role of nurse staffing and patient care outcomes. UR – Unreported

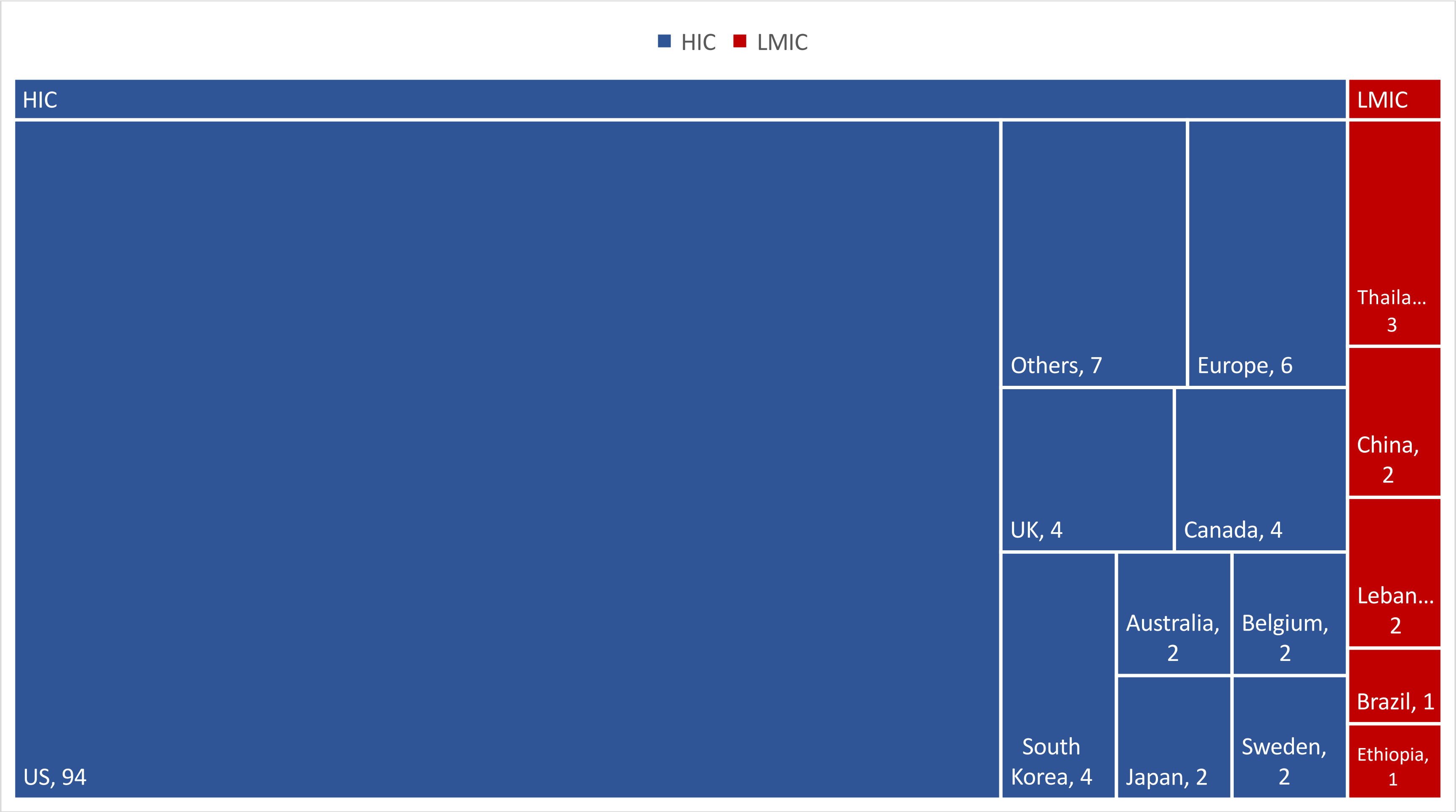


Figure 3.2– Tree map showing the origin of primary papers in all systematic reviews.

3.1.3.5 Measures of nurse staffing and reported staffing range across settings.

I found 29 different nurse staffing metrics reported within the literature. Table 3.3 shows these nurse staffing metrics and defines the more common ones, along with the number of studies employing these metrics. The most frequently reported metric was the nursing hour per patient day (NHPPD), derived by dividing the total productive hours worked by registered nurses in a defined period by the total number of patients admitted for care in the same specified period (Reported by 45 studies, Table 3.3). The patient-to-nurse ratio per shift, which is the average reported number of patients by nurses on their last shift, was employed by 34 primary studies (Table 3.3).

Table 3.3– Summary of nursing metrics reported across the identified papers.

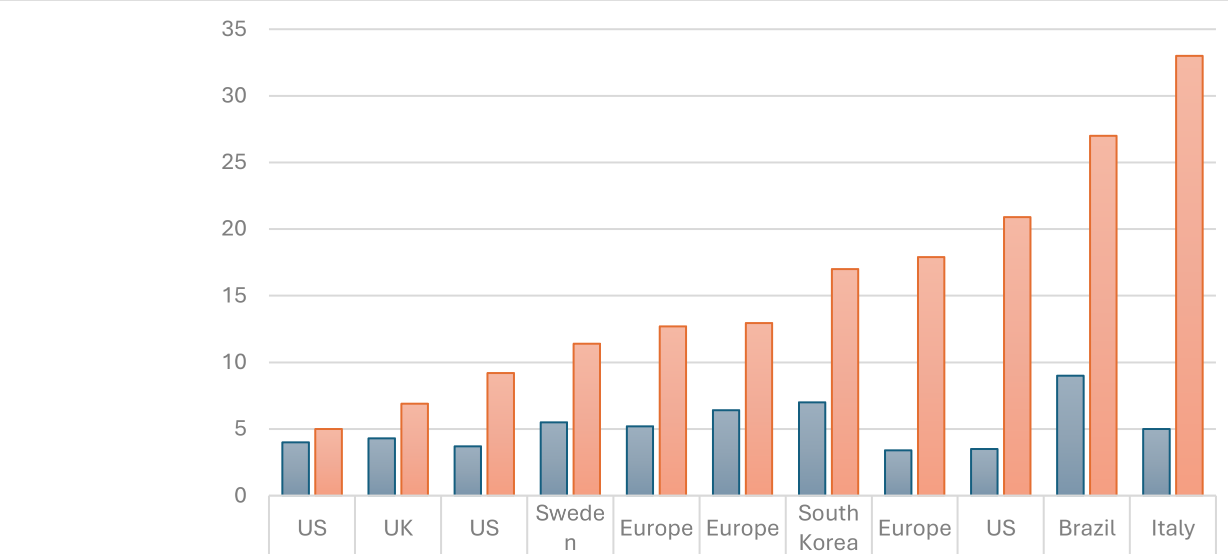
Nursing Metrics	Various definitions of individual metrics	Number of studies reporting a particular metric	Total number of studies reporting metrics
Nursing hour per patient day	Total productive hours (care hours provided to patients) were worked by registered nurses in a defined period/ Total number of patients admitted for care in the same period.	33	45
	Total number of all nursing hours provided to patients in a defined period (includes any combination of registered nursing hours, licensed practice nursing hours and nurse assistant hours)/ Total number of patients admitted for care in the same period.	11	
	The average number of nursing hours provided by registered nursing and licensed practice nursing in a defined period/average number of patients admitted for care in the same period.	1	
Patient-to-nurse ratio per shift	The average reported number of patients by nurses on their last shift. Nurses' answers are averaged across a hospital to get a value.	32	32
Bed-to-nurse ratio/ Nurse per bed ratio	Total number of beds divided by the total number of full-time equivalent registered nurses (RNs) working in the general ward	2	10
	Number of FTE nurses divided by the number of hospital beds	6	
	Number of inpatient nurses per 100 occupied beds	1	
	Infection control nurse-to-bed ratio	1	

Table 3.3 (continued)– Summary of nursing metrics reported across the identified papers.

Nurse-to-patient ratio/patient-to-nurse ratio	The ratio of nurse productive hours worked to "patient census days/24	1	7
	The ratio of total nurse staff to the total number of patients in a defined period	2	
	The measure of the number of patients assigned to each nurse who has a direct patient care assignment	2	
	Undefined	2	
Registered Nurse Full-time equivalent (RN-FTE) per 1000 patient days	Number of Full-time registered nurses per 1000 patient days	5	6
	The number of registered nurse full-time equivalents (FTEs) per 1000 in-patient days.	1	
Registered Nurse per adjusted admission	Number of registered nurses/ adjusted admissions	1	2
	Number of full-time equivalent registered nurses per 100 adjusted admissions	1	
Others*		18	

*Others – Includes metrics that have frequencies of 1. This group includes - nursing hours per patient per shift, Inpatient clinical nursing worked hours per OCW), Mean difference between actual and expected nurse-to-patient ratio, RN hours per adjusted patient day, RN FTE, Total nursing hours, FTE RN to total hospital adjusted patient day, RN FTE per hospital, Daily average hours of care, All hours of direct care per patient day, RN per average daily census, The ratio of required to actual patient care hours, Required nursing personnel per shift, Number of licensed nurses, FTE RNs per adjusted average daily census, labour efficiency ratio, Daily average utilisation of RNs, Acuity-adjusted nursing hour per patient day

There was marked heterogeneity in how papers reported NHPPD and patient-to-nurse ratio per shift. Some reported absolute values, mean, median, ranges, percentiles, or categories. For those reporting either a range, mean, or median, we have summarised their values in Figure 3.3 and Figure 3.4. Figure 3.3 depicts the mean number of patients per nurse for nine studies (8 HICs and 1 LMIC study). Studies from HICs reported best staffing ratios (smallest patient per nurse ratio) ranging between 4 patients per nurse and 7 (26,75,76,126–129), and this was in contrast to the sole LMIC study from Brazil which reported the best ratio of 9 patients per nurse (130). Similarly, the worst ratios documented in studies ranged between 9 and 18 patients per nurse within HICs, contrasting to 27 patients per nurse in the LMIC study (Figure 3.3)(130).



	US	UK	US	Swede n	Europe	Europe	South Korea	Europe	US	Brazil	Italy
best staffing ratio	4	4.3	3.7	5.5	5.2	6.41	7	3.4	3.5	9	5
worst staffing ratio	5	6.9	9.2	11.4	12.7	12.95	17	17.9	20.9	27	33

best staffing ratio worst staffing ratio

Figure 3.3– Bar chart showing the best and worst staffing ratios from studies reporting the mean number of patients per nurse.

For studies reporting total mean NHPPD, the three reported LMIC studies (from Thailand and Lebanon) had the lowest values (4.25 and 5.33 nursing hours per day, Figure 3.4) (131–133). These were almost 2.5-fold below studies conducted in some HICs (Figure 3.4) (134–139).

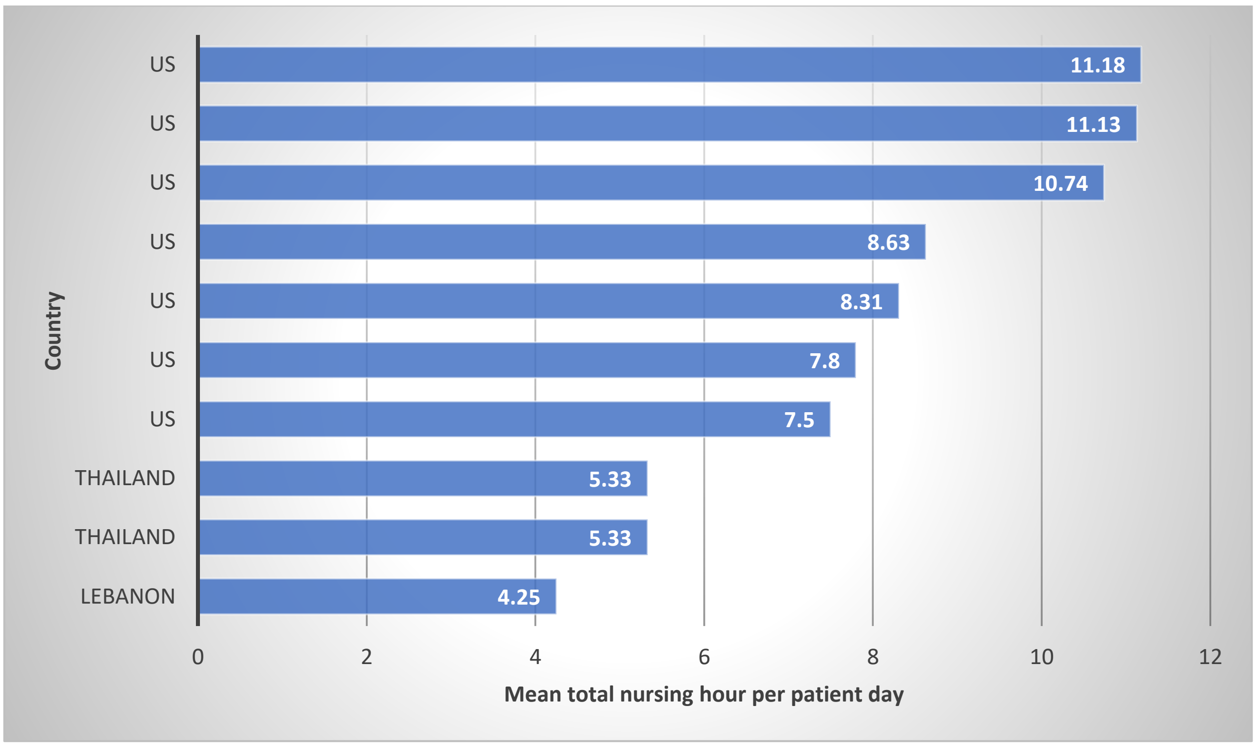


Figure 3.4– Bar chart showing the best and worst staffing ratios from studies reporting the mean number of patients per nurse.

3.1.3.6 Reported patient care outcomes and differences across research settings (LMICs and HICs)

The included reviews reported 23 patient care outcomes, each reporting between one and 15 outcomes. The most frequently reported outcomes were patient mortality, pressure ulcers and the incidence of hospital-acquired infections (eight times each) (Figure 3.5). Only eight of the 23 patient care outcomes were reported by a study conducted in an LMIC setting. These were missed nursing care, mortality, pressure ulcers, length of stay, treatment errors, falls and hospital-acquired injuries (Figure 3.5). Other outcomes, such as postoperative complications, cardiac arrests, deep venous thrombosis, failure to rescue, unplanned extubations and incidence of restraint use, were not reported in LMICs (Figure 3.5).

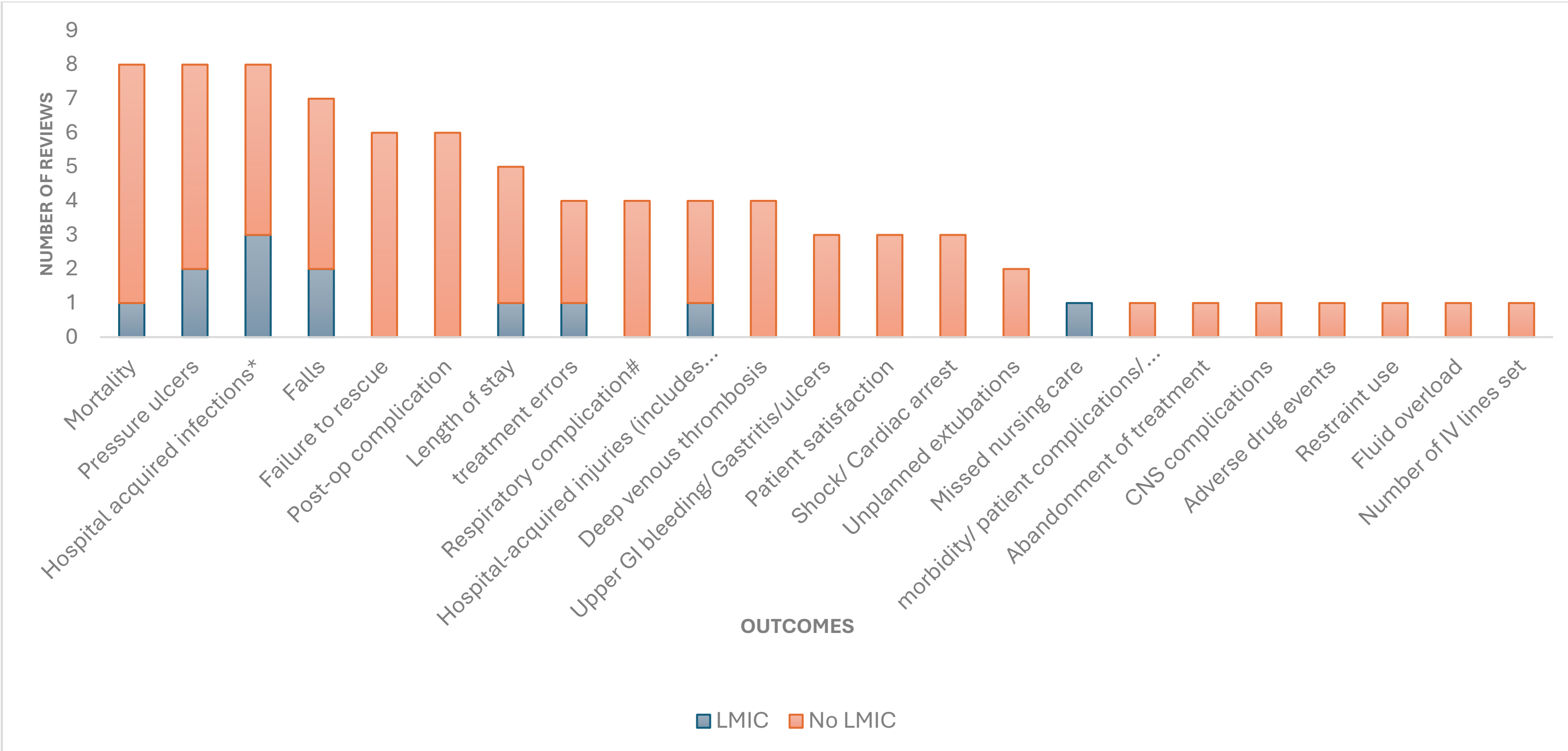


Figure 3.5 - Stacked bar chart showing the range of patient care outcomes reported across reviews and the number of reviews which report this in an LMIC study (Blue- number of reviews reporting the result from an LMIC study, Orange – number of reviews reporting the outcome from only non-LMIC studies)

3.1.3.7 Quality assessment of included reviews.

I assessed all included systematic reviews using the AMSTAR-2 quality assessment tool (102)**.** The least performance by reviews was recorded in AMSTAR-2 question 2 (Q2), question 7 (Q7) and question 10 (Q10). Eleven out of 14 systematic reviews did not refer to a study protocol or provide explicit statements of their methods being established before the conduct of the reviews (Q2, Figure 3.6). Most reviews (12 out of 14) did not provide a list of excluded studies with justifications for reasons for excluding these studies (Figure 3.6, Q7). Discussions on how the risk of bias assessments of individual studies might have impacted the review results were also limited (Figure 3.6, Q10)

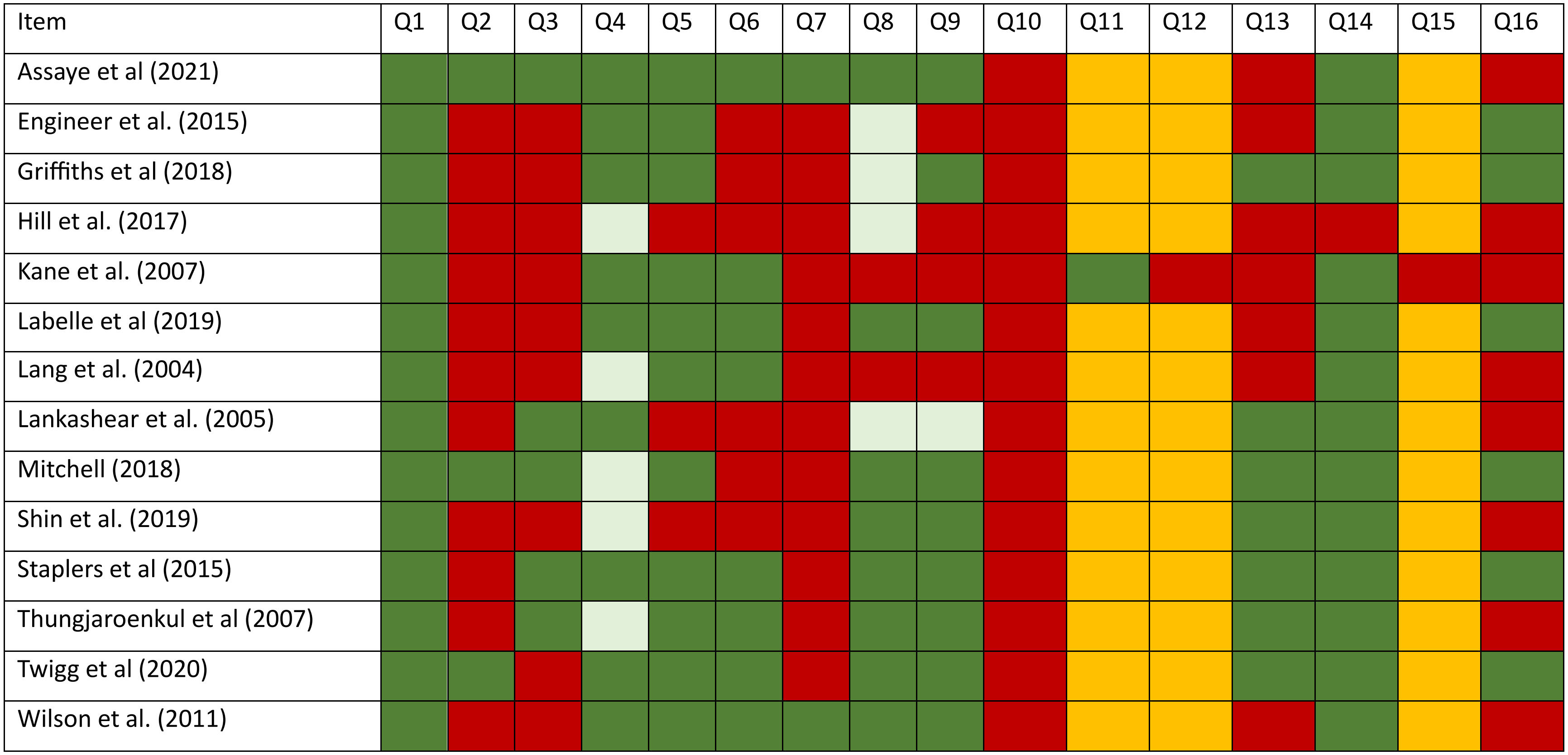


Figure 3.6 - Risk of Bias assessment using the AMSTAR-2 checklist. Q1 to Q12 represent the 12 questions of the AMSTAR-2 checklist.

(Key: Red – No, Green – Yes, lighter green – Partially Yes, Yellow – Not applicable)

3.1.4 Discussion

My umbrella review examines the evidence gaps for LMICs in published systematic reviews that link nurse staffing to patient care outcomes. The results show a dearth of research evidence from LMIC contexts. Ten out of 14 included systematic reviews reported no data from LMICs despite no geographical search restrictions applied to their search strategies. The few published primary studies from LMICs in these reviews (five out of 136 unique primary studies) were restricted to only four countries (Thailand, Lebanon, China, and Ethiopia). This finding highlights the extent of the research evidence gap linking nurse staffing and quality of patient care in LMICs.

Forty-three unique staffing metrics were reported across the primary studies in the included reviews. The two most used were the Nursing Hour Per Patient Day (NHPPD), a measure describing the ratio of total hours of nursing care provided to patients to the number of patients admitted for care, and the patient-to-nurse ratio per shift. On average, data from the few LMIC studies showed that nurse staffing measured using these metrics was significantly poorer in LMICs. This is unsurprising, as around 90% of global nursing shortages occur in LMICs (2). To change the current landscape and inform policy, it is thus crucial that more studies be conducted in these settings.

My review described a narrower range of patient care outcomes previously studied in LMICs compared to HICs. In total, 23 outcomes were analysed in the published systematic reviews, with only eight being researched in an LMIC setting. More specific patient care outcomes, such as the incidence of deep venous thrombosis, postoperative complications, and complications from body systems such as the Central Nervous System, were not reported from LMICs. This perhaps links to limited administrative and secondary data sources in LMICs, which preclude the collection and reporting of such outcomes. Overall, most of the researched patient care outcomes were outcome-based indicators of quality of care (22 of 23). The sole process-based indicator of quality of care was missed nursing care (this defines partially or wholly omitted or delayed nursing care during their duties). Although outcome-based quality of care measures signify validity that exposure or an intervention resulted in a change, they are criticised for being influenced by multiple factors outside the primary factor (99), in this case, nurse staffing. An example of this is mortality, which was reported by eight different systematic reviews, and which is causally distant from the effect of nurse staffing. Thus, it is more likely to be affected by factors external to nurse staffing.

Overall, the reviews identified in this overview of reviews were mainly on studies conducted in adult settings, with only one review conducted in a Paediatric setting (121). The paediatric review also had significantly less data examining nurse staffing and quality neonatal care further demonstrates how under-researched this area is.

3.1.5 Limitations

This review synthesises secondary data from published systematic reviews. The quality of the information provided in the review is thus highly dependent on the underlying quality of the systematic reviews. While some reviews scored low on the risk of bias scores because the focus was a broad description of global evidence gaps for LMICs, I still included them in my synthesis.

Due to limitations in translation, this review only focused on studies published in English.

It was not possible to compare nurse staffing levels across a wide range of studies. This is because there was marked heterogeneity in the measurement and reporting of nurse staffing levels. My synthesis describing the range of nurse staffing levels across studies was thus limited to only a few studies that had used the most popular metric to describe staffing levels.

3.2 Chapter 3B - A systematic review of missed nursing care in acute care hospital settings in low-income and middle-income countries. [3]

3.2.1 Introduction

In Chapter 3A above, I examined the range of patient care outcomes previously reported in the nurse staffing and quality of care literature. I selected one of these outcomes, missed nursing care, the only process-based measure of the quality of care I identified as a proxy indicator for care quality. I report on a systematic review of missed nursing care in the current chapter.

Missed nursing care is defined as patient care that is wholly or partially missed or delayed during the conduct of nursing duties by Kalisch *et al.* (85,86). It arises when nurses prioritise some aspects of patient care over others due to increased work pressures (85). Missed nursing care has significant relevance to patient safety and quality of care in acute hospital care settings and is associated with adverse patient care outcomes such as medication administration errors, hospital-acquired infections and patient mortality (87,140–143). Missed nursing care is also strongly associated with nurse staffing levels (111).

Previous reviews on missed nursing care have been in the literature, mainly from high-income countries (111,144–148). This might be because tools to measure missed nursing care originate from high-income countries (111,144–148). Recently, these tools have been validated in low and middle-income countries (LMIC) with increased research in this subject area. There are also adapted versions of some

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[3] This chapter contains contents from the following publication - *Imam A, Obiesie S, Gathara D, Aluvaala J, Maina M, English M. Missed nursing care in acute care hospital settings in low-income and middle-income countries: a systematic review. Human resources for health. 2023 Mar 14;21(1):19.*

existing tools to measure missed nursing care, which have been translated into local languages in some LMIC contexts (149–151).

In this systematic review, I investigate the tools used to measure missed nursing care and document the factors associated with missed nursing care in published literature. This process was necessary for selecting a tool to measure missed nursing care (my primary study outcome) and guiding my analytic strategy in subsequent chapters.

3.2.2 Aim and objectives.

This systematic review aimed to describe the tools used to measure missed nursing care, determine the factors associated with missed nursing care and identify nursing care that was most frequently missed in the literature. Specifically, my systematic review answered the following research questions:

1. What tools have been used to measure missed nursing care in LMIC settings?
2. What categories of nursing care are most frequently missed in acute hospital settings in LMIC?
3. What factors are associated with missed nursing care in LMIC settings?

3.2.3 Methods

3.2.3.1 Overview of methods

I conducted and reported this systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidance (103). I used the Newcastle-Ottawa Scale to assess the risk of bias for individual studies (152). Before conducting my systematic review on missed nursing care, my protocol details were registered on the International Prospective Register of Systematic Reviews (PROSPERO), registration number - CRD42021286897.

3.2.3.2 *Eligibility criteria*

Eligibility criteria using the population, exposure, comparator, outcome and setting format are shown in Table 3.4.

Table 3.4 – Eligibility criteria for the systematic review of missed nursing care.

Criteria	**Inclusion**	**Exclusion**
Population	Studies on care that nurses missed	Studies on care that were missed by other hospital staff, for example, nursing assistants
Exposure	Studies report any combination of categories of missed nursing care or factors and reasons for missed nursing care.	
Comparator	Not applicable	
Outcome	Studies have reported on missed nursing care using any of its other synonyms, such as omission of care, unmet nursing needs, and implicit rationing of nursing care.	Studies on medication errors, which are errors of commission, unlike missed nursing care which arises from the omission
Setting	Studies that reported on missed nursing care in acute care hospitals. I also considered only studies conducted in LMICs and studies with the following designs - observational and interventional studies describing or investigating missed nursing care.	Studies from ambulatory or community care, for example missed nursing care in nursing homes. I also excluded studies conducted in high-income country settings and studies using the following designs - Qualitative studies, mixed-method studies, systematic reviews, umbrella reviews, protocols, and commentaries.

3.2.3.3 *Information sources*

I searched five electronic databases for published papers on missed nursing care in LMIC settings. These were Embase (OVID), Medline, Global Health, WHO Global Index Medicus and Cumulative Index to Nursing and Allied Health Literature (CINAHL). My searches were conducted from the inception of the database. I conducted forward-searching in Scopus using each selected primary article and checked the references of each article for additional relevant articles.

3.2.3.4 *Search strategy.*

I worked with a health information librarian to develop the search strategy for this review, as shown in Appendix 11.

3.2.3.5 *Selection of primary papers*

Screening

I exported the search results to Zotero reference software, where I removed duplicates. Following this, I exported the remaining articles for screening to Rayyan (114), a web-based application for screening papers where I and a 2nd reviewer screened article titles and abstracts using the pre-defined inclusion and exclusion criteria. Following this process, we agreed on a list of potential papers for inclusion in the review and settled on a final list after completing full-text reviews. The excluded papers following this process and the reasons for their exclusion are in Appendix 12. Our disagreements were resolved with discussions. In the following subsections, I use 'we' to describe activities undertaken by the 2nd reviewer and me in subsequent sections.

Data items

I abstracted data from the final list of papers included in the review using a standardised tool I developed for data abstraction in Microsoft Excel, and my 2nd reviewer cross-checked this. This data included the first author, surname and year of publication, the study objective and design, the country and setting where the research was conducted, the study population, sample size, type of exposure/intervention studies and the instrument used to measure missed nursing care (Appendix 13).

Quality assessment

We independently conducted a risk of bias assessment for each study using an adapted version of the Newcastle-Ottawa Scale for cross-sectional studies (152,153). The assessment comprises seven questions grouped into three domains with a maximum combined score of 10 (Table 3.5). Typically, a paper being appraised would receive a score for each question based on a reviewer's assessment. Table 3.5 provides a summary of the scale, including the maximum score for each domain.

While using the risk of bias tool, researchers might decide to pre-specify cut-off points for study inclusion or include all studies. I included all studies irrespective of the risk of bias, as I aimed to describe a broad range of studies. I investigated its potential impact in later subsections of this chapter. All disagreements between the 2nd reviewer and I were managed through discussion. I further classified the studies into high quality (7 – 10 points), medium quality (4 – 6 points) and poor quality (0 – 3 points) based on previous research that used the same scale.

Table 3.5 – Newcastle-Ottawa quality assessment scale shows the domain, quality assessment questions and score for a reviewer's assessment (152).

Domain	Question	Reviewer assessment	The score for each assessment	Maximum domain score
Selection	Representativeness of the sample	Truly representative of the average in the target population (all subjects or random sampling).	1	5
		Somewhat representative of the average in the target population. (non-random sampling)	1	
		A selected group of users	0	
		No description of the sampling strategy	0	
	Sample size	Justified and satisfactory	1	
		Not justified	0	
	Non-respondents	Comparability between respondents and non-respondents' characteristics is established, and the response rate is satisfactory	1	
		The response rate is unsatisfactory, or the comparability between respondents and non-respondents is unsatisfactory	0	
		No description of the response rate or the characteristics of the responders and the non-responders	0	
	Ascertainment of the exposure (risk factor)	Validated measurement tool	2	
		Non-validated measurement tool, but the tool is available or described	1	
		No description of the measurement tool	0	

Table 3.5 (continued) – Newcastle-Ottawa quality assessment scale shows the domain, quality assessment questions and score for a reviewer's assessment (152).

Comparability	The subjects in different outcome groups are comparable based on the study design or analysis. Confounding factors are controlled.	The study controls for the most critical factor	1	2
		The study controls for any additional factor.	1	
Outcome	Assessment of the outcome	Independent blind assessment	2	3
		Record linkage	2	
		Self-report	1	
		No description	0	
	Statistical test	The statistical test used to analyse the data is clearly described and appropriate, and the measurement of the association is presented, including confidence intervals and the probability level (p-value).	1	
		The statistical test is not appropriate, not described, or incomplete	0	

3.2.3.6 Synthesis of results

To identify the categories of nursing care most frequently missed across all studies, I used a similar method to an earlier review published by *Griffiths et al.* (111)**.** This involved ranking nursing care tasks from least to most missed within each study, using the most popular measuring tool – the MISSCARE tool (I describe tools in the result section). For each nursing care task listed within the MISSCARE tool, I then calculated a cross-study median rank score which I rank ordered to identify the least to most frequently missed nursing tasks (Appendix 14).

Because there are various tools for measuring missed nursing care, I used the American Nurses Association (ANA) classification to categorise nursing activities into broad domains, allowing cross-tool comparisons and identifying broad patterns of missed care (154). The ANA categorises nursing activities into six domains - patient assessment, provision of emotional support, medical needs, physical needs, planning and teaching (154). Four other reviewers and I categorised these domains, and a consensus was reached when four out of five of us agreed on a classification.

I extracted data from individual studies to identify factors associated with missed nursing care. I used a bubble plot to semi-quantitatively determine how the risk of bias score might explain variations in the significance level of a task.

3.2.4 Results

3.2.4.1 Search results.

I identified 1248 articles from my initial search of five databases. From this, we (myself and the 2nd reviewer) excluded 495 duplicate articles and had 753 unique articles. We then screened the titles and abstracts of these, and we identified 35 eligible articles for full-text screening, following which we included 24 papers. From my reference searching and forward searching of the included papers, I identified seven additional papers, which I included in my final synthesis (Table 3.5). In total, I included 31 papers. The PRISMA flow chart in Figure 3.7 summarises my screening process.

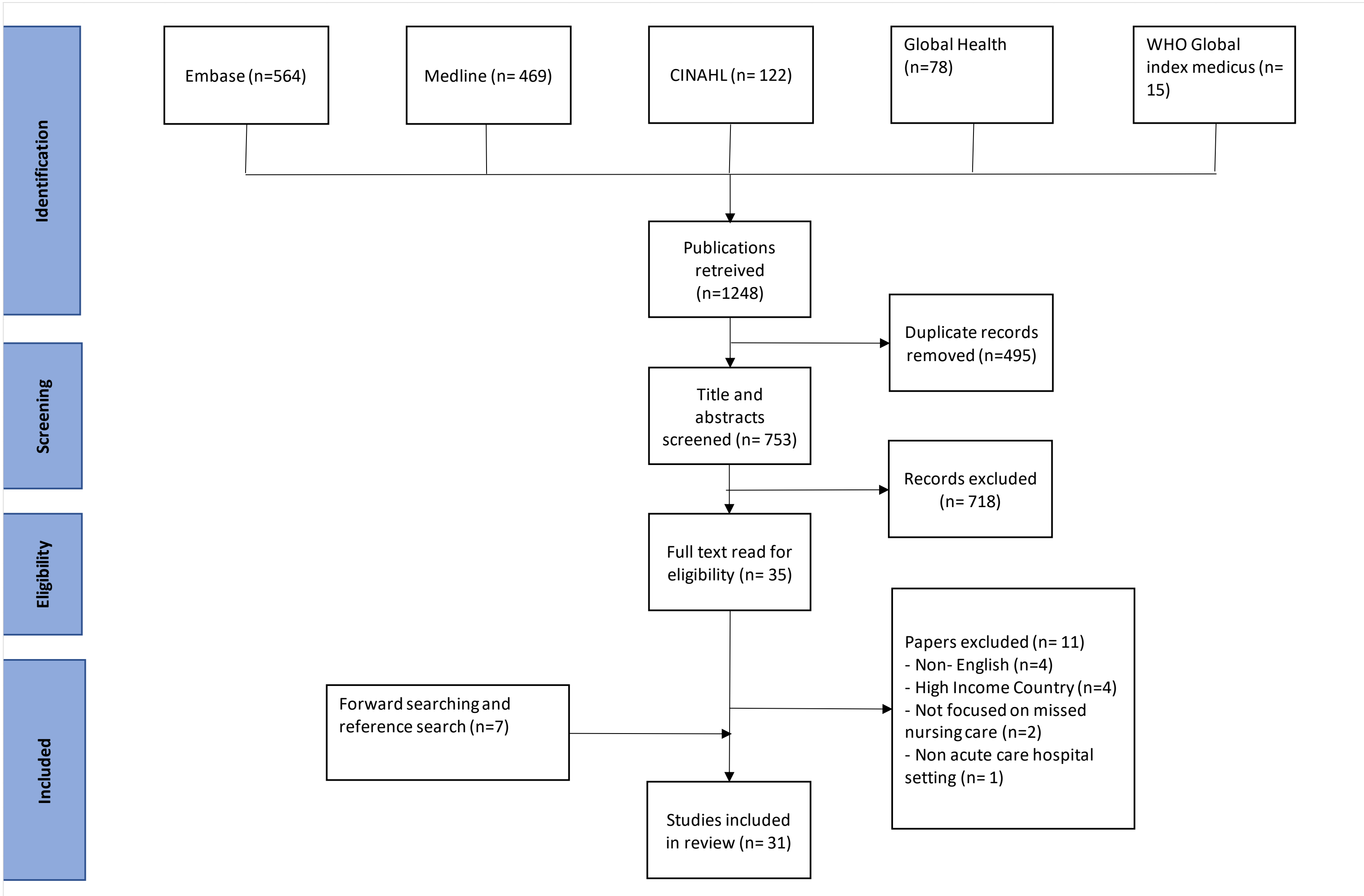

Figure 3.7 - PRISMA flow diagram for the selection of studies on missed nursing care

3.2.4.2 Study characteristics.

Table 3.6 summarises the general characteristics of the studies I included in this review. Six different missed nursing care tools were used (Table 3.6). Twenty-two out of 31 studies (70.9%) used the Missed Nursing Care Survey tool (MISSCARE): 14 in its original form (either in English or translated to a local language)**,** 5 used an adapted Brazilian version. One each used an adapted Chinese tool, an adapted version to assess maternal health, and an adapted tool for assessing pressure ulcers (Table 3.6). The nine other studies each used one of the following tools: Basel Extent of Rationing of Nursing Care (BERNCA-R), Missed Nursing Care Observational Checklist, Nursing Care Index, the RN4Cast Questionnaire, Missed Nursing Care Scale (MNCS); one study used an unnamed tool (Table 3.6). These tools were primarily based on nurse or patient self-reports except for two studies, which used the Missed Nursing Care Observational Checklist and a structured observational tool, which were both based on direct observations of care provided (Table 3.6) (28,155). In Table 3.7, I provide a list of all the missed nursing care tools used, along with a brief description of these tools

Table 3.6: A summary of papers included in this systematic review showing the general characteristics of each paper.

First author (year)	Study location	Study design	Study setting	Sample population and size	Exposure for missed nursing care studied	Missed nursing care tool
Al-Faouri et al (2021) (151)	Jordan	Cross-sectional	Three hospitals (public, private, and university) in Jordan.	300 Nurses	Factors and reasons	MISSCARE (Arabic translated)
Arslan et al (2021) (156)	Turkey	Cross-sectional	Surgical, Medicine, and Intensive Care units of 3 tertiary hospitals	233 Nurses	Ethical leadership	MISSCARE (Turkish translated)
Assaye et al (2022) (150)	Ethiopia	Cross-sectional	Medical and surgical units in two (public and private) hospitals	74 and 80 nurses (2-time points), 517 patients	Factors	BERNCA-R (Translated to Amharic)
Bacaksiz et al (2020) (157)	Turkey	Cross-sectional	25 private hospitals	897 Nurses	Factors and reasons	MISSCARE (Turkish translation)
Bekker et al (2015) (158)	South Africa	Cross-sectional	60 medical and surgical units in private hospitals and public hospitals	1166 nurses	Non-nursing tasks and missed care	MNCS
Chegini et al (2020) (159)	Iran	Cross-sectional	Medical and surgical units of 8 public and private hospitals	215 Nurses	Factors and reasons	MISSCARE (translated to Persian)
Du et al (2020) (160)	China	Cross-sectional	34 secondary and tertiary hospitals	6158 Nurses	Factors and reasons	MISSCARE-Chinese
Dutra et al (2019) (161)	Brazil	Cross-sectional	Adult hospitalisation units for clinical and surgical treatment of a single tertiary (teaching) hospital	58 Nurses and nursing technicians	Types and reasons	MISSCARE-Brasil
Gathara et al (2020) (28)	Kenya	Cross-sectional	Six health facilities in Kenya. (Public, private and mission hospitals).	216 Newborn infants	Prevalence and factors	Nursing Care Index
Ghezeljeh et al (2020) (162)	Iran	Cross-sectional	Emergency departments in educational medical centres affiliated with a university (tertiary)	213 Nurses	Factors	MISSCARE (Persian translation)

Table 3.6 (continued)**:** A summary of papers included in this systematic review showing the general characteristics of each paper.

First author (year)	**Study location**	**Study design**	**Study setting**	**Sample population and size**	**Exposure for missed nursing care studied**	**Missed nursing care tool**
Haftu et al (2019) (163)	Ethiopia	Cross-sectional	Obstetrics and gynaecologic units in 8 general hospitals	401 Nurses and midwives	Factors and reasons	MISSCARE (modified by maternal health experts)
Hammad et al (2021) (164)	Egypt	Cross-sectional	50 units at a single tertiary Hospital	553 Nurses	Factors and reasons	MISSCARE (Arabic translated)
Hernández-Cruz et al (2017) (165)	Mexico	Cross-sectional	A single private hospital	71 Hospital nurses	Factors	MISSCARE
John et al (2016) (166)	Nigeria	Multi-method (Cross-sectional, Before and after study design (interventional))	Medical, surgical, Obstetrics and Gynaecology units of 4 hospitals providing direct adult care (2 tertiary and two secondary-level)	186 nurses and 120 patients/ relatives	Prevalence and frequency. Effect of a 4-week capacity building intervention for nurses	Unnamed tool
Kalisch et al (2013) (167)	Lebanon and US	Cross-sectional	Medical-surgical unit, intermediate unit, and ICU in a single tertiary (teaching) hospital	114 Nurses	Factors and reasons	MISSCARE
Kalisch et al (2020) (155)	Egypt	Before and after study design	Single paediatric nephrology unit at a tertiary (teaching) hospital	28 Staff nurses	MISSCARE orientation program	Missed Nursing Care Observational Checklist,
Labrague et al (2020) (168)	Philippines	Cross-sectional	Six hospitals in the Philippines	549 Nurses	Nurse caring behaviours	MNCS
Labrague et al (2022) (169)	Philippines	Cross-sectional	14 hospitals (7 government and seven private hospitals at various levels of healthcare)	295 nurses	Factors	MNCS

Table 3.6 (continued): A summary of papers included in this systematic review showing the general characteristics of each paper.

First author (year)	Study location	Study design	Study setting	Sample population and size	Exposure for missed nursing care studied	Missed nursing care tool
Lima et al (2020) (170)	Brazil	Cross-sectional	Ten hospitalisation units of a single public tertiary (teaching) hospital	267 nurses, technicians, and auxiliaries	Prevalence and reason	MISSCARE-Brasil
Moura et al (2020) (171)	Brazil	Longitudinal Interventional	4 In-patient units at a single tertiary (university) hospital	96 Nurses	Primary Care Nursing Model	MISSCARE Brasil
Moreno-Monsiváis et al (2015) (172)	Mexico	Cross-sectional	Medical and surgical units of a single private hospital	160 Nurses and 160 private patients	Factors	MISSCARE
Nahasaram et al (2021) (173)	Malaysia	Cross-sectional	Medical and surgical unit of a large tertiary hospital	364 Nurses	Factors and reasons	MISSCARE (Malay translated)
Nantsupawat et al (2022) (174)	Thailand	Cross-sectional	43 units in Five university (tertiary) hospitals	1188 nurses	Relationship between staffing, adverse events and missed nursing care	RN4Cast Questionnaire
Pereira Lima Silva et al (2020) (175)	Brazil	Cross-sectional	Three large ICUs. 2 from large public institutions and a 3rd from a private hospital offering complex services	29 ICU care nurses	Practice environment and nursing workload	MISSCARE Brasil
Saqer et al (2018) (149)	Jordan	Cross-sectional	Six Jordanian hospitals (Government, university, and private hospitals)	362 Hospital nurses	Reasons and predictors of missed care, confidence in delegation	MISSCARE (Arabic-translation)
Silva et al (2021) (176)	Brazil	Cross-sectional	Women's Health Care Unit of a single tertiary (teaching) hospital	62 Nurses	Factors and reasons	MISSCARE-Brasil
Siqueira et al (2017) (177)	Brazil	Cross-sectional	Single large-scale tertiary (teaching) hospital	330 nurse aides, technicians, nurses, and nurse administrators	Confirmatory Factor Analysis and factors	MISSCARE Brasil

Table 3.6 (continued): A summary of papers included in this systematic review showing the general characteristics of each paper.

First author (year)	Study location	Study design	Study setting	Sample population and size	Exposure for missed nursing care studied	Missed nursing care tool
Taskiran et al (2022) (178)	Turkey	Cross-sectional	10 Public, University, and private hospitals	1310 nurses	Frequency, reasons, correlates, and predictors	MISSCARE (Turkish translation)
Valles et al (2016) (179)	Mexico	Cross-sectional	A single tertiary hospital	161 Nurses and 483 patients	Factors for missed nursing care	MISSCARE (Adapted for pressure ulcers)
Zárate-Grajales et al (2022) (180)	Mexico	Cross-sectional	11 Specialised public hospitals (tertiary) in Mexico	315 nurses	Frequency and factors	MISSCARE
Zhu et al (2019) (181)	China	Cross-sectional	Medical and surgical units from 181 hospitals (Secondary and tertiary level)	7802 Nurses	NA	Basel Extent of Rationing of Nursing Care (BERNCA-R)

BERNCA - Basel Extent of Rationing of Nursing Care, BERNCA-R - Basel Extent of Rationing of Nursing Care- Revised, MISSCARE - Missed nursing care survey tool, MNCS - Missed Nursing Care scale.

Table 3.7: A summary of instruments used to measure missed nursing care in LMIC settings.

Instrument (Original reference for tool)	**Level of measurement of missed nursing care**	**Brief tool description**	**Adaptations**	**Number of questions**	**Scale/ score category**	**Studies in the review employing specific tools (references in footnote)**
Basel Extent of Rationing of Nursing Care-Revised (BERNCA-R) **(182)**	Nurse self-report	The scale consists of 32 nursing activities; nurses report on the degree to which they could not carry these out in their preceding week of duty. Activities are broadly divided into five domains of care: -Activity of daily living, e.g., bathing, changing bed linens. -Caring-support -Rehabilitation-instruction-Education -Monitoring-Safety -Documentation	Revised from the BERNCA, which was adapted from the International Hospital Outcome Study	32	5-point Likert scale that measures the frequency with which care was missed: 0=not required (i.e., rationing of nursing activity was not required in the last week) 1 = never 2= rarely 3= sometimes 4= often	a, b
MISSCARE **(183)**	Nurse self-report	Two parts (A and B). Part A is designed to measure missed nursing care and consists of a list of nursing activities; nurses are asked to report if they missed these on their previous shifts. Part B measures perceived nurse reasons for missed nursing care in three domains: Labour, material, and communication/ teamwork.	Not applicable	Part A – 24 questions Part B – 17 questions	5-point Likert scale to measure the frequency of missed nursing care: 1 – Never missed (. i.e., nurse activity being measured is never missed) 2- rarely 3- occasionally 4 – frequently 5 – Always missed	c, d, e, f, g, h, i, j, k, l, m, n, o

Table 3.7 (continued) : A summary of instruments used to measure missed nursing care in LMIC settings.

Instrument (Original reference for tool)	**Level of measurement of missed nursing care**	**Brief tool description**	**Adaptations**	**Number of questions**	**Scale/ score category**	**Studies in the review employing specific tools (references in footnote)**
MISSCARE-Brasil **(177)**	Nurse self-report	Same as the MISSCARE tool	Addition of a few questions to reflect the Brazilian context.	Part A – 28 questions Part B – 28 questions	Same as the MISSCARE tool	p, q, r, s, t, u
MISSCARE-Chinese **(160)**	Nurse self-report	Same as the MISSCARE tool	Some original MISSCARE questions were modified with additional questions to reflect the Chinese context.	Part A – 29 questions Part B – 22 questions	Same as the MISSCARE tool	v
MISSCARE (modified by maternal health experts) **(163)**	Nurse self-report	A modification of the MISSCARE tool by maternal health experts. Contains questions covering timely cervical examinations and labour support to fit nursing activities in an Obstetrics and Gynaecology unit	Adapted specifically to assess missed care in Obstetrics and Gynaecology	26 questions	Same as MISSCARE tool	w
MISSCARE-PU **(179)**	Nurse self-report	An abridged version of MISSCARE tools with some modified questions and additional questions to cover aspects of pressure ulcer management	Adapted specifically to assess missed care in nurses' management of pressure ulcers	13 questions	Same as MISSCARE tool	x

Table 3.7 (continued) : A summary of instruments used to measure missed nursing care in LMIC settings.

Instrument (Original reference for tool)	Level of measurement of missed nursing care	Brief tool description	Adaptations	Number of questions	Scale/ score category	Studies in the review employing specific tools (references in footnote)
Missed Nursing Care Scale (MNCS) **(158)**	Nurse self-report	The questionnaire covers 12 essential nursing tasks left undone on the most recent nursing shift.	Not applicable	12 questions	4-point Likert scale measuring the degree to which nursing activities were left undone: 0 – never 1-rarely 2- occasionally 3-frequently	y z
Structured observational tool **(28)**	Direct observation of patients	A bedside observer uses a structured tool to collect data about care delivered to a newborn. Covers domains such as routine newborn care, vital sign monitoring and medications	Not Applicable	Not Applicable	Observed care is summed up and expressed as a proportion of explicitly defined expected care to derive a patient-level aggregate score of care called the nursing care index	aa
RN4Cast Questionnaire **(87)**	Nurse self-report	A questionnaire covering a list of 13 necessary nursing activities to which nurses are asked to identify which were left undone in their most recent shifts because of time constraints. Activities measured include those related to clinical care, patient care planning and communication	Adapted from the International Hospital Outcome Study	13 questions	Binary – care is missed or not missed, and results are reported as a percentage of specific care that is missed	ab

Table 3.7 (continued) : A summary of instruments used to measure missed nursing care in LMIC settings.

Instrument (Original reference for tool)	Level of measurement of missed nursing care	Brief tool description	Adaptations	Number of questions	Scale/ score category	Studies in the review employing specific tools (references in footnote)
Unnamed tool **(166)**	Nurse self-report	The questionnaire covers a list of 15 nursing activities, including clinical, planning patient education and counselling	Not applicable	15 questions	Binary – care is missed or not missed, and results are reported as a percentage of specific care that is missed	ac

a- Assaye et al (2022), b- Zhu et al (2019), c- Arslan et al (2021), d- Nahasaram et al (2021), e- Al-Faouri et al (2021), f- Hammad et al (2021), g- Chegini et al (2020), h- Bacaksiz et al (2020), i- Saqer et al (2018), j - Hernández-Cruz et al (2017) , k - Kalisch et al (2013), l - Moreno-Monsiváis et al (2015) , m - Ghezeljeh et al (2020), n- Taskiran et al (2022), o - Grajales et al (2022) , p – Moura et al(2020), q- Lima et al (2020), r-Dutra et al (2019), s – Silva et al (2021), t - Pereira Lima Silva et al (2020), u - Siqueira et al (2017) , v- Du et al (2020), w -Haftu et al (2019) , x- Valles et al (2016), y- Labrague et al (2020), z- Labrague et al (2022) aa- Gathara et al (2020), ab- Nantsupawat et al (2022) , ac- John et al (2016)

3.2.4.3 Quality assessment of included studies

Based on the classification into high, medium, and low-quality studies described above, of the 31 studies included in this review, 18 (58.1%) were assessed to be high quality, 12 (38.7%) studies were evaluated as moderate quality and 1 (3.3%) of poor quality (Table **3.8**). Most of the studies (28/30) provided no information about study non-respondents, and 1 in 2 studies had no information on sample size determination (Table 3.8).

Table 3.8: Risk of bias assessments using the Newcastle Ottawa Scale

	SELECTION				COMPARABILITY	OUTCOME		
Study	**Sample representativeness**	**Sample size**	**Non-respondents**	**Exposure (risk factor) ascertainment**	**Comparable groups. Confounding factors are controlled.**	**Outcome Assessment**	**Statistical test**	**Total Score (Maximum – 10)**
Al-Faouri et al 2021	1	1	0	2	0	1	0	5
Arslan et al 2021	0	1	0	2	2	1	1	7
Assaye et al, 2022	1	1	0	2	2	1	1	8
Bacaksiz et al. 2020	1	0	0	2	0	1	0	4
Bekker et al, 2015	1	0	0	2	0	1	1	5
Chegini et al 2020	1	0	0	2	2	1	1	7
Du et al 2020	1	1	0	2	1	1	1	7
Dutra et al 2019	1	0	0	2	0	1	0	4
Gathara et al 2020	1	1	1	1	2	2	1	9
Ghezeljeh et al 2020	1	1	0	2	2	1	1	8
Haftu et al 2019	1	1	0	2	2	1	1	8
Hammad et al 2021	1	1	0	2	0	1	0	5
Hernández-Cruz et al 2017	1	0	0	2	2	1	1	7
John et al., 2016	1	0	0	0	0	1	0	2
Kalisch et al 2013	1	0	0	2	2	1	1	7
Kalisch et al 2020	1	0	1	2	0	1	0	5
Labrague et al 2021	1	0	0	2	2	1	1	7
Labrague et al, 2022	1	1	0	2	2	1	1	8
Lima et al 2020	1	0	0	2	0	1	1	5
Moreno-Monsiváis et al. 2015	1	0	0	2	0	1	0	4
Moura et al 2020	1	0	0	2	0	1	0	4
Nahasaram et al 2021	1	1	0	2	2	1	1	8
Nantsupawat et al, 2022	1	1	0	2	2	1	1	8
Pereira Lima Silva et al. 2020	1	0	0	2	0	1	0	4
Saqer et al., 2018	1	1	0	2	2	1	1	8
Silva et al 2021	1	0	0	2	0	1	1	5

Table 3.8 (continued): Risk of bias assessments using the Newcastle Ottawa Scale

	SELECTION				COMPARABILITY	OUTCOME		
Study	**Sample representativeness**	**Sample size**	**Non-respondents**	**Exposure (risk factor) ascertainment**	**Comparable groups. Confounding factors are controlled.**	**Outcome Assessment**	**Statistical test**	**Total Score (Maximum – 10)**
Siqueira et al, 2017	1	1	0	2	2	1	1	8
Taskiran et al, 2022	1	1	0	2	2	1	1	8
Valles et al, 2021	1	1	0	2	0	1	1	6
Zárate-Grajales, 2022	0	1	0	2	2	1	1	7
Zhu et al., 2019	1	0	0	2	2	1	1	7

Green shading means the paper scored full points in the criteria. Orange shading indicates the paper scored partial points in the requirements, while red shading means no points were scored.

3.2.4.4 Relative frequencies and categories of nursing care that are missed in LMIC.

Seven studies employed the original MISSCARE tool and presented complete data, while six did the same for MISSCARE- Brazil (Table 3.9). Nursing tasks in the planning and provision of physical needs domains were the most missed nursing activities based on cross-study median ranks (Table 3.9). Nursing tasks under the assessment's domain constituted the three least missed nursing care elements (Table 3.9). Most studies were broadly consistent in the relative rankings of the least and most missed nursing activities. The actual task frequency scores and proportions reported in the original studies used to determine the ranks are provided along with the nursing task activity rankings in Appendix 14.

For studies that used the MNCS (two studies), the three most missed activities were in the emotional and physical need domains, while the three least missed were all related to the provision of medical needs (168,169). Other versions of the MISSCARE tool, the MISSCARE modified for pressure ulcers, MISSCARE modified for Obstetrics and Gynaecology, the MISSCARE-Chinese version and the RN4Cast questionnaire, BERNCA, BERNCA-R, the structured observational tool, were all used by single studies or only had one study that reported complete data and so were not included in the final synthesis.

Table 3.9: Table showing nursing dimensions of care, individual nurse task rank within the study, overall rank across primary studies and relative position of activities for studies which used the original MISSCARE survey

Nursing dimensions of care	**Nurse activities**	**Arslan et al.**	**Nahasaram et al.**	**Al-Faouri et al.**	**Hammad et al.**	**Chegini et al.**	**Saqer et al.**	**Kalisch et al.**	**Lima et al.**	**Haftu et al.**	**Lima Silva et al.**	**Moura et al.**	**Dutra et al.**	**Silva et al.**	**Median Rank**	**Relative Position%**
Assessments	**IV/central line site care and assessments**	**24**	**20**	**22**	**24**	**7**	**21**	**21**	**17**	**19**	**15**	**19**	**20**	**19**	**20**	**22nd**
	Bedside glucose monitoring as ordered	**17**	**24**	**24**	**21**	**21**	**24**	**23**	**23**	**21**	**24**	**24**	**22**	**23**	**23**	**24th**
	Focused reassessments according to patient condition	5	14	18	8	7	16	19	16	14	13	14	15	19	14	14th
	Monitoring intake/output	18	12	18	20	17	18	10	11	9	21	11	10	6	12	11th
	Vital signs assessed as ordered	**23**	**22**	**23**	**23**	**23**	**21**	**24**	**19**	**21**	**21**	**22**	**22**	**24**	**22**	**23rd**
	Patient assessments performed each shift	22	15	18	14	4	18	17	17	11	11	18	12	22	17	18th
	Assess the effectiveness of medications	16	10	12	12	21	12	12	9	8	6	16	9	18	12	11th
Emotional support	Emotional support to patient and/or family	8	6	7	11	2	8	3	7	3	5	10	3	16	7	6th
Medical needs	Response to call light is initiated within 5 min	4	17	15	17	4	14	14	6	14	10	4	15	8	14	14th
	PRN medication request acted on within 15 min	14	15	17	15	13	16	15	14	18	4	7	19	14	15	16th
	Wound care	20	23	16	16	19	18	15	24	21	20	13	22	8	19	21st
	Medications are administered within 30 minutes before or after the scheduled time	15	13	14	19	7	12	20	13	7	6	12	8	11	12	11th

Table 3.9 (continued): Table showing nursing dimensions of care, individual nurse task rank within the study, overall rank across primary studies and relative position of activities for studies which used the original MISSCARE survey

Nursing dimensions of care	Nurse activities	Arslan et al.	Nahasaram et al.	Al-Faouri et al.	Hammad et al.	Chegini et al.	Saqer et al.	Kalisch et al.	Lima et al.	Haftu et al.	Lima Silva et al.	Moura et al.	Dutra et al.	Silva et al.	Median Rank	Relative Position%
Physical needs	Setting up meals for patients	12	10	8	13	23	8	17	10	6	15	3	7	8	10	8th
	Turning patient 2 hourly	**6**	**4**	**5**	**9**	**7**	**5**	**5**	**4**	**4**	**6**	**5**	**4**	**2**	**5**	**3rd**
	Mouth care	12	5	4	4	7	2	6	8	14	17	6	15	1	6	4th
	Feeding patient when the food is still warm	8	7	3	6	19	2	10	20	11	19	19	12	3	10	8th
	Ambulation 3 times per day or as ordered	**1**	**3**	**1**	**2**	**13**	**1**	**2**	**2**	**2**	**1**	**2**	**2**	**7**	**2**	**2nd**
	Assist with toileting needs within 5 minutes of request	10	8	6	9	7	8	8	15	9	6	8	9	3	8	7th
	Patient bathing/skincare	7	17	11	3	17	8	22	21	19	21	19	20	12	17	18th
Planning	**Attending family /interdisciplinary conferences**	**2**	**1**	**2**	**1**	**3**	**2**	**1**	**1**	**1**	**3**	**1**	**1**	**5**	**1**	**1st**
Teaching	Teach patient about plans for their care after discharge	3	9	9	7	1	5	13	3	5	2	9	6	13	6	4th
	Patient teaching about procedures, tests, and other diagnostic studies	11	2	10	5	4	7	4	12	14	11	17	15	15	11	10th
Undefined	Hand washing	18	21	13	18	16	14	7	22	21	17	23	22	19	18	20th
	Full documentation of all necessary data	20	19	21	22	13	21	9	5	13	13	15	14	16	15	16th

The individual ranks are missed nursing activities ordered within the study; the median rank determines a median across all reported study ranks while the position compares the relative position of the task based on the calculated median rank

*Emboldened lines - Top and least three most missed nursing activities. % - Relative positions – 1st ranks as the most missed nursing activity while 24th is the least missed

3.2.4.5 Factors associated with missed nursing care in LMIC.

I grouped factors associated with missed nursing care into nurse and workplace characteristics. The most studied factor was nurses' gender (Figure 3.8), and this was significant in six out of 10 studies which suggested male nurses were more likely to miss patient care (Figure 3.8) (156,157,159,160,184,185). Similarly, the number of patients the nurse oversaw in their last shift was a commonly investigated risk factor, and a higher order of patients was associated with greater missed nursing care in five out of eight studies (28,156,159,164,174). Other nursing characteristics, such as nurses' age, educational level and total work experience, were not significantly associated with missed nursing care (Figure 3.8). The type of hospital and unit/ward were the most studied work environment characteristics and demonstrated mixed associations with missed nursing care (Figure 3.8). The overall quality of the studies did not affect whether factors were significantly associated with missed nursing care (Figure 3.8).

Characteristics	Factors	Inverse associations p ≤0.001	Inverse associations p ≤0.01	Inverse associations p<0.05	Non -significant associations p≥0.05	Direct associations p<0.05
Nurses characteristics	Gender@	1, 12, 13		4, 11, 10	2, 3, 5, 6	
	Age				3, 4, 6, 1, 14	5, 10, 12
	Nurses education level				3, 4, 5, 12	11, 13
	Working hours per week	15			1, 3, 8, 5	4
	Total work experience				15, 13, 1, 5, 6, 14	
	Number of patients nurse oversaw in previous shift	3, 7, 9		1, 10	4, 8, 5	
	Intention to quit job	13, 16			1, 3, 11	
	Job satisfaction	11, 16			5, 12	
	Nurses position	11			3, 4, 17	
Work environment	Type of hospital*	2, 15	17, 11		1, 4, 6, 5	
	Type of ward/unit%	14, 2, 3, 16			4, 12	
	Shift time or type^	5, 13			16, 6	

Figure 3.8– Bubble plot showing factors associated with missed nursing care and the individual studies which reported these factors, their quality (The larger the bubble, the higher the study quality), p-values and direction of association (direct or inverse relationship with missed nursing care).

The diagram contains factors that were reported by four or more studies.

Inverse association means that the risk factor and missed nursing care are associated in different directions; for example, higher levels of the factor are associated with less missed nursing care and vice versa. Direct association means that the level of missed nursing care and the factor are associated in the same direction.

@- Gender: all studies report male nurses having greater levels of missed nursing care, except for bubble 11, which reported female nurses having higher levels.

*- Type of hospital: greater missed nursing care in public hospitals than in private hospitals (Bubble 2 and 15), less in tertiary and specialised care (Bubble 11), less in smaller than larger hospitals (Bubble 17)

% - Type of ward/unit, greater missed nursing care in surgical than medical wards (Bubble 7), greater levels in general than critical care wards (Bubble 2 and 3), less in closed units – Intensive care, hemato-oncology, bone marrow transplant units (Bubble 16)

^ - Later shifts, such as night or evening, are associated with greater missed nursing care than day shifts

Bubble plot showing factors associated with missed nursing care

3.2.5 Discussions

In my systematic review of missed nursing care in LMICs, I identified 31 papers reporting missed nursing care using six tools to measure the construct. These tools differed in terms of the specific nursing activities they measured. Most missed nursing care measuring tools were based on nurses' self-reporting of care they missed during their previous shifts. Recall and social desirability bias are known challenges associated with self-reported outcome assessments. Only two studies employed tools for measuring missed nursing care based on direct observations of care provided. These were a structured observation checklist for an earlier study in Kenya and the Missed Nursing Care Observation tool employed by a study from Egypt (28,155). Observational tools provide a more accurate reflection of missed nursing care as they are not associated with the afore-mentioned biases linked with conducting surveys but they are comparatively challenging to undertake when compared to administering questionnaires (which are the basis for the nurse self-report data), and investigators would need to manage the Hawthorne effect, a direct consequence of observation (105).

I found marked heterogeneity in reporting missed nursing care across the studies included in this review. Even when studies employed the same tool, results were expressed differently. For example, studies that used the MISSCARE tool reported a median or mean Likert score based on nurses' self-report of care they missed in previous shifts (151,160,186), or a dichotomised score which determined a proportion of nurses who missed particular nursing care tasks (159,171,187). To mitigate this challenge and directly compare data across studies, I rank ordered the missed activities and calculated a median rank across studies for studies with complete data that used the same tool. As such, I could summarise the findings from a subset of studies that used either the MISSCARE or MISSCARE-Brasil tool. This subset was similar to the underlying data as they mainly came from tertiary care settings and adult medical and surgical settings, but a higher proportion of studies were conducted in Brazil. Grouping nursing activities within these tools using the American Nurses Association classification for nursing activities allowed us to identify broad dimensions of the least and most missed nursing activities.

I noted that the least missed nursing care activities were clinical nursing assessments, while the most missed were planning and providing for patient physical needs. Although clinical assessments were the least missed in relative terms, studies show that even high-priority activities such as patient monitoring are missed, which might pose the greatest threat to patient safety (157). For example, although in one study, patient assessments were the least missed, they were still reportedly missed by 16% of nurses (157). Earlier published reviews from HICs have reported similar observations of nurses missing patient physical needs over their clinical needs (111,188). This suggests patterns of care prioritisation related to missed nursing care are broadly similar across diverse contexts and perhaps associated with the training or socialisation of nurses. Such clinical prioritisation, however, undermines the provision of holistic nursing care. This also guided my selection of my evaluation tool in later Chapters to consider a tool that measures both clinical and physical patient needs.

Additionally, similar to the overview of reviews, there were very few studies on missed nursing care in Paediatric settings and only one study reported data from a neonatal setting (28). This further highlights the gaps in evidence as regards neonatal care quality in LMIC settings.

This review also found that the most widely reported nurse-level factors associated with missed care were age, gender, education level, working hours per week, nurses' work experience, their intention to quit their jobs, and the number of patients they cared for in their previous shifts. Overall, studies essentially reported non-significant associations between nurse-level characteristics and missed nursing care except for two factors – gender (male nurses miss more care, Refer to Figure 3.8) and number of patients cared for in the previous shift (156,159,174,185). The type of hospital, ward or unit and the nursing shift time or type were the most frequently explored work environment factors, and this showed a largely mixed picture. Studies that reported a significant relationship with missed nursing care showed a greater prevalence in government-owned (public) hospitals (150), while hospitals providing tertiary care had comparatively less missed nursing care compared to other hospital types (160). Similarly, missed nursing care was less in intensive care wards than in regular wards and greater on night and evening nursing shifts than on the day shift (151,185,180). These findings were important to influence the choice of confounding variables in later Chapters and informed aspects of my study design, for example stratifying shifts into day and night and weekend and weekdays (Described in previously in the Methodology Chapter 2).

The literature on missed nursing care in LMICs in this review comprises observational studies that describe the existing problem. Only two studies focused on interventions to improve missed care, and both of these scored low in our risk of bias scores (166,171). The lack of intervention research to address missed nursing care is not unique to LMICs but has been reported globally (187). One recent review on interventions for missed nursing care reported only 13 studies, all from high-income country settings (189). This provides further evidence for my workforce intervention study described in Chapter 5.

3.2.6 Limitations

The data presented in this review mainly comes from upper-middle-income settings. Thus, I cannot draw solid conclusions for low-income and lower-middle-income settings due to the limited data in these settings. The review was also limited to English due to translation limitations on the team. Also, due to the multiple forms of missed nursing care tools employed, which differed in length, questions assessed and completeness, I could only pool together a fraction of studies to determine the most and least missed nursing care categories.

3.2.7 Conclusions

There is a lack of standardisation in measuring missed nursing care in LMIC, and the current tools are not transferrable across care settings. The existing data are mainly from upper-middle-income country settings, and most existing tools are based on nurses' self-reporting. There is also limited data from neonatal settings and very limited intervention studies.

Clinical nursing activities were the least missed, while non-clinical patient needs were the most missed. This undermines the concept of holistic nursing but also suggests a possible space for carefully designed task-shifting. Contextual research from low-income and low-middle-income countries is needed to determine the effects of increasing nurse numbers or adding nurse support workers on missed nursing care, particularly in neonatal care settings where the evidence is extremely limited.

Chapter 4- Nursing care provision and its relationship with nurse staffing.

4.1 Background

In Chapter 3A, I identified metrics used to measure nurse staffing in the research literature. In Chapter 3B, I reviewed tools used to measure missed nursing care, an indicator of quality care. In the current chapter, I examine nursing care provision (including nurse-delivered care) and nurse staffing across the eight study neonatal units. I use previously identified nurse staffing metrics from Chapter 3A to measure nurse staffing and an adaptation of a structured observational checklist identified in my systematic review in 3B to measure nursing care provision.

Nursing care provision in this thesis describes the total amount of nursing care provided to babies in the neonatal unit, recognising that nurses might provide direct care (nurse-delivered care), delegate care to others, or altogether miss care. Data from the structured observational checklist tool identified from my review in Chapter 3B was used to derive a nursing care index (NCI), a patient-level aggregate of nurse-delivered care (rather than report care that is missed, it reports care that is performed) (28). Because of my specific adaptations to the tool described in Chapter 2, which included identifying who conducted nursing tasks, I could provide greater detail on nursing care provision to extend beyond just care provided by nurses alone.

In this chapter and the subsequent one, I focus my main outcome measures on care that is carried out rather than missed, using variants of the NCI as indicators for quality care. These variants cover nurse-delivered care and nursing care delegated by nurses to others within the unit.

Introduction

In the past, access to facility-based care was seen as most important for improved health outcomes (190). In recent times, however, despite improvements in access to care in many low—and middle-income countries (LMICs), this has not translated into significantly better patient care outcomes (191). There is a renewed focus on facility care quality as the possible missing link between access and improved care outcomes by researchers and policymakers (192).

While providing quality care undoubtedly requires a system-wide approach (192), having competent and motivated human resources for health is recognised as central to improving the quality of care in health facilities (66,193). Indeed, the World Health Organization, in its maternal and newborn quality of care framework, highlights the health workforce as one of the critical healthcare quality domains (66). Having adequate human resources for health is thus an essential pre-condition for providing quality patient care in neonatal units (194).

Nurses are a critical human resource for health, and they form the backbone of facility service delivery and care provision, playing a crucial role in the quality of care patients receive (2). Providing quality in-patient nursing care is thus central to providing quality newborn care within health facilities (195)**.** This is evidenced by an expanding body of literature showing poor nurse staffing levels and low nursing skill mix are associated with worsening patient care outcomes (82,110,112,116,196). Mediating the critical relationship between nurse staffing or skill mix and patient care outcomes are nursing care processes, including nurse-delivered care and nursing care provision in general (181).

Previously, a large proportion of the research evidence on nurse-delivered care has come from high-resource settings that employ nurses' self-report data and are conducted in settings with comparatively better nurse staffing levels than low-resource settings (82). This research has also primarily focused on care that nurses do not provide while performing their duties (missed nursing care) rather than what they offer (87,127,197).

In many LMICs, nurse shortages and low staffing are viewed as the norm. In practice, shift-level staffing is usually poor, and it is unknown how much this impacts nurse-delivered care or influences the dynamics of nursing care provision. Some data from a few qualitative studies suggest that nursing tasks in these settings are shared with caregivers, but there is no indication of the magnitude of this problem (55,198,199). Studies providing quantitative estimates of nursing care provision have only focused on specific aspects of care, for example, drug administration and documentation, with less of a holistic view of care provision in general (200–203).

Understanding nurse-delivered care and nursing care provision in low-resourced settings is essential in explaining the observed quality gap seen in such settings. It is also necessary to help understand how interventions might be structured to improve care delivery in low-resource settings and might provide valuable information to improve staffing and consider task shifting to further support the role of nurses in these settings.

4.2 Rationale

The most significant risk of newborn deaths occurs in low and middle-income countries (LMICs) such as Kenya (204). Despite increasing facility care, newborn deaths continue unchanged (192). There is recognition that to improve neonatal mortality, there needs to be improvement in the quality of service delivery (192). A reality in neonatal units in many LMICs is that they are under-resourced and poorly staffed (107). The effect of this understaffing is not well described in the literature. Although there are qualitative studies that describe neonatal nursing care provision in under-resourced newborn units, there is an absence of quantitative evidence on the magnitude of who provides care in under-resourced newborn units with limited staffing (54,55,205). Nurses are meant to oversee critical in-patient care, such as feeding, monitoring vital signs, and providing life-saving medicines; they also translate patient care into actual steps and engage with newborn equipment and technology in care provision. Nursing care provision thus represents a vital indicator of the quality of newborn care.

4.3 Objective

The specific objective of this chapter is to use observation of care data (described in Chapter 2) collected from eight neonatal units in Kenya to:

1. Examine nursing care provision across neonatal units.
2. Determine the relationship between nurse staffing and nursing care provision (focusing especially on nurse-delivered care) using a patient-level aggregate of nursing care provided–the nursing care index.

4.4 Methods

4.4.1 Study design.

In Chapter 2, I describe my data collection process across the eight study neonatal units (four intervention and four non-intervention units). The current chapter is based on a descriptive cross-sectional analysis of observation of care data collected pre-intervention in the four intervention hospitals and data from the four non-intervention neonatal units. Common to this dataset is being in the 'natural state' of the neonatal units, i.e., with no workforce intervention in place, which is thus ideal for describing baseline nurse staffing and nursing care provision in these units.

4.4.2 Study setting

4.4.2.1 Neonatal unit contexts

All the study neonatal units were in government-owned health facilities, and they provide 24-hour, seven-days-a-week care to newborn infants admitted for in-patient care. Nursing teams in these units majorly had general nursing diplomas and no specialised neonatal training. These units also had ward assistants who did not have patient-facing roles and who provided support for non-nursing tasks, such as washing utensils or delivering and collecting neonatal unit supplies. The units served as training centres for nursing students enrolled at universities and nursing colleges. These students were present for supervised learning at different times of the year.

In subsequent sections of this chapter, I refer to the neonatal units using the abbreviations H1 to H8 for each of the eight neonatal units. These labels are also consistently used to describe individual neonatal units throughout the thesis.

4.4.2.2 Neonatal unit organisation and routines

Each neonatal unit was organised differently. For example, H1 had a single 10-hour shift during the day (from 07:30 to 17:30), while H2 had a 5-hour morning shift (from 07:30 to 12:30), which was followed by a 6-hour afternoon shift (from 12:30 to 18:30) (Table 4.1). All units had only one night shift, which started after the day shift was completed, and this varied in length across units (Table 4.1).

Within each neonatal unit, babies with similar illness severity were kept together. They were usually in three distinct cohorts– Category A, B and C (as described in Chapter 2 (2.4.5)). Nurses were typically allocated to entire sections rather than specific babies and were responsible for caring for all babies within their allocated section. Care within these units was typically bundled; for example, all babies requiring medication or vital signs or needing a bathe or cord care had these carried out at set time intervals (54,55). The nurses thus seemed to work around a schedule (54,55).

Table 4.1: Nursing shift structure across the eight newborn units

Variables	H1	H2	H3	H4	H5	H6	H7	H8
Morning shift (07:30 – 12:30)					(07:30 – 13:30) *			
Afternoon shift (12:30 – 18:30)					(13:30 – 18:30) *		(12:30 – 18:00) *	
Evening shift (07:30 – 16:30)	(07:30 – 17:30) *		(07:30 – 18:30) *					
Night shift (18:30 -07:30)	(17:30 – 07:30) *							

H1 to H8 represent the individual neonatal units.

Blue-shaded boxes mean the nursing shift is present in a neonatal unit.

*- This unit has a slightly different shift length from the standard shift time in other neonatal units.

4.4.3 Study participants

Recruited newborn infants were babies admitted for care across the eight study units. These babies cut across three patient care categories: A, B and C.

4.4.4 Structure of observations

Within each neonatal unit, observers were present to observe the care of recruited babies on randomly selected nursing shifts, which covered the entire day or night shift length. For example, an observation spanned both shifts in H4 (Table 4.1), which had two sequential shifts in the day. An observation period thus spanned an average of 12 hours. During this time, observers took breaks alongside the nursing staff and at periods when care activities were less likely to happen. Care is typically bundled in each of these units (54), and observers were familiar with individual unit nursing care patterns following the pilot week in their units (described in Chapter 2.4.4). The observers also had off days built into their weekly observation schedules and, on average, had a maximum of three 12-hour shifts in any one week.

4.4.5 Data collection tools

In Chapter 2, I fully describe the two data collection tools: The structured observation tool and the health facility assessment tool (see 2.4.4). Briefly, the structured observational tool has three sections –part A to collect shift-level data, part B for general baby information on the specific baby and part C for patient-facing nursing care data across 14 nursing domains (Appendix 1). Part A also collected key details on nurse staffing present on nursing shifts. In subsequent subsections, I focus on the data collection processes and practical data collection considerations by an observer using the structured observation tool and briefly discuss the role of the health facility assessment tool (Appendix 2) in observations.

4.4.5.1 Practical use of the structured observation checklist

At the start of their shift, an observer sequentially picked up structured checklists prelabelled with a unique identification number. Pre-labelling was used to minimise errors in recording participant identification numbers. Actual observations started with an observer attending a nursing handover and filling out shift and patient information from observations and the patient's medical records. Part C of the checklist (Appendix 1) was mainly completed during observations, while the documentation aspects were completed from the patient's medical record after the shift.

Before starting an observation, the observer reviewed the interventions a baby was on and indicated this on the checklist; for example, only a subset of babies on nasogastric tube feeding would need nasogastric tube care, while all babies would need to have their temperature taken at least once. Because they had become familiar with their unit patterns, they also knew the timing of such nursing tasks; for example, intravenous medication rounds or vital sign monitoring occurred at specific periods of the day. In this way, each observer knew what tasks they were observing for and at what particular periods. When a nursing task was not expected, for example, in the case of ward rounds during a night shift (Table 4.2), this was indicated as not applicable. In other instances where the observer was unsure whether the task was conducted, they filled this as indeterminate. Essentially, the observers observed whether nursing tasks were performed and who conducted these tasks. When a nurse supervised a nursing student conducting a task (directly observed their practice), observers were asked to record this as if the nurse carried out the task. When it was unsupervised, it was recorded as if a nursing student had carried out the task. In the first round of data collection (baseline data in the four intervention hospitals), data on who carried out intravenous medications, phototherapy, oxygen and CPAP care were not taken as we did not consider nursing students will be involved in such advanced patient care. The structured observation checklist was later updated to take this data in the subsequent data collection period.

4.4.5.2 Health Facility Assessment (HFA) tool and observations

As mentioned in Chapter 2, the HFA tool (Appendix 2) was used to provide contextual information for each unit. In practice, this allowed me to be familiar with each neonatal unit's specific standards of care and compare this with planned standards for the observations.

4.4.6 Data

4.4.6.1 Variables

Main exposure variables

My primary exposure variable for this analysis is a measure of nursing input, the nursing hours per patient per 12-hour shift (206). This metric defines the total number of nursing hours available for each patient on a 12-hour nursing shift (206). It is one of the nursing metrics reported from my umbrella review process in Chapter 3A. I derived this measure by determining the total number of nursing hours available on a nursing shift and dividing this by the number of patients present at the beginning of the shift. For example, if two nurses were on a 10-hour day shift with 40 patients present, each nurse contributed 10 hours of patient care, so the total nursing hours available on the shift was 20. Factoring in the patient numbers will be 0.5 hours (30 minutes) per patient (20 nursing hours/ 40 patients). To compare this metric across nursing shifts in the various units with varying length shifts, I standardised this metric to 12 hours across all neonatal units. For example, in the previous example, 20 nursing hours on a 10-hour day shift standardised to 12 hours would be equivalent to 24 nursing hours if 12-hour shifts were worked (20 hours X 1.2). Standardised hours were then divided by the total number of patients on the nursing shift to derive the nursing hours per patient per 12-hour shift. As an exploratory exposure variable, I derived an additional metric that included nursing student hours in the measure of nursing hours per patient per 12-hour shift. This exploratory metric explored the impact of more significant variability in nurse staffing input on the outcome of interest and nursing care delivered.

Outcome variable

As my primary analysis outcome, I selected the nursing care index (NCI), identified from my systematic review process in Chapter 3B. The NCI is a measure of nursing care provision and has previously been employed in Kenyan neonatal units to study nurse-delivered care (107). The index is an unweighted patient-level aggregate score of nursing care delivered to a baby using nursing care data from part C of the structured observational checklist (Appendix 1). The NCI is expressed as a proportion of expected care provided to a baby. Expected care provision for babies was based on a baby's individual medical and nursing needs (obtained at the start of an observation period while conducting the health facility assessment) and the draft minimum standards of nursing care for admitted newborn infants determined by a panel of nursing experts and published in earlier research (33). These standards have been content validated and been widely presented to stakeholders, including the Ministry of Health in Kenya (33). Some expected care varied based on patient illness severity; for example, Category A babies required more frequent care in some domains of nursing care, such as vital sign monitoring, than other care categories. Expected care provision also depended on the length of the observation period. When observations were truncated, for example, when a baby was discharged or referred to a different facility or a baby's location was changed away from the observation area, the index's denominator (expected care) was recalculated for the expected observations within that period. For example, a category A baby observed for only eight hours rather than 12 hours would be expected to have two temperature measurements in eight hours (temperatures are expected to be taken every four hours for this category of babies). Table 4.2 summarises the expected care standards on which the structured observational tool was based and details any modifications made to these care standards based on the health facility assessment of the neonatal units. The table also contains all the variables that comprise the nursing care index grouped into 14 nursing task domains.

Table 4.2 – Individual variables for deriving the nursing care index and draft minimum standards for expected nursing care.

The Nursing Care Index tool domain	**Patient category dependent (Yes/ No)[%]**	**Minimum expected number of times nursing tasks should be carried out on a 12-hour shift based on reference standards***	**Modification based on health facility assessment conducted at the neonatal units[#]**
Routine nursing care			
Patient handover	No	Once	None
Patient assessment before the nursing shift	No	Once	None
Hand washing before first patient contact	No	Once	None
Ward round attendance	No	Once	Only assessed during day weekday shifts - ward rounds do not occur on night shifts or weekends.
Health communication with caregivers	No	Once	None
Vital signs			
Temperature	Yes	Patient category A: At least thrice (4 hourly) Patient category B: At least twice (6 hourly) Patient category C: At least once (12 hourly)	None
Pulse rate	Yes		
Respiratory rate	Yes		
Pulse oximetry	Yes		
Routine newborn care*			
Top tailing	No	Once	None
Linen change	No	Once in 24 hours	Only assessed on shifts where a linen change is expected – Differed between night and day shifts according to the neonatal unit
Weight check	No	Alternate days	None
Check incubator settings	Yes	Once – only in preterm infants	None
Diaper change	No	Once	None
Cord care	No	Once in 24 hours	Only assessed for on shifts where a linen change is expected – Differed between night and day shift according to the neonatal unit
Turning the baby	No	Four times (3 hourly)	None
Feeding	No	Four times (3 hourly)	None

Table 4.2 (continued)– Individual variables for deriving the nursing care index and draft minimum standards for expected nursing care.

The Nursing Care Index tool domain	Patient category dependent (Yes/ No)[%]	Minimum expected number of times nursing tasks should be carried out on a 12-hour shift based on reference standards*	Modification based on health facility assessment conducted at the neonatal units[#]
Nasogastric tube feeding process			
Check tube positioning	Yes	Four times (3 hourly) -Only completed for babies on nasogastric tube feeding	None
Measure nasogastric tube feeds	Yes		
Position the baby after nasogastric tube feeding	Yes		
Intravenous medication	Yes	As per the drug schedule - It is only completed for babies on intravenous medications.	None
Oral medication	Yes	Only completed for babies on oral medications	None
Intravenous medication processes			
Review of treatment sheet	Yes	Once before the first round of intravenous medication- Only completed for those on IV medication.	None
Cannula flush with saline before drug administration	Yes		
Cannula flush with saline after drug administration	Yes		
Supervision of Kangaroo Mother Care	Yes	Once- Only completed for babies on Kangaroo Mother Care	None
Phototherapy			
Turning/positioning	Yes	Thrice (4 hourly) - Only completed for babies on phototherapy	None
Skin assessment	Yes	Twice (6 hourly) - Only completed for babies on phototherapy	
Eye care	Yes	Once (12 hourly) - Only completed for babies on phototherapy	
Changing eye pads	Yes		
Continuous Positive Airway Pressure (CPAP)			
Checking nasal prong position	Yes	Thrice (4 hourly) - Only completed for babies on CPAP.	None
Checking oxygen flow rate	Yes		

Table 4.2 (continued)– Individual variables for deriving the nursing care index and draft minimum standards for expected nursing care.

The Nursing Care Index tool domain	**Patient category dependent (Yes/ No)[%]**	**Minimum expected number of times nursing tasks should be carried out on a 12-hour shift based on reference standards***	**Modification based on health facility assessment conducted at the neonatal units[#]**
Oxygen therapy			
Checking nasal prong position	Yes	Thrice (4 hourly) - Only completed for babies on Oxygen therapy	None
Checking oxygen flow rate	Yes		
Nursing documentation			
Neonatal assessment	No	Once	None
Nursing care plan	No	Once	None
Temperature measurements	Yes	Patient category A: At least thrice (4 hourly) Patient category B: At least twice (6 hourly) Patient category C: At least once (12 hourly)	None
Heart rate	Yes		
Respiratory rate	Yes		
Oxygen saturation	Yes		
Ward round details	No	Once - Only completed for babies where a ward round was conducted	None
Frequency and volume of feed	No	Once- Only completed for babies who were on oral feeding	None
Health Communication	No	Once	None
Volume of intravenous fluids	No	Once - Only completed for babies on intravenous fluids	None
Weight check	No	Alternate days- Only completed for babies who had a weight check	None

% -Patient category dependent defines whether the frequency of the expected nursing task depended on a baby's illness severity.

*- Reference standard of expected frequency of care (33).

#- Modifications were based on the standard of care in the neonatal units – if the standard of care was lower than the reference standards, expected care was replaced with the local neonatal unit standard.

Nursing care index (NCI) groups

As previously mentioned, because of my specific adaptations of the structured observation tool, I could identify who conducted a nursing task and, as such, go beyond exploring nurse-delivered care alone. I used three forms of the NCI that differed in terms of their numerators (the NCI is calculated using observed tasks as a numerator and expected tasks as the denominator). These were:

1. Nurse-delivered care (nNCI) - This index considered a task as performed only if it was conducted by a qualified nurse or a nursing student supervised by a nurse. In the event tasks were done by others unsupervised, this was classed as not done using this indicator. For example, if an unsupervised nursing student measured a baby's temperature, this was categorised as not done.
2. Nursing student and nurse index (sNCI) - This index considered a task carried out only if it was performed by a qualified nurse or an unsupervised nursing student.
3. Nursing care delivery by anyone (aNCI) - This index considered a nursing task as performed irrespective of who carried it out.

4.4.6.2 Data analysis

Deriving the outcome (Nursing Care Index) from the structured observation tool

I used previously published methods to derive the individual NCI for a baby (107). To do this, responses from the structured observational checklist were scored as 1 (when a task was carried out) and 0 (when it was not conducted). I summed up scores across all the nursing tasks to derive a total observed score of nursing care for each baby, which I then divided by the total expected score to determine the proportion of expected care carried out for each baby (NCI). Observed scores were the smallest for the nNCI, which was based on only nurse-delivered care, and as such, the proportions were also the smallest. Both scores and proportions were the largest for the aNCI, which considered nursing care provided by anyone. In general, within NCI groups, a smaller NCI meant less care was provided to a baby, while a larger NCI meant more care was provided.

Considerations for nursing care index group.

While deriving the three nursing care indices (nNCI, sNCI and aNCI), I made a priori decisions on what structural observational checklist tool domains and variables (described in Table 4.3) to include in their derivation. Table 4.3 is a pictorial representation of all tool domains and nursing care variables that make up each of the three indices. For nursing care domains/ variables that I omitted, I have listed the reasons for these decisions below:

1. I did not use any variables from the nursing care documentation domain to derive any of the three indices as documentation was at significant variance with our observations and hence not reflective of whether a task was carried out (this variation is presented in results Table 4.9)
2. I added nasogastric tube feeding but did not add the nasogastric tube feeding processes domain to any of the three indices as this would have unfairly weighted this feeding approach compared to other modes of feeding such as cup feeding or breastfeeding. This is because while breast or cup feeding had only a single variable (Fed or not), nasogastric tube had a fed or not variable but also consisted of other variables under the process's domain, for example, checking if tube in place, measuring feeds, positioning the baby after feeding (see Appendix 1).
3. I added intravenous medication administration but did not add the intravenous medication processes domain to any of the three indices as this would have unfairly weighted this medication variable when compared to oral medication. Similar to nasogastric tube feeding processes above, Intravenous medication also had additional variables, for example, flushing intravenous cannula before and after drug administration (see Appendix 1)
4. Within the routine nursing care domain, weight check was also not added to the nNCI or sNCI as this was a nursing role delegated to nutritionists in these units.

5. Supervision of KMC was not added to the nNCI as I did not collect data on who supervised KMC, (whether a nurse of nursing student).

Table 4.3- Nursing care index (NCI) grouping showing individual variables used to calculate each NCI score.

Nursing Care Index tool domain	**Nurse-delivered care (nurses only)**	**Nursing care delivery (nurses and nursing students)**	**Nursing care delivery (anyone)**
Routine nursing care	[green]	[green]	[green]
Vital signs	[green]	[green]	[green]
Routine newborn care#	[orange]	[orange]	[green]
Turning the baby	[green]	[green]	[green]
Feeding (fed or not)*	[orange]	[orange]	[orange]
Nasogastric tube feeding process	[red]	[red]	[red]
Intravenous medication administration (Given or not)	[green]	[green]	[green]
Intravenous medication processes	[red]	[red]	[red]
Oral medication administration (Given or not)	[green]	[green]	[green]
Phototherapy	[green]	[green]	[green]
Continuous Positive Airway Pressure (CPAP)	[green]	[green]	[green]
Oxygen therapy	[green]	[green]	[green]
Supervision of Kangaroo Mother Care	[red]	[green]	[green]
Nursing documentation%	[red]	[red]	[red]

Green shading indicates that all variables within the domain were used to derive the index, orange shading indicates that some of the variables within the domain were used to derive the index, and red shading indicates that the domain was not used to derive the index.

#- both nurse-delivered care (nurses only) and nursing care delivery (nurse and nursing students) do not include the weight check variable

*- All feeds included except for breastfeeding

% - No nursing documentation was added to any of the indices

Statistical analysis

I used basic descriptive statistics – frequencies and percentages to provide summary statistics for individual nursing tasks. I used summary statistics (mean, median, standard deviation, interquartile range, and range) and graphical displays (box plots) to summarise the data on my primary exposure- nurse staffing measured using the nursing hours per patient per 12-hr shift and for categories of the outcome variable - nursing care index (NCI)- nNCI, sNCI and aNCI.

I initially explored the relationship between exposure and outcome using scatterplots and determining correlations of my exposure and outcome using the spearman's correlation co-efficient (because my data was non-normally distributed). I also conducted some explanatory analysis with a nursing input that combined nurse student and nurse hours into a combined nursing hours per patient per 12-hour shift. This metric examined the impact of a more significant variability in nurse staffing input.

As explained in Chapter 2, the hierarchical nature of my data guided my analytic approach. I, therefore, conducted multivariable regression analysis using multilevel modelling to determine how changes in nurse staffing levels measured as nursing hours per patient per 12-hour shift directly affect nurse-delivered care (nNCI) and indirectly affect nursing care provided by anyone (aNCI). I conducted further exploratory analysis to determine the effect of the combined nursing and student hours per patient per 12-hour shift on the aNCI. Using Akaike's Information Criteria (AIC), Bayesian Information Criteria (BIC) and Likelihood ratio tests (LRT), I determined the best-fit model for my analysis. Model building was done sequentially, and the best base model was selected using the AIC, BIC, and LRT (Appendix 15). Variables were added sequentially until the best-fit model was determined (the model with the lowest AIC and BIC and an LRT that did not suggest a significant improvement over the previous simpler model). Multilevel modelling addresses the nested nature of my data (babies nested on neonatal shifts, which were nested in hospitals) by reflecting the clustered nature of the dataset in the reported 95% confidence intervals.

All my data analysis was conducted in STATA version 18. I provide a sample STATA code for my analysis in Appendix 16.

4.5 Results

4.5.1 Study population

This descriptive study comprises data collected across eight neonatal units comprising data from 161 nursing shifts for 597 babies. The flow chart in Figure 4.1 shows the study population distribution. The distribution of babies across the neonatal units was largely balanced and the minimum sample size of 213 babies in both the four intervention and four non-intervention units was achieved.

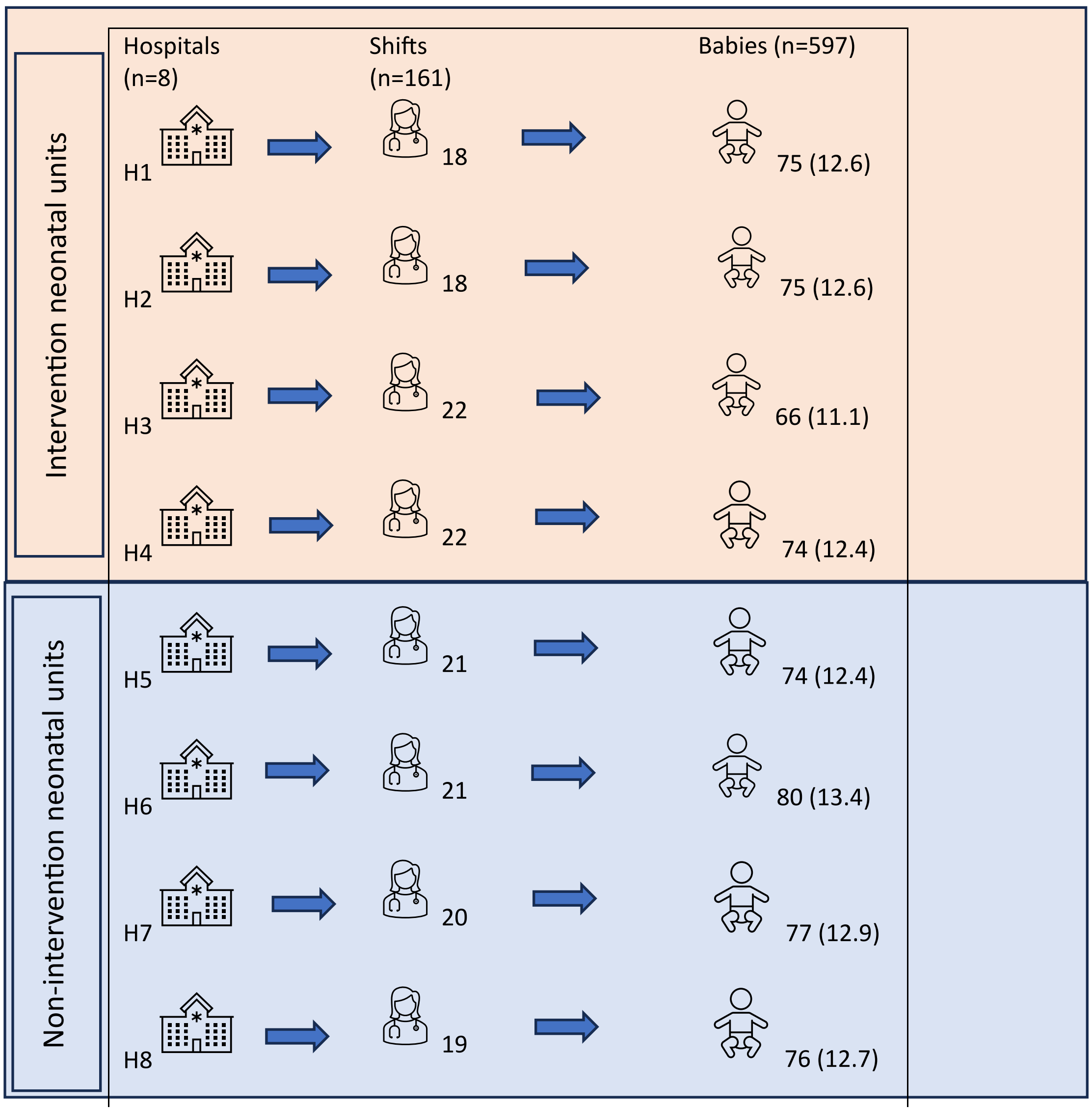

Figure 4.1 – Flow chart showing distribution of nursing shifts and the study population across neonatal units

4.5.2 Description of the 8 study neonatal units.

Table 4.4 provides a description of bed capacity, staffing and equipment across the eight study neonatal units (H1 to H8). Bed capacity and staffing varied across these units. The total number of nurses allocated to these neonatal units ranged from eight nurses in H4, which had a bed capacity of 47 (1 nurse: 5.9 beds), to 17 nurses in H2, which had a bed capacity for 53 babies (1 nurse: 3.1 beds). Most units had between one and three ward assistants, with only H5 having six. The nursing skill mix was similar across the neonatal units, with most nursing staff having diplomas or higher diplomas. Each neonatal unit had its unique nursing shift pattern (Table 4.4).

Table 4.4 - Description of the eight study neonatal units (n=8).

Domain	Variable	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**
Physical structure	Bed capacity	50	53	47	38	50	71	28	26
	Type of unit**	Discrete	Discrete	Nested ward	Discrete	Nested ward	Discrete	Discrete	Nested ward
Nurse staff strength	Nurses	11	17	8	10	14	13	10	12
	Nurse support workers	3	3	1	1	6	3	2	1
Nurse skill mix	Masters	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (7.7)	0 (0.0)	0 (0.0)
	Bachelors	1 (9.1)	2 (11.8)	0 (0.0)	0 (0.0)	1 (7.1)	1 (7.7)	1 (10.0)	0 (0.0)
	Higher Diploma	2 (18.2)	6 (35.3)	0 (0.0)	1 (10.0)	3(21.4)	2 (15.4)	2 (20.0)	2 (16.7)
	Diploma	7 (63.6)	7 (41.2)	7(87.5)	9 (90.0)	11 (78.6)	8 (61.5)	7 (70.0)	10 (83.3)
	certificate	1 (9.1)	2 (11.8)	1 (12.5)	0 (0.0)	0 (0.0)	1 (7.7)	0 (0.0)	0 (0.0)
Number of functional equipment for essential newborn care and neonatal resuscitation	Radiant warmers	3	3	3	3	9	4	1	3
	Suction machines	3	4	3	3	2	2	2	2
	Glucometers	2	1	0	1	3	1	1	1
	Incubators	8	7	3	5	12	11	4	2
	CPAP machines	9	3	2	3	7	6	2	2
	Phototherapy	5	5	2	5	7	6	6	5

Table 4.4 (continued) - Description of the eight study neonatal units.

Domain	Variable	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**
Shift pattern and length (hours)	Morning shift	NA	5	NA	5	6	NA	NA	5
	Afternoon shift*	NA	6	6	6	5	6	5.5	6
	Evening shift*	10	NA	11	NA	NA	9	9	NA
	Night shift	14	13	13	13	13	13	13	13

H1- H4 are intervention hospitals. H5 – H8 are non-intervention hospitals.

*Evening and afternoon shifts overlap for H4, H6 and H7.

**-Neonatal units were considered discrete when they were stand-alone. Nested units were a section of the maternity ward/ complex.

NA is not applicable.

4.5.3 Nursing shift characteristics

Table 4.5 summarises 161 observed nursing shifts, focusing on nurse staffing and patient numbers on these shifts. Across all nursing shifts, there were an average of 38 patients, and patient numbers ranged between 12 and 73 (Table 4.5). On night shifts, there were on average two nurses to 37 babies. While on day shifts, there were, on average, 41 patients with 1 – 2 nurses for the morning, afternoon, or evening shifts (there was some overlap across shifts). This shift overlap across neonatal units is highlighted in Table 4.1.

The median total nursing hours for a standardised 12-hour shift was 23.9 hours and ranged between 9.8 hours and 36 hours across all nursing shifts. The median nursing hours per patient per 12-hour shift was 0.51 hours per patient (equivalent to 30 minutes per patient). There was also significant variation in the number of nursing students on a shift (Range 0 to 35, Table 4.5). Each nursing shift had babies requiring multiple interventions (Table 4.5).

Table 4.5 – Nurse staffing and patient load on nursing shifts (n=161)

Nursing shift characteristics	Median (Interquartile range)	Range
Total nursing hours per 12-hour shift (hours)[a]		
Day shift (n=74) [b]	24.0 (16.4 to 26.2)	9.8 to 36.0
Night shift (n=87)	23.9 (12.0 to 23.9)	12.0 to 35.9
All shifts	23.9 (12.0 to 24.0)	9.8 to 36.0
Nursing hour per patient per 12-hour shift[c]		
Day shift (n=74)	0.52 (0.43 to 0.70)	0.15 to 1.45
Night shift (n=87)	0.47 (0.41 to 0.66)	0.28 to 1.5
All shifts	0.51 (0.41 to 0.68)	0.15 to 1.5
Nurse student numbers	5 (2 to 9)	0 to 35
Patient numbers		
All shifts[d]	38 (23 to 52)	12 to 73
Day shifts (n=74)	41 (24 to 55)	15 to 73
Night shifts (n=87)	37 (23 to 52)	12 to 68
Patient numbers by intervention		
Babies on CPAP	0.5 (0 to 2)	0 to 4
Babies on oxygen	7 (4 to 12)	1 to 21
Babies on Intravenous therapy[e]	18 (12 to 25)	4 to 37
Babies on phototherapy	3 (2 to 5)	0 to 11
Babies on nasogastric and orogastric tube feeding	13 (7 to 19)	2 to 29
Babies on incubator care	6.5 (4 to 11)	0 to 26
Babies on Kangaroo Mother care	5 (3 to 8)	0 to 12
Babies in acute room	12 (7 to 18)	0 to 32

a- Total nursing hours per 12-hour shift are cumulative hours on either a day or night shift standardised to 12 hours.

b- Day shifts combine morning, afternoon, and evening shifts.

c- Total nursing hours per 12-hour shift are cumulative hours on either a day or night shift standardised to 12 hours and adjusted for patient numbers.

d- Patient numbers at the start of observations

e- Intravenous therapy are patients on intravenous antibiotics and intravenous fluids.

4.5.4 Variation in nurse staffing levels across neonatal units

Although the median nursing hour per patient per 12-hour shift across all shifts was 0.51 nursing hours per patient, this differed across individual neonatal units, ranging from 0.32 nursing hours per patient in H8 (equivalent to 19.2 minutes, Figure 4.2) to 1.20 nursing hours per patient in H7 (equivalent to 72.0 minutes, Figure 4.2).

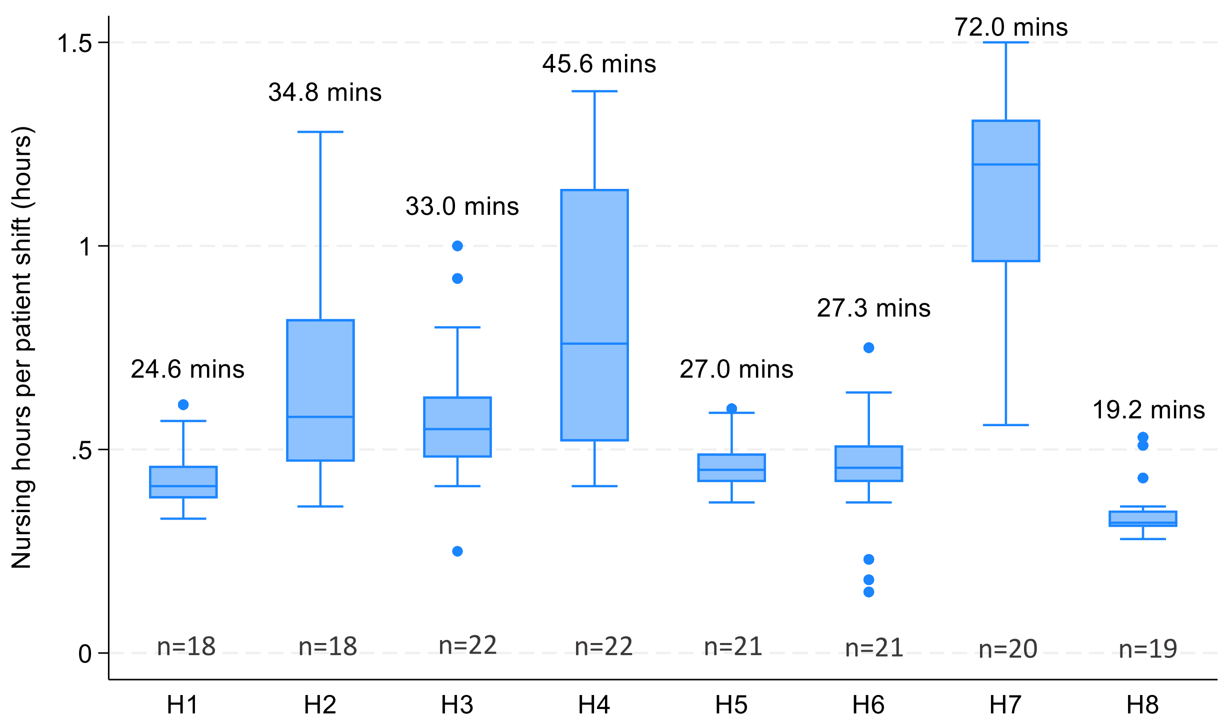

Figure 4.2- Shift-level Nursing input measured as nursing hours per patient per 12-hour shift across eight neonatal units (H1 to H8) (n=161).

The boxes represent the middle 50% of the data, while the whiskers represent the top and bottom 25% of the data.

The legends above each boxplot represent the median nursing hours per patient per 12-hour shift translated to minutes.

Values of n below each box plot are the number of shifts the box plot is based on

4.5.5 Neonatal care provision in the study newborn units

We observed 14271 expected nursing tasks in 597 babies across the eight neonatal units. Of these, roughly a third were performed by nurses, another third was performed by others (nursing students and mothers), and one-third was missed.

4.5.6 Nurses' role in care provision within the neonatal units

Table 4.6 depicts nursing care provision across the pooled neonatal data from the eight study neonatal units and provides cluster (hospital) adjusted 95% confidence intervals. The topmost five completed nursing tasks by nurses were conducting patient handovers (95.0% [95% CI - 82.9, 98.7]), patient clinical assessments before commencing a shift (81.0% [95% CI - 52.7, 94.3]), Handwashing before patient contact (54.7% [95% CI -25.4, 81.0]), Checking oxygen flow rates for babies on Continuous Positive Airway Pressure ventilation (53.8% [95% CI - 5.3, 96.0] and giving intravenous medications (47.9% [95% CI -7.7, 91.0]). Nursing tasks least carried out by nurses were nasogastric feeding (0.0% [95% CI - 0.0, 0.0]), cleaning babies (0.5% [95% CI- 0.1, 2.6], cord care (0.9% [95% CI - 0.2, 4.8], weighing babies (1.1% [95% CI -0.1, 11.1]) and changing baby diapers (1.2% [95% CI - 0.5, 2.9].

4.5.7 Informal neonatal unit task shifting.

Several nursing tasks that nurses least carried out were commonly done by /delegated to others. Mothers of babies played significant roles in cleaning babies, changing baby linens, changing diapers, and all forms of baby feeding, including providing nasogastric tube feeding, turning babies, giving oral medications, and performing cord care (Table 4.6). For example, mothers provided 95.9% of nasogastric tube feeding. Unsupervised nursing students also played significant roles in nursing tasks such as administering intravenous medications, vital sign monitoring, caring for babies on oxygen or Continuous Positive Airway Pressure and phototherapy (Table 4.6). They administered 43.0% of intravenous medications for all babies in the sample population and conducted 54.5% and 54.1% of temperatures and pulse rates, respectively (Table 4.6).

4.5.8 Missed nursing care.

Table 4.6 also shows the percentage of nursing tasks for babies that were expected but missed. i.e. not done at all by anyone. The five most missed nursing tasks were attending ward rounds (85.3%), changing eye pads for babies under phototherapy (65.8%), changing linens (59.1%), patient communication (53.2%) and checking nasogastric tubes were in-situ before a nasogastric tube feed (49.7%). The nursing tasks least missed by anyone (including mothers) were checking oxygen prongs for babies on oxygen therapy (1.4%), cup feeding babies (1.7%), diaper change (2.3%), physical turning babies (2.7%), measuring feeds for nasogastric tube feeding (4.1%).

Table 4.6– Nursing care provision in pooled newborn data from 8 study neonatal units(n=597)

Domain	**Task**	**Required for all babies observed on a shift**	**Number of babies**	**Percentage of babies whose tasks were performed by a nurse (Hospital adjusted CI)**	**Percentage of babies whose tasks were performed by others. (Hospital adjusted CI)**	**Percentage of babies whose tasks were missed. (Hospital adjusted CI)**
Routine nursing care	Patient handover	Yes	597	95.0 [82.9, 98.7]	NA**	5.0 [1.3, 17.1]
	Patient clinical assessment before a shift	Yes	596	81.0 [52.7, 94.3]	NA	19.0 [5.7, 47.3]
	Hand washing	Yes	567	54.7 [25.4, 81.0]	NA	45.3 [19.0, 74.6]
	Ward round attendance	No	156	14.7 [5.9, 32.3]	NA	85.3 [67.7, 94.1]
	Patient communication	Yes	590	46.8 [26.0, 68.7]	NA	53.2 [31.3, 74.0]
Vital sign monitoring	Temperature	Yes	594	9.4 [3.8, 21.7]	54.5 [29.6, 77.4]	36.0 [16.0, 62.5]
	Pulse rate	Yes	595	12.1 [6.0, 22.9]	54.1 [25.4, 80.3]	33.8 [13.3, 62.9]
	Respiratory rate	Yes	594	11.1 [5.4, 21.5]	42.8 [20.3, 68.6]	46.1 [27.5, 65.9]
	Pulse oximetry	Yes	532	13.9 [7.3, 24.8]	49.1 [21.6, 77.1]	37.0 [15.1, 66.0]
Routine newborn care	Cleaning baby	No	421	0.5 [0.1, 2.6]	62.5 [31.7, 85.7]	37.1 [13.9, 68.2]
	Linen change	No	479	1.9 [0.9, 3.8]	39.0 [19.9, 62.3]	59.1 [35.8, 78.9]
	Weight check	No	189	1.1 [0.1, 11.1]	83.1 [63.7, 93.2]	15.9 [6.3, 34.7]
	Checking incubator settings	No	83	24.1 [6.1, 60.9]	48.2 [20.1, 77.5]	27.7 [8.9, 60.1]
	Diaper change	Yes	597	1.2 [0.5, 2.9]	96.5 [89.1, 98.9]	2.3 [0.5, 9.6]
	Cord care	No	344	0.9 [0.2, 4.8]	56.7 [28.9, 80.8]	42.4 [18.3, 70.8]
Physical turning	Turning	Yes	593	2.2 [0.8, 6.1]	95.1 [87.6, 98.2]	2.7 [0.7, 10.3]
Feeding	Cup feeding	No	177	3.4 [1.3, 8.6]	94.9 [88.3, 97.9]	1.7 [0.5, 5.4]
	Nasogastric tube feeding	No	196	0.0 [0.0, 0.0]	95.9 [90.4, 98.3]	4.1 [1.7, 9.6]

Table 4.6(continued) – Nursing care provision in pooled newborn data from 8 study neonatal units(n=597)

Domain	**Task**	**Required for all babies observed on a shift**	**Number of babies**	**Percentage of babies whose tasks were performed by a nurse (Hospital adjusted CI)**	**Percentage of babies whose tasks were performed by others. (Hospital adjusted CI)**	**Percentage of babies whose tasks were missed. (Hospital adjusted CI)**
Nasogastric tube feeding processes	Check tube position before feed	No	197	3.0 [0.9, 9.5]	47.2 [14.6, 82.4]	49.7 [17.0, 82.7]
	Feed measuring	No	198	0.0 [0.0, 0.0]	96.0 [90.4, 98.3]	4.0 [1.7, 9.6]
	Position baby after feed	No	196	0.5 [0.1, 4.6]	89.3 [71.9, 96.4]	10.2 [3.1, 28.6]
Medication	Intravenous medication*	No	142	47.9 [7.7, 91.0]	43.0 [4.9, 91.7]	9.2 [2.3, 30.4]
	Oral medication	No	74	9.5 [1.9, 36.0]	66.2 [23.5, 92.6]	24.3 [3.9, 71.8]
Phototherapy* care	Turning baby	No	41	9.8 [2.6, 30.2]	85.4 [47.4, 97.4]	4.9 [0.2, 54.5]
	Skin assessment	No	40	35.0 [2.5, 92.0]	20.0 [1.7, 78.0]	45.0 [4.8, 93.0]
	Eye care	No	38	31.6 [1.1, 95.1]	42.1 [4.6, 91.7]	26.3 [0.8, 93.9]
	Changing eye pads	No	38	26.3 [3.6, 77.3]	7.9 [1.0, 43.2]	65.8 [16.8, 94.8]
Continuous Positive Airway Pressure (CPAP)*	CPAP prong check	No	13	38.5 [2.4, 94.1]	46.2 [0.9, 98.8]	15.4 [0.3, 91.8]
	Oxygen flow rate check	No	13	53.8 [5.3, 96.0]	15.4 [0.1, 97.5]	30.8 [0.3, 98.6]
Oxygen therapy*	Oxygen prong check	No	69	21.7 [5.3, 58.0]	76.8 [36.4, 95.0]	1.4 [0.0, 34.1]
	Oxygen flow rate check	No	70	22.9 [12.4, 38.3]	52.9 [11.7, 90.5]	24.3 [3.3, 75.2]

*- This data is based on data from 4 out of the eight neonatal study units

**-NA is not applicable. These were tasks where only a nurse was observed. For example, whether a nurse washed their hands at first patient contact or handed over a baby was observed.

4.5.9 Difference in care provided by nurses across patient care categories.

Table 4.7 summarises care provision across patient care categories and examines who conducted nursing tasks and what tasks were missed (not done at all). The proportion of care provided by nurses has been emboldened within the table. Overall, nurses provided greater care to unstable babies (category A), while less care was provided to stable but ill (category B) and stable (category C) babies. Nurses attended ward rounds for 22.5% of category A babies, compared to 11.4% and 6.8% of category B and C babies. Nurses also conducted temperature measurements on 22.5% of category A babies and 3.2% and 2.4% of category B and C babies, respectively. Tasks already deprioritised by nurses did not follow any pattern based on patient categories; for example, the number of babies cleaned by nurses, cord care they performed or diaper changes by them did not differ across categories (Table 4.7).

Table 4.7 – Specific nursing tasks disaggregated by patient care category and whether the task was performed by the nurse, others or missed (n=597).

Domains	Task	Category A babies				Category B babies				Category C babies			
		n	Nurse	Others	Missed	n	Nurse	Others	Missed	n	Nurse	Others	Missed
Routine nursing care	Patient handover	202	**99.5** [94.8, 100.0]	NA	0.5 [0.0, 5.2]	187	**95.2** [63.9, 99.6]	NA	4.8 [0.4, 36.1]	208	**90.4** [66.2, 97.8]	NA	9.6 [2.2, 33.8]
	Patient assessment before a shift	202	**90.1** [57.3, 98.4]	NA	9.9 [1.6, 42.7]	186	**83.3** [44.8, 96.9]	NA	16.7 [3.1, 55.2]	208	**70.2** [42.0, 88.5]	NA	29.8 [11.5, 58.0]
	Hand washing	197	**61.9** [32.4, 84.7]	NA	38.1 [15.3, 67.6]	180	**56.7** [22.3, 85.6]	NA	43.3 [14.4, 77.7]	190	**45.3** [15.6, 78.7]	NA	54.7 [21.3, 84.4]
	Ward round attendance	68	**22.1** [10.2, 41.4]	NA	77.9 [58.6, 89.8]	44	**11.4** [1.3, 56.2]	NA	88.6 [43.8, 98.7]	44	**6.8** [1.1, 33.1]	NA	93.2 [66.9, 98.9]
	Patient communication	200	**55.5** [33.7, 75.4]	NA	44.5 [24.6, 66.3]	186	**46.2** [20.1, 74.6]	NA	53.8 [25.4, 79.9]	204	**38.7** [21.4, 59.5]	NA	61.3 [40.5, 78.6]
Vital sign monitoring [a]	Temperature	200	**22.5** [7.8, 50.0]	50.5 [26.9, 73.9]	27.0 [13.0, 47.9]	186	**3.2** [0.9, 11.3]	60.8 [28.1, 86.0]	36.0 [12.2, 69.5]	208	**2.4** [0.3, 14.9]	52.9 [26.7, 77.6]	44.7 [19.9, 72.4]
	Respiratory rate	200	**26.5** [11.2, 50.9]	48.0 [23.5, 73.5]	25.5 [15.6, 38.8]	186	**3.2** [1.0, 10.0]	50.5 [22.3, 78.4]	46.2 [19.9, 74.9]	208	**3.4** [0.7, 15.4]	30.8 [13.5, 55.8]	65.9 [42.2, 83.6]
	Pulse rate	201	**28.9** [12.6, 53.3]	55.2 [28.1, 79.5]	15.9 [6.7, 33.2]	186	**2.7** [0.6, 10.7]	61.3 [26.0, 87.7]	36.0 [10.2, 73.7]	208	**4.3**[1.3, 13.2]	46.6 [18.7, 76.8]	49.0 [19.7, 79.1]
	Pulse oximetry	177	**33.3** [15.3, 58.1]	48.0 [23.1, 74.0]	18.6 [8.3, 36.7]	171	**4.1** [1.4, 11.3]	57.9 [23.1, 86.3]	38.0 [11.0, 75.3]	184	**4.3** [1.1, 16.2]	41.8 [13.7, 76.6]	53.8 [20.3, 84.2]

Table 4.7 (continued) – Specific nursing tasks disaggregated by patient care category and whether the task was performed by the nurse, others or missed (n=597).

Domains	Task	Category A babies				Category B babies				Category C babies			
		n	Nurse	Others	Missed	n	Nurse	Others	Missed	n	Nurse	Others	Missed
Routine newborn care[b]	Cleaning baby	152	**0.7** [0.1, 6.7]	67.1 [41.1, 85.6]	32.2 [13.6, 59.0]	132	**0.0**	60.6 [24.9, 87.7]	39.4 [12.3, 75.1]	137	**0.7** [0.1, 7.2]	59.1 [23.8, 87.0]	40.1 [12.6, 75.8]
	Linen change	172	**2.9** [1.1, 7.2]	47.1 [27.5, 67.6]	50.0 [28.8, 71.2]	154	**0.0**	33.8 [14.1, 61.2]	66.2 [38.8, 85.9]	153	**2.6** [0.7, 9.4]	35.3 [13.1, 66.5]	62.1 [32.1, 85.0]
	Weight check[c]	79	**2.5** [0.2, 22.4]	79.7 [53.0, 93.2]	17.7 [5.3, 45.3]	57	**0.0** [0.0, 0.0]	80.7 [47.8, 95.0]	19.3 [5.0, 52.2]	53	**0.0** [0.0, 0.0]	90.6 [37.7, 99.3]	9.4 [0.7, 62.3]
	Diaper change	202	**2.0** [0.8, 4.8]	95.5 [86.4, 98.6]	2.5 [0.5, 11.5]	187	**0.0** [0.0, 0.0]	98.4 [91.9, 99.7]	1.6 [0.3, 8.1]	208	**1.4** [0.5, 4.4]	95.7 [82.8, 99.0]	2.9 [0.4, 17.5]
	Cord care	138	**0.7** [0.1, 8.7]	53.6 [29.3, 76.4]	45.7 [22.8, 70.6]	115	**1.7** [0.4, 8.0]	53.9 [26.2, 79.4]	44.3 [18.9, 73.2]	91	**0.0** [0.0, 0.0]	64.8 [24.4, 91.3]	35.2 [8.7, 75.6]
Physical turning[a]	Physical turning	200	**3.5** [1.1, 10.3]	90.5 [75.0, 96.8]	6.0 [1.5, 20.9]	186	**1.6** [0.3, 8.2]	97.3 [91.3, 99.2]	1.1 [0.2, 4.7]	207	**1.4** [0.5, 4.4]	97.6 [90.8, 99.4]	1.0 [0.1, 9.3]
Feeding[a]	Cup feeding	15	**6.7** [0.4, 56.5]	93.3 [43.5, 99.6]	0.0 [0.0, 0.0]	64	**1.6** [0.2, 14.1]	96.9 [87.5, 99.3]	1.6 [0.2, 14.1]	98	**4.1** [2.1, 7.9]	93.9 [87.2, 97.2]	2.0 [0.5, 7.8]
Medication	Oral medication[a]	31	**9.7** [3.3, 25.4]	61.3 [26.2, 87.6]	29.0 [5.8, 73.2]	12	**16.7** [2.4, 62.4]	75.0 [44.7, 91.8]	8.3 [1.1, 42.5]	31	**6.5** [0.1, 83.3]	67.7 [2.7, 99.4]	25.8 [0.4, 96.7]

NA – Not applicable, a -Other group is majorly mothers, b - Other group is majorly nursing students c- Other group is majorly nutritionists.

Emboldened numbers in table show the percentage of the particular task performed by nurses and how this change across patient care categories.

4.5.10 Nursing documentation compared with observed nursing care provision.

Table 4.8 compares nursing documentation on specific nursing tasks and observations of these tasks. Patient assessments were the most documented nursing tasks (91.6% of babies). Patient communication was the least documented (0.2% of babies). Nursing task documentation was at variance with observations. Patient assessments and ward round details were documented more than they were observed to happen. The former was observed in 81.0% of babies but documented for 91.6%, while the latter was observed in 14.7% of babies but documented for 36.8%. Patient communication was documented for only 0.2% of babies despite being observed for 46.8%.

Table 4.8 also compares the frequency of vital signs performed for babies with documentation of these signs. More vital signs were documented than were carried out in practice. More than half of babies had at least three temperature measurements documented, compared to 14.7% of observed babies. This disparity was also observed across pulse, respiratory rates, and pulse oximetry measurements (Table 4.8).

Table 4.8 – Reported documentation of nursing task contrasted with observed care.

Documentation domain	Tasks performed or not	n	% Nursing task documentation (hospital-adjusted 95% CI)	n	% Observed nursing task (hospital-adjusted 95% CI)
Patient assessment	Done	597	91.6 [79.8, 96.8]	596	81.0 [52.7, 94.3]
	Indeterminate		0.2 [0.0, 1.8]		NA
	Not done		8.2 [3.0, 20.3]		19.0 [5.7, 47.3]
Nursing care plan	Done	597	35.7 [9.8, 73.9]		NA
	Indeterminate		0.2 [0.0, 1.8]		NA
	Not done		64.2 [26.1, 90.1]		NA
Ward round attendance	Done	152	36.8 [13.6, 68.4]	156	14.7 [5.9, 32.3]
	Indeterminate		0.7 [0.1, 7.7]		NA
	Not done		62.5 [31.2, 86.0]		85.3 [67.7, 94.1]
Patient communication	Done	591	0.2 [0.0, 1.8]	590	46.8 [26.0, 68.7]
	Indeterminate		0.2 [0.0, 1.8]		NA
	Not done		99.7 [96.5, 100.0]		53.2 [31.3, 74.0]
Vital signs	Frequency of task	n	Frequency of documentation (%)	n	Frequency of tasks during observations (%)
Temperature measurements	0	593	140 (23.6)	597	188 (31.5)
	1		57 (9.6)		181 (30.3)
	2		80 (13.5)		140 (23.5)
	≥3		316 (53.3)		88 (14.7)
Pulse rate measurements	0	595	126 (21.2)	597	183 (30.7)
	1		51 (8.6)		164 (27.5)
	2		80 (13.5)		149 (25.0)
	≥3		338 (56.8)		101 (16.9)
Respiratory rate measurements	0	594	133 (22.4)	597	238 (39.9)
	1		51 (8.6)		154 (25.8)
	2		81 (13.6)		123 (20.6)
	≥3		329 (55.4)		82 (13.7)
Pulse oximetry measurements	0	589	204 (34.6)	597	240 (40.2)
	1		55 (9.3)		139 (23.3)
	2		72 (12.2)		130 (21.8)
	≥3		258 (43.8)		88 (14.7)

4.5.11 Nursing care provision using the nursing care index.

Table 4.9 summarises the three NCI indices (nNCI, sNCI, and aNCI). The table also examines if the average scores of these indices vary by shift type and patient care categories. On average, nurses alone provided 32% of all expected newborn care (median nNCI (interquartile range) 0.32 (0.27 – 0.38)). This proportion was similar across shift types and patient care categories. Nurses combined with nursing students, on average, provided 41% of all expected newborn care (median sNCI (interquartile range) 0.41 (0.25 – 0.53)). Care provision showed a graded increase across care severity. The sickest babies had the greatest combined nurse and nurse student care (median (interquartile range) 0.50 (0.37 – 0.59) while the most stable babies had the least combined nurse and nurse student care (median (interquartile range) 0.29 (0.19 – 0.44). The combined care provision varied across shift types and was higher on day than night shifts. On average, 68% of all expected nursing care was delivered to babies by anyone. (median aNCI (interquartile range) -0.68 (0.52 – 0.81)). This was similar across patient categories but was higher on the day than on the night shift.

Table 4.9 **–** Summary statistics for nursing care delivery by nurses and all others in the neonatal unit.

Variable	**n**	**Median (IQR)**	**Range**
Nursing hour per patient per shift *(equivalent time in minutes)*		0.50 (0.41 – 0.68) *(30 mins (24.6 mins – 40.8 mins))*	0.15 – 1.50 *(9mins – 90mins)*
Nurse-delivered care (nNCI)	**597**	**0.32 (0.27 – 0.38)**	**0.06 – 0.83**
Nurse-delivered care (by shift type)			
Weekday day	179	0.32 (0.28 – 0.38)	0.11 – 0.83
Weekday night	206	0.33 (0.26 – 0.40)	0.06 – 0.78
Weekend day	103	0.32 (0.27 – 0.38)	0.18 – 0.61
Weekend night	109	0.32 (0.26 – 0.35)	0.14 – 0.83
Nurse-delivered care (by patient category)			
Category A	202	0.33 (0.26 – 0.40)	0.11 – 0.83
Category B	187	0.29 (0.26 – 0.33)	0.16 – 0.71
Category C	208	0.35 (0.29 – 0.40)	0.06 – 0.78
Nurse & nurse student delivered care (sNCI)	**597**	**0.41 (0.25 – 0.53)**	**0.05 – 0.79**
Nurse & nurse student delivered care (by shift type)			
Weekday day	179	0.43 (0.29 – 0.53)	0.06 – 0.82
Weekday night	206	0.33 (0.21 – 0.50)	0.06 – 0.78
Weekend day	103	0.47 (0.35 – 0.57)	0.15 – 0.79
Weekend night	109	0.38 (0.27 – 0.55)	0.09 – 0.78
Nurse & nurse student delivered care (by patient category)			
Category A	202	0.50 (0.37 – 0.59)	0.07 – 0.82
Category B	187	0.41 (0.26 – 0.53)	0.09 – 0.79
Category C	208	0.29 (0.19 – 0.44)	0.05 – 0.65
Nursing care provided by anyone (aNCI)	**597**	**0.68 (0.52 – 0.81)**	**0.20 – 1.00**
Nursing care provided by anyone (by shift type)			
Weekday day	179	0.71 (0.55 – 0.82)	0.31 – 1.00
Weekday night	206	0.64 (0.50 – 0.78)	0.20 – 1.00
Weekend day	103	0.74 (0.60 – 0.82)	0.32 – 1.00
Weekend night	109	0.61 (0.48 – 0.79)	0.30 – 0.95
Nursing care provided by anyone (by patient category)			
Category A	202	0.69 (0.56 – 0.81)	0.31 – 1.00
Category B	187	0.68 (0.52 – 0.82)	0.20 – 1.00
Category C	208	0.64 (0.50 – 0.81)	0.20 – 1.00

Emboldened data show the average value for each index of nursing care delivery

4.5.12 Variation in nursing care provision across study neonatal units

Figure 4.3 compares the proportion of expected nursing care provision using the nNCI (for nurse-delivered care) and aNCI (for all nursing care provided) across the eight study neonatal units using box plots. The proportion of expected nursing care specifically delivered by nurses was similar across all study neonatal units as median nNCI did not vary significantly. Average total nursing care delivered irrespective of who performed the task (aNCI) differed across units (this was greatest in H8 and least in H6).

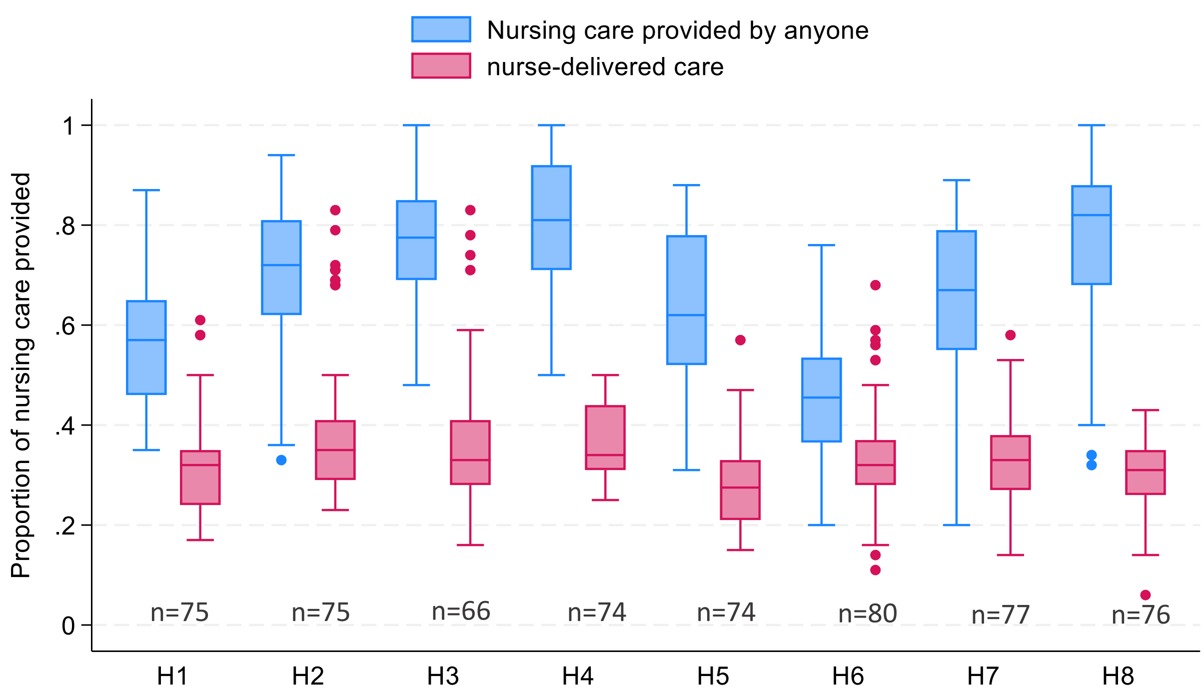

Figure 4.3– Box plots showing nurse-delivered (nNCI) and nursing care provided by anyone (aNCI) to babies across neonatal units (H1-H8) (n=597).

Nurse-delivered care focuses on care delivered specifically by nurses.

Nursing care is provided by anyone, including nursing care provided by nurses, nursing students, mothers and others.

The boxes represent the middle 50% of the data, while the whiskers represent the top and bottom 25% of the data.

Values of n below each box plot are the number of shifts the box plot is based on

4.5.13 Primary analysis - Examining the relationship between neonatal unit staffing and nursing care provision (measured as nNCI and aNCI)

Figure 4.4 and 4.5 are scatter plots that show the relationships between nurse staffing (measured as nursing hours per patient per 12-hour shift) and nursing care provision (measured as nurse-delivered care (nNCI) and the proportion of nursing care provided by anyone (aNCI), respectively). Nursing hours per patient per 12-hour shift correlated poorly with the nNCI (r=0.14, Figure 4.4) and aNCI (r=0.13, Figure 4.5).

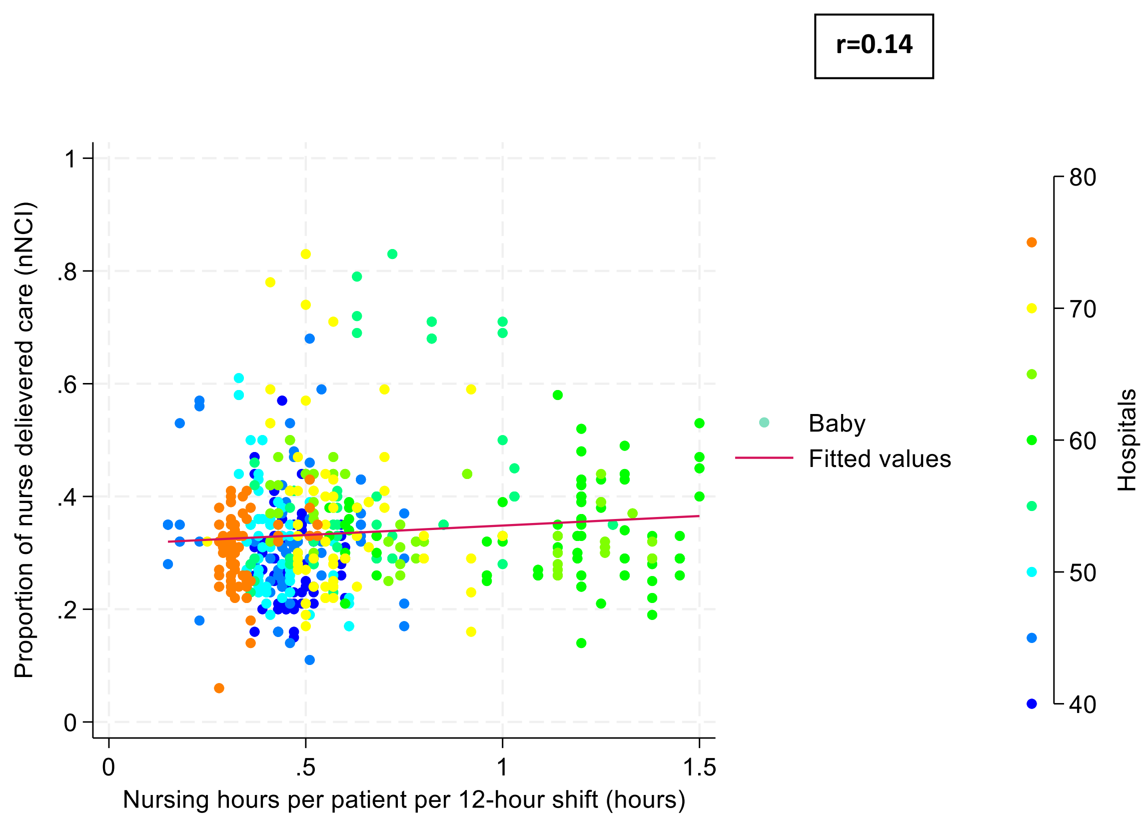

Figure 4.4– Scatter plot showing the relationship between nursing hours per patient per 12-hour shift and proportion of nurse-delivered care (nNCI). r value in the top-right corner represents the Spearman's correlation =0.14

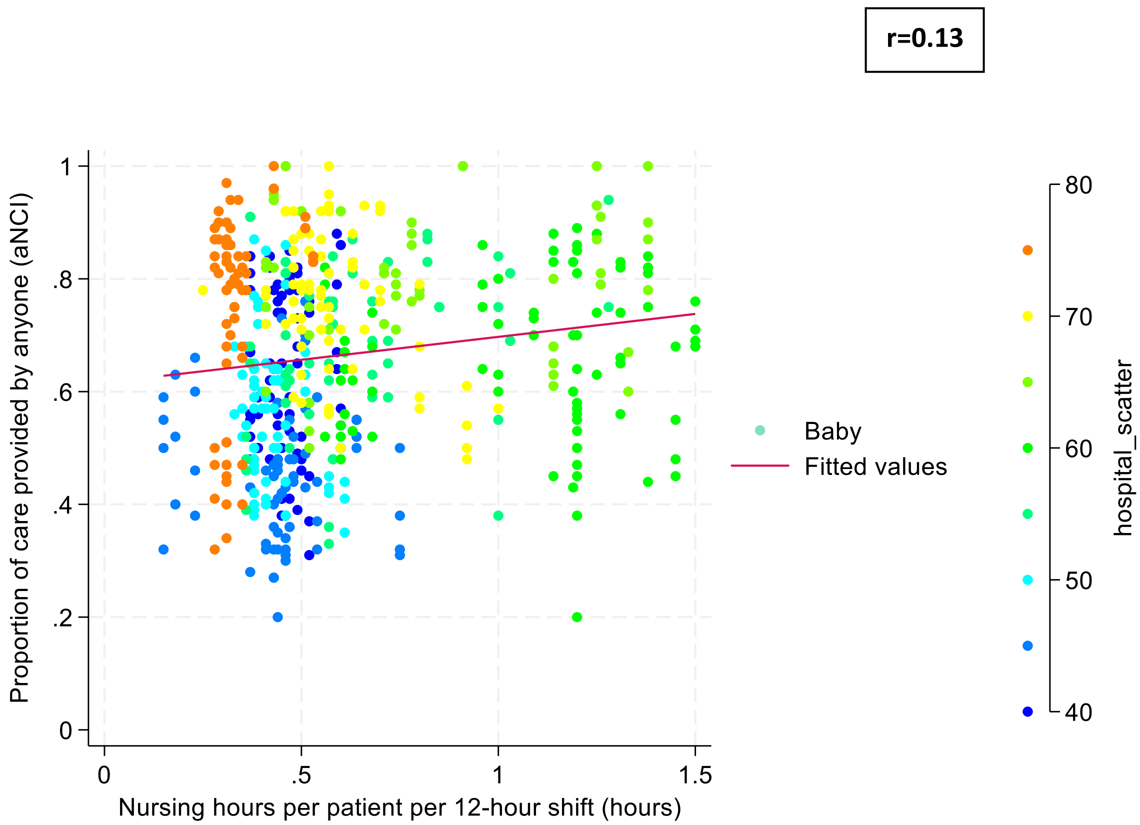

Figure 4.5 – Scatter plot showing the relationship between nursing hours per patient per 12-hour shift and proportion of care provided by anyone (aNCI). r value in the top-right corner represents the Spearman's correlation =0.13

4.5.14 Exploratory analysis - Examining the relationship between neonatal unit staffing (measured as a combined hours per patient per 12-hour shift) and nursing care provision (measured as sNCI and aNCI)

Figure 4.6 shows the relationship between a combined nurse and nurse student staffing input and the proportion of nurses and nursing student-delivered care (sNCI), while Figure 4.7 shows the relationship between the combined staffing input and the proportion of nursing care provided by anyone (aNCI). The combined hours per patient per 12-hour shift had stronger correlations with nursing care provision than the nursing hours per patient per 12-hour shift (its correlation with the sNCI was 0.48 (Figure 4.6), and the aNCI was 0.57 (Figure 4.7).

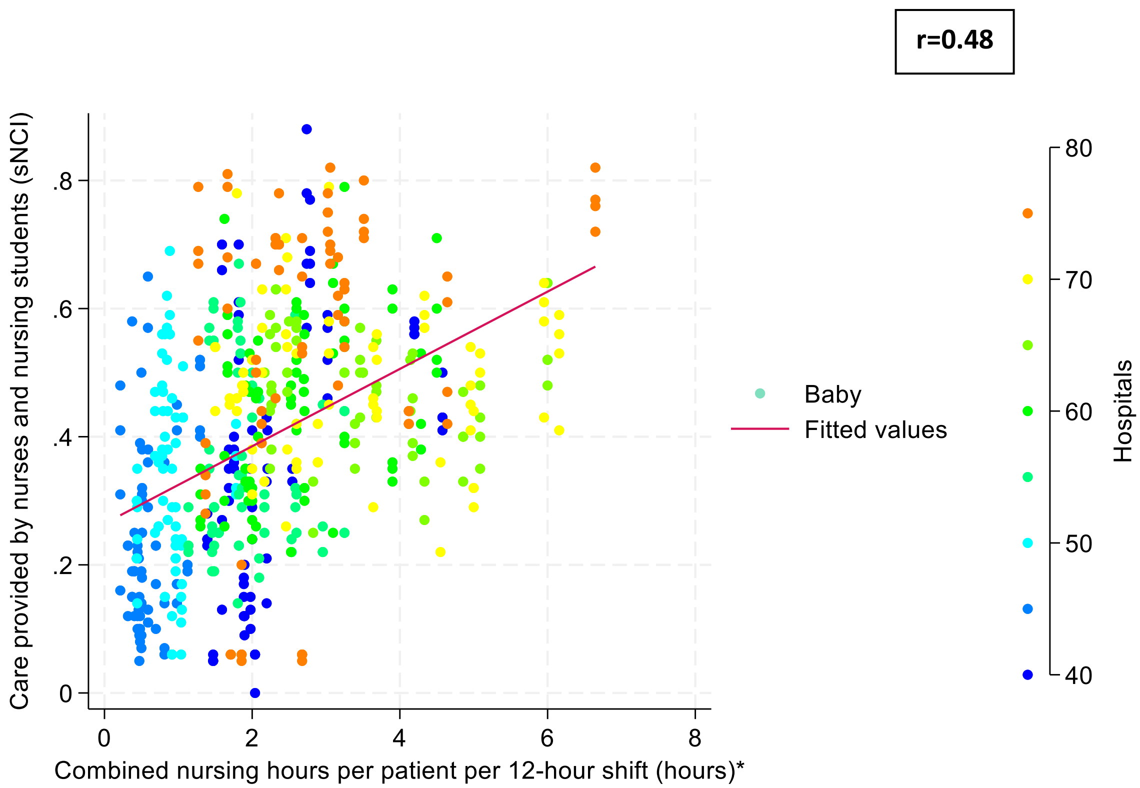

Figure 4.6 – Scatter plot showing the relationship between combined (nurses and nursing students) nursing hours per patient per 12-hour shift and proportion of care provided by both nurses and nursing students (sNCI) (Spearman's correlation =0.48)

*- Combined nursing hours per patient per 12-hour shift includes nursing student hours in the measure of nursing hours per patient per 12-hr shift

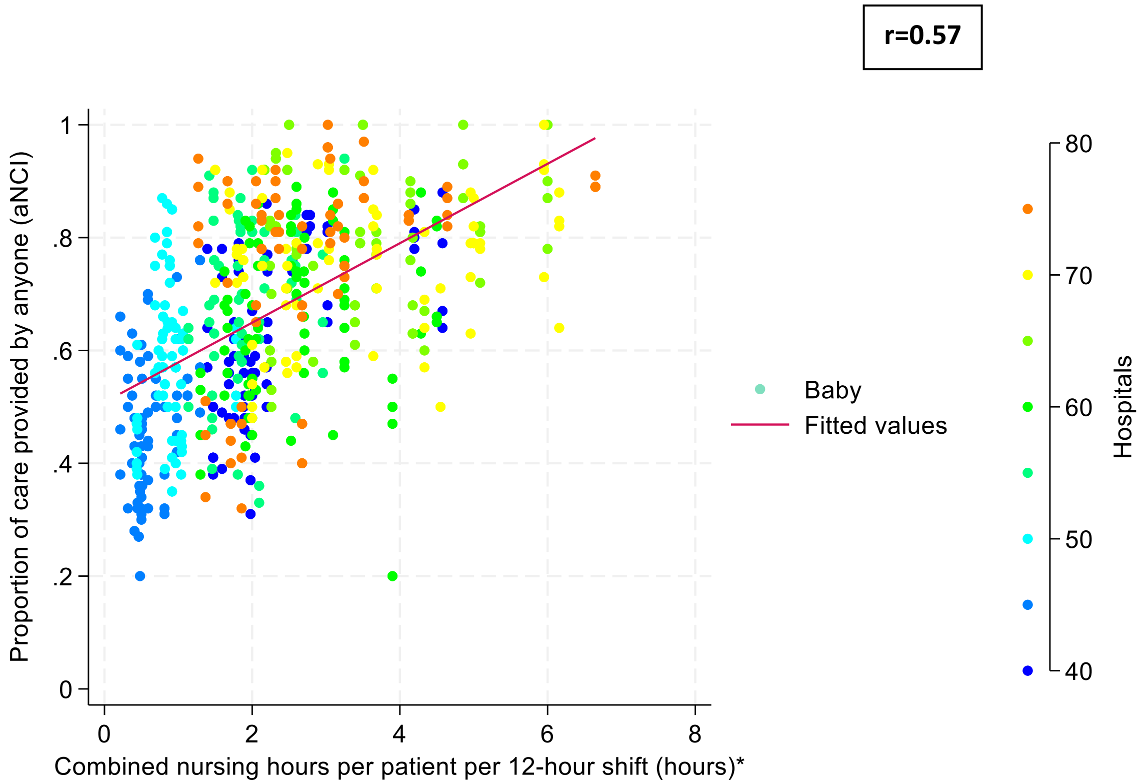

Figure 4.7 - Scatter plot showing the relationship between combined (nurses and nursing students) nursing hours per patient per 12-hour shift and proportion of care provided by anyone (aNCI) (Spearman's correlation =0.57)

*- Combined nursing hours per patient per 12-hour shift includes nursing student hours in the measure of nursing hours per patient per 12-hr shift

4.5.15 Multilevel modelling examining nurse staffing and nursing care provision.

Table 4.10 shows the multilevel regression model and 95% confidence intervals for the relationship between nurse staffing and nurse-delivered care (nNCI). The unadjusted multilevel model suggested a non-significant 3.4% increase in nurse-delivered care (0.034 (-0.009 to 0.078), Table 4.10) for every one-hour increase in nursing hours per patient per 12-hour shift. Adjusting the model for patient severity did not result in a significant relationship between nurse staffing and nurse-delivered care (-0.011 (-0.065 to 0.044), Table 4.10). There was also no significant relationship between nurse staffing and care provided by anyone (aNCI) (unadjusted model - 0.014 (-0.078 to 0.107), and adjusted best-fit model - 0.004 (-0.082 to 0.090), Table 4.10) The combined nurse and nurse student hours per patient per 12-hour shift which allowed for a more significant variation in nursing hours was associated with a 4.4% increase in care provided by anyone (aNCI) (0.044 (0.025 to 0.062) for each one hour increase in the metric.

Table 4.10 **–** Multilevel regression model and 95% confidence intervals for the relationship between nurse staffing and nurse care provision

Multilevel models	***Variables***	**Unadjusted two-level random-intercept model. Coefficient (95% confidence level)**	**Best-fit model Coefficient (95% confidence level)**
Model 1 - Nurse-delivered care (outcome)	**Nurse hour per patient per shift**	0.034 (-0.009 to 0.078)	-0.011 (-0.065 to 0.044) *
	Patient care categories		
	Category A (Reference group)		1.00
	Category B		-0.064 (-0.093 to -0.035)
	Category C		-0.012 (-0.040 to 0.016)
Model 2 –Care provided by anyone (outcome)	**Nurse hour per patient per shift**	0.014 (-0.078 to 0.107)	0.004 (-0.082 to 0.090) #
	Number of nursing students on a shift		0.008 (0.005 to 0.011)
Model 3 – Care provided by anyone (outcome)	**Combined nursing hour per patient per shift**	0.044 (0.025 to 0.062)	

*- The best-fit model for nurse-delivered care is a three-level random intercept model adjusted for patient severity

- The best-fit model for nursing care is a three-level random intercept model adjusted for the number of nursing students (as a continuous variable) on a shift

4.6 Discussion

4.6.1 Summary of findings

In the current chapter, I examined nurse staffing levels and nursing care provision (including nurse-delivered care) in eight newborn units in Kenya and the relationship between both variables. My findings show extremely poor nurse staffing and high workloads across the neonatal units. They also show high informal task sharing with mothers and nursing students and considerable missed nursing care.

4.6.2 Nurse staffing levels across neonatal units

The neonatal units were variably staffed, ranging from eight nurses employed in H4 with a bed capacity for 47 babies (nurse-to-bed ratio of 1:5.9) to 17 nurses employed in H2 with a bed capacity for 53 babies (nurse-to-bed ratio of 1:3.1). At nursing shift level, this translated to an average nursing hour per patient per 12-hour shift (NHPPS) of 0.51 hours equivalent to 30.6 minutes per patient across all neonatal units. This starkly contrasts with studies from high-resource settings where nursing time available for patient care is much higher. A study conducted in the US reported average nursing hours per patient per 12-hour shift to be 5.43 hours (325.8 minutes) in settings with a similar patient acuity level to the units in this study (206)This suggests that the nursing workload in the study neonatal units was, on average, 10-fold higher than in a comparative high-resource setting.

In addition to limited nurse staffing, this study noted some variability in shift-level nurse staffing. H8, with a total nurse-to-bed ratio of 1:2.1, was the least staffed, with an NHPPS of 0.32 hours (19 minutes). While H7, with a total nurse-to-bed ratio of 1:2.8, was the best-staffed hospital with an NHPPS of 1.20 hours (72.0 minutes). The apparent absence of a direct link between the nurse-bed ratio and actual shift-level staffing is partly explained by the high bed occupancy rate in these settings. It is expected to have cot and incubator sharing within this context. As many as 2 to 3 babies have been known to share an admission bed, making this an unsuitable measure for nursing input in such contexts. The poor and variable staffing levels are also partly explained by Kenya having no neonatal unit nurse staffing policy to mandate a minimum nurse-to-patient number (207) (208). In high-income settings, neonatal nurse staffing is guided by policies mandating average staffing ratios. For example, in the UK, a minimum of 1:1 nursing is recommended for neonatal intensive care, while 1:2 and 1:4 are recommended for high dependency and special care, respectively (209). The low nurse staffing within the study context might influence care provision in these neonatal units, as such set-ups create highly stressful work environments for nurses, making it impossible to deliver all expected care. It is perhaps unreasonable and impractical to expect nurses in such settings to meet quality standards comparable to international standards (54).

4.6.3 Nursing care provision - task prioritisation

The data shows that nurses favoured conducting some tasks and not others. Clinically oriented tasks were preferred at the expense of non-clinical tasks requiring less skill. The top five tasks carried out by nurses were conducting patient handovers (95.0%), patient clinical assessments before commencing a shift (81.0%), Handwashing before patient contact (54.7%), Checking oxygen flow rates for babies on Continuous Positive Airway Pressure ventilation (53.8%) and giving intravenous medications (47.9%). The increased focus on CPAP also provides some evidence that in poorly staffed settings, such technology can consume the time of nurses and take them away from other essential care. Non-clinical tasks were least carried out by nurses and appeared deprioritised; for example, no baby on nasogastric tube feeding was fed by a nurse, and nurses cleaned and provided cord care for only 0.5% and 0.9% of babies. This task deprioritisation might stem from the need to prioritise more technical nursing tasks due to impossible nurse-patient ratios at the expense of holistic nursing care (55). Such findings have been shown in studies conducted in other low and middle-income countries and reported in ethnographic research from Kenya (54,55,210).

Prioritisation was also seen in nurses selectively providing nursing care for some babies over others. In the current data, nurses were more involved in care provision to critically ill babies who inadvertently require more technical nursing care than the most stable babies. For example, nurses measured at least one temperature for 22.5% of critically ill babies compared to just 2.4% of stable babies. Nzinga *et al.,* using qualitative methods, also documented similar evidence of nurses triaging care due to competing demands for their time (55). This has also been observed in earlier work from Kenya by Gathara *et al.* (107). Task prioritisation by nurses creates another question as to who fills the care gap in these units left by nurses. This is discussed in the following subsection.

4.6.4 Informal/invisible neonatal unit task shifting.

This study found that only a third of the expected care needs of all babies were provided by qualified nurses in level 2 neonatal units that have a background of high neonatal mortality. This should be taken in the context of the structured observational tool measuring only patient-facing nursing tasks. Wider qualitative work from the HIGH-Q programme (my DPhil parent project described in Chapter 2) shows that nurses were also involved in administration, checking, and requesting supplies, supervising and teaching student nurses and non-professional neonatal unit staff. Of the patient-facing tasks measured by the structured observational tool, a further third of nursing tasks were informally shifted to unsupervised nursing students and mothers of babies admitted to the neonatal units. Unsupervised nursing students played critical roles in complex nursing care delivery, including caring for critically ill babies on CPAP and oxygen, monitoring patients' vital signs, and giving intravenous medications. Similarly, mothers were responsible for several deprioritised nursing tasks; for example, they played significant roles in cleaning babies, changing baby linens, changing diapers, and all forms of baby feeding, including providing nasogastric tube feeding, turning babies, giving oral medications, and performing cord care. These task-shifting practices within these units are not formalised or evidence-based and appear normative, likely arising from system maladaptation to chronic nurse staffing shortages. The role nurse staffing shortages play in informal task shifting is further supported by research in Kenya showing these practices were absent in better-staffed non-government owned neonatal units in Kenya (199). This raises concerns about healthcare inequality within the study context, as most newborns in Kenya receive public-sector neonatal care (53).

In addition to the potential for inequality, I noted a few issues of potential patient safety significance arising from the informal task-shifting process. One problem was related to nasogastric tube feeding, a complex and specialised form of nursing care with necessary key steps (211). Mothers who were solely responsible for nasogastric tube feeding were observed to miss critical aspects such as checking if a nasogastric tube was in place before feeding, raising concerns about how competent mothers were to undertake this nursing task (This was based on direct observation of this task using the structured observation checklist). The bedside observers (who were using the structured checklist) also noted that nurses in these units provided mothers with some training on nasogastric tube feeding, which usually happened during first insertion; more training appeared to occur in the form of peer-to-peer learning where mothers who had spent a considerable amount of time in the unit provided support and training to mothers who were new to the unit. A similar setup has been described by Oluoch et al., who researched mothers' experiences of care in neonatal units (199). This is not unique to poorly staffed newborn units in Kenya, as ethnographic research from Iran in newborn units with limited nurse staffing levels also reported informal task shifting to mothers (212). Ethnographic data from critical care settings in Bangladesh and India also show caregivers being involved in the care of critically ill patients with minimal support (213). I also noted other issues of potential safety significance with the work of unsupervised nursing students. The data shows that more patient vital signs were documented than were observed to be conducted. Field staff (observers) in the study noted unsupervised nursing students filling out patient documentation for vital signs, including pulse oximetry, which they had not carried out, and this was widespread across some of the study sites. This creates a challenge regarding the reliability of nursing care documentation within such contexts and is likely to impact patient clinical management and perhaps research related to documentation.

The observed way of working differed from the concept of family-centred care, which has central tenets of supporting and working collaboratively with families in voluntary care provision (214). In the neonatal unit, this is ideally phased step-by-step learning tailored to the caregiver and family needs and scaffolded and supported by the nursing team. In the study setting, caregivers were delegated nursing tasks largely without support as such tasks appeared to be viewed as primarily the caregiver’s, not the nurse's, role. The data shows that when the caregivers did not carry these out, they were not done at all, including occasionally feeding at night. In addition, the data also shows that task delegation to mothers occurred in all acuity of babies, as mothers in these units still provided care to the sickest and most critical of babies, notwithstanding their variable levels of maternal experience. Nurses have expressed such role transfer in qualitative studies, where nurses view some tasks as a mother's role and view themselves as assisting mothers incapable of providing such care (199,212).

4.6.5 Missed nursing care.

In the current study, various tasks were missed and not done at all. About one-third of all expected tasks were missed (not done at all). Commonly missed nursing tasks were attending ward rounds (85.3%), changing eye pads for babies under phototherapy (65.8%), changing linens (59.1%), patient communication (53.2%) and checking nasogastric tubes were in-situ before a nasogastric tube feed (49.7%). Some of these tasks have immediate safety implications, such as checking if nasogastric tubes were in place before feeding (this has been discussed previously). In the wider literature, missed nursing care is associated with poor quality patient care and adverse patient outcomes (111). Some studies have shown a strong direct relationship between nurse staffing levels and the magnitude of missed nursing care (107,215).

4.6.6 Overall nursing care provision across neonatal units and its relationship with nurse staffing.

I used three indices to measure overall nursing care provision across neonatal units. The first index measures nurse-delivered care (nNCI), the second determines nurse and unsupervised nursing students-provided care (sNCI) and the third measures nursing care provided by anyone (aNCI). Nurses provided 32% of all expected newborn care on average (nNCI), nurses combined with unsupervised nursing students offered 41% of all expected newborn care (sNCI), while care provided by anyone (aNCI) was 68%. As discussed in the previous section, the rest of the care was not done.

The nNCI was similar across all neonatal units, suggesting that nurses performed similar volumes of tasks across these units. What differed across units was the number of tasks conducted by anyone (aNCI), and this showed a strong relationship with the number of nursing students in the neonatal unit. This supports the critical role of nurse students providing care in these units and perhaps their collaborative role with mothers in care provision. Additionally, in contrast to the earlier study by Gathara et al (used to determine the study sample size) which showed significant variability in the nNCI (28), my study showed limited variability. This is linked to the study by Gathara *et al* being conducted in a wider range of neonatal units including private and faith-based units which are known to have much better nurse staffing than public sector neonatal units (28).

On examining the relationship between nurse staffing and overall nursing care provision, available nursing staffing measured using the nursing hours per patient per 12-hour shift (NHPPS) correlated poorly with nurse-delivered care (nNCI) and nursing care provided by anyone (aNCI). The poor correlation with both metrics was possibly linked to inadequate staffing within these units, limited variation in nursing input (the best NHPSS was less than 1.5 nursing hours) and perhaps well-established norms of care provision. In addition, the NCI does not measure non-patient facing tasks that might take up nursing time, such as student supervision or neonatal admissions. This might have partly explained the poor correlation between staffing and nurse-delivered care (nNCI). The apparent lack of a relationship between the aNCI (which consists mainly of care provided by caregivers and unsupervised nursing students) might also reflect limited supervision of these groups by nurses.

In contrast, when I explored the relationship between nursing care provision and a combined metric which assumed nursing students to be nurses within these units, there was greater variability (from a maximum of 1.5 hours to around 7 hours) in the staffing input metric and a stronger relationship with both the nurse and nurse student specific nursing care index (sNCI) and nursing care provided by anyone (aNCI). This suggests that greater nursing time is associated with more care delivered by someone with nurse training (even if incomplete). It also shows that greater staffing investments are needed to increase nursing care provision. The significant correlation of the combined metric with the aNCI also further buttresses the likely collaborative role between nursing students and mothers (which I also observed during my stay in some units).

On multivariate analysis using the less variable metric, nursing hours per patient per 12-hour shift, there was no significant relationship between staffing and changes in nurse-specific nursing care index (relative risk: -0.011, (95%CI: -0.065 to 0.044)) and nursing care provision by anyone (relative risk: 0.004, (95% CI: -0.082 to 0.090). With the more variable staffing metric that included nursing student hours and nursing hours, there was a significant increase in nurse-delivered care. For each hour increase in the combined nursing hours per 12-hour shift, there was a 4.4 % increase in nursing care delivery. This further buttress the need for a substantial increase in the 'dose' of staffing to observe an effect but that there may come a point at which this dose effect is no longer (approximately) linear.

4.7 Limitations

Several limitations exist for this research. The data for this study was derived using direct observation of nursing care with an observer present by the bedside of a baby. One known limitation of observation is the Hawthorne effect, in which individuals who are being observed modify their work because they are being followed (105). In Chapter 2 (methods), I mentioned various techniques I used to minimise the Hawthorne effect, including observers conducting observations on randomly selected neonatal nursing shifts and having a pilot before actual data collection. Despite this, it is possible that there might have been some residual Hawthorne effect. However, this effect would likely lead to a higher NCI, biasing my results to be more favourable than reality.

This data only focused on newborn units in government-owned hospitals (public hospitals). In Kenya, nurse staffing levels are better in private and faith-based facilities, so these findings are unlikely to be generalisable in such settings (28). Public hospitals are, however, responsible for most neonatal care in the Kenyan setting and account for as much as 70% of in-patient neonatal care in the Kenyan capital, Nairobi and likely a higher proportion of care in other counties outside the capital (195).

Data collection in the intervention and non-intervention sites used for this study were not contemporaneous. While this was linked to funding and the need for contingency planning in case of a massive change in staffing resulting from potential health system volatility (described in Chapter 2), this decision however has some disadvantages. One major downside of combining non-contemporaneous is the data are not temporal and can be affected by cyclical changes in the research context. In the case of my data, variables such as workload and nursing care delivery might potentially be affected by temporal changes in some factors, for example, the number of admitted babies or number of nursing students (who play major role in nursing care delivery). While in my models, I have adjusted for the number of nursing students, it is impossible to adjust or measure all temporal changes resulting from my use of non-contemporaneous data.

4.8 Implications of the findings

Task shifting, using lower cadre workers to support the work of highly skilled workers, has been proposed as one of the measures to stem the effect of health worker shortages. In Kenya, there has been little focus on the neonatal unit context, where unsupervised nursing students and mothers of babies are already providing a significant proportion of care. Such practice is not backed by policy or formal research evidence and likely has essential patient safety issues. This evidence currently supports a need for an urgent increase in nursing staff in government-owned Level 2 neonatal units. It perhaps also suggests a role for formal task shifting to a lower cadre of regulated staff that would support nurses in providing nursing care. Ideally, this cadre would work to support the role of nurses rather than serve as a replacement for qualified, skilled nurses. Currently, ancillary staff support housekeeping in some of the study units. The new cadre will likely take more patient-facing and less-skilled nursing tasks within these units. Evidence from high-income settings suggests that replacing nurses results in a poorer skill mix associated with poor-quality patient care and greater odds of patient mortality (11,73). To support such a task-shifting/sharing reform, there needs to be an initial investment in nursing workforce expansion. In the current study, I observed poor supervision of nursing students who were providing care, and this is likely to be a similar situation where lower-skilled staff are added to the current nursing workforce without initially increasing nursing numbers. To create a nurse support role within newborn units in Kenya, the current task-shifting policy would need to be adapted, as the current guidelines do not include a role for nursing support workers (207). Nursing roles shifted are likely to include non-clinical tasks which are low risk, for example, cleaning babies or changing linens and support for clinical tasks such as vital sign monitoring already being conducted by nursing students in this setting.

The finding of a likely dose-dependent relationship between nurse staffing levels when students are included in the input metric and nursing care delivery suggests that considerable investments in staffing levels are needed to increase nursing care delivery significantly.

4.9 Summary and conclusion

Current nurse staffing levels in the study contexts are impractical and lead to nursing care being missed or carried out by untrained personnel, potentially impacting care quality and patient safety. There is an urgent need for nursing workforce expansion in Level 2 neonatal units in the public sector in Kenya, which might be complemented by exploring the potential for task shifting to lower cadre workers to support nurses. It is critical to have a policy that defines minimum nurse staffing in neonatal units and potentially other units in public hospitals in Kenya, which should be guided by research evidence.

Chapter 5- - Effect of the nursing workforce Intervention on patient care quality

5.1 Background

Data from Chapter 4 examines nursing care provision (including nurse-delivered care) across the study neonatal units without any workforce intervention in place. In Chapter 4, I also introduced three nursing care index groups: nurse-delivered care (nNCI), care provided by anyone (aNCI), and nurse student and nurse-delivered care (sNCI).

In the current chapter, using a before and after analysis in the four intervention neonatal units, I examine how nurse-delivered care (nNCI) as an indicator of the quality of newborn care changes following the addition of extra neonatal nurses. This is a measure of the direct effect of the staffing intervention to increase the number of shift-level nurses, i.e. does increasing the number of nurses affect the volume of care, they (nurses) can deliver? I also conduct exploratory analysis examining changes in care provision by anyone (aNCI), as a measure of the indirect effect of the staffing intervention on all care provided in the neonatal unit. I go on to further explore the effects of the intervention on priority nursing tasks. This analysis was linked to my observations in Chapter 4 that nurses prioritised some nursing tasks over others (I discuss this later in detail in the method section of this chapter).

5.2 Introduction

The importance of nurse workforce planning and an adequate number of nurses to ensure patient safety and improved patient care outcomes is a long-established principle (110,124). Available evidence links limited nursing numbers or an inappropriately skilled nursing workforce to poor-quality care and adverse patient outcomes (29,216). This research has come mainly from observational research from high-income countries using large administrative health data sets (82). There has, however, been a lack of interventional research, in part linked to the complexities associated with conducting and evaluating such interventions (82). The available evidence is used in many high-income countries to advocate for safe nurse staffing, with many such settings having minimum acceptable nurse staffing standards (209,217,218).

Although there is observational study evidence, in many resource-constrained LMIC settings such as Kenya, there are no prescribed minimum nurse staffing levels, and extreme nurse-to-patient ratios observed within such settings are largely seen as a norm. In some of such contexts, a single nurse can care for as many as 20 patients (107,219). This is further supported by extremely poor nurse staffing observed in the study neonatal units described in Chapter 4. This starkly contrasts with ratios ranging from 1 to 1 nursing in intensive care to between 1 to 4 and 1 to 8 in general wards in some higher resource settings (209). Closing the nursing workforce gap and, in general, the human resources for health gap between the stark realities in LMICs and current standards in HICs would require significant investments that may appear unattainable and paralysing to policymakers. Studies that show that investing in additional nurses as an intervention in these settings improves care may be needed to advocate for policy changes.

In the current study, I evaluate the effects on nurse-delivered care (as a primary outcome) of a prospectively designed workforce intervention study to improve nurse staffing in resource-constrained hospital newborn units. One key consideration of the staffing intervention proposed was a modest increase in nurse staffing numbers similar to what might be affordable for health policymakers in contexts with broader resource constraints. I further explore the effect of the intervention on care provided by anyone (as an indirect effect of the intervention) and on nursing tasks prioritised by nurses from my findings in Chapter 4.

5.3 Methods

5.3.1 Study design

This study is a prospective before and after study and is based on an analysis of observation of nursing care delivery data collected before and after the addition of a workforce intervention in the four intervention newborn units. In Chapter 2, I provide greater detail of this data collection. Briefly, trained bedside observers collected data on nursing care delivery before the workforce intervention and six months after in the four intervention neonatal units. Six months was considered sufficient time for the intervention to take effect in the study contexts.

5.3.2 Study setting

I previously described the neonatal unit context in Chapters 2 and 4. Briefly, these newborn units were in government-owned hospitals, and they provided intermediate-level (Level 2) neonatal care 24 hours a day and seven days a week, serving as first-referral neonatal units for the community and primary care facilities. Each hospital was located within a county (introduced in Chapter 1), equivalent to the sub-national level in Kenya. The study neonatal units also supported a wider body of research under the Harnessing Innovations in Global Health for Quality Care (HIGH-Q) programme and were the recipients of a bundle of technologies from the NEST360° programme, as detailed in Chapter 2. At this stage, the NEST360 ° programme was at a 'mature' stage, provided neonatal technologies were in use in the neonatal units and all hospital-level training was complete. The NEST360° programme continued with 3-monthly support supervision visits and promoting local quality improvement - so NEST360 ° inputs were constant across the pre and post-intervention period.

5.3.3 Sample population.

The sample population for this study consisted of recruited babies receiving care in each of the four intervention neonatal units during the pre-intervention and post-intervention survey periods. These babies were selected based on three well-defined patient acuity levels that were earlier described

– severely ill (Category A), stable but ill (Category B), and stable (category C) babies – who were in the neonatal units at the time of randomly selected nursing shifts. Details of shift randomisation were provided in Chapter 2.

5.3.4 The nursing workforce intervention

The nursing workforce intervention was introduced in Chapter 2. In this Chapter, I go into greater detail about the intervention. The intervention involved adding three extra nurses concurrently to each of the four intervention units to increase the number of nurses available for direct patient care in all four neonatal units. The project grant paid for the salaries of these nurses through a third-party Kenyan-based non-governmental organisation - The Kenya Paediatric Research Consortium (220). The HIGH-Q project introduced the additional nurses for 15 months, initially for eight months alone and then together with neonatal ward assistants afterwards. My work focuses on the first eight months before adding the ward assistants.

Adding three extra nurses to each neonatal unit was intended to increase total nurse staffing numbers by between 17.6 and 37.5% across the intervention units (Table 5.1). The added nurses had nursing diplomas (at least three years of nurse training) and a minimum of two years of post-nursing school experience. Most pre-existing nurses in these newborn units also had ordinary diplomas, as graduate nurses remain uncommon, and very few nurses have specialised in neonatal care. Pre-intervention, the additional nurses were equipped with essential neonatal training using the five-day Emergency Triage, Assessment, and Treatment Plus (ETAT+) training on neonatal care (221)**.** This entailed short lectures on important neonatal care topics, for example, neonatal resuscitation, feed, and fluids management, but also more specific hands-on practical training and demonstration on individual aspects of care and use of key technologies (221). Appendix 17 shows the content of the neonatal ETAT+ training employed in this study.

Table 5.1 - Predicted change in nurse staffing following intervention in the four neonatal units.

Neonatal units	Baseline nurse staffing numbers	Predicted numbers post-intervention*	Predicted percentage change in nurse staffing (%)
H1	11	14	27.3
H2	17	20	17.6
H3	10	13	30.0
H4	8	11	37.5
All neonatal units (H1 to H4	46	58	26.1

*-Predicted numbers are based on the addition of three extra nurses to baseline numbers

5.3.5 Stakeholder engagement pre-intervention.

Before the deployment of additional nurses, I and other project team members engaged key county, hospital, and newborn unit stakeholders. This included county officials, hospital management, senior nurse managers, ward nurse managers and nurses in each intervention hospital. They were all sensitised to the study's goals, and we sought buy-in into the project. We also had presentations in each of the hospitals where we invited nurses from the neonatal unit and postnatal wards to discuss the project and its goals and to address any questions arising. The HIGH-Q project signed a memorandum of understanding (MoU) with each hospital and county government aimed at preventing the movement of nursing staff from the neonatal units following the addition of extra staff, as this was crucial to the success of the intervention. In the next chapter - Chapter 6, I examine whether attempts at stakeholder engagement and signing an MoU ensured fidelity (uptake) of the intervention.

5.3.6 Approach to deploying the intervention.

We chose a pragmatic approach to intervention deployment after adding the extra nurses to each neonatal unit. This allowed nursing ward managers who oversaw nurse staffing allocation in these units to use the added nurses as they deemed appropriate to increase shift-level nurse staffing. This approach was favoured as it will likely mirror a real-world addition of nursing staff to a particular unit. I summarise the intervention in Table 5.2 using the Template for Intervention Description and Replication (TIDieR) checklist and guidance (222).

Table 5.2 – Nursing workforce intervention described using the template for intervention description and replication (TIDieR) checklist and guidance.

TIDieR component	Intervention
Brief name	Nursing workforce intervention to improve nurse staffing numbers.
Why	Improving neonatal nursing staff numbers is likely to lead to increased nurse available time for patient care and ultimately increase nurse-delivered care.
What	Three additional nurses who had ordinary diplomas and who received additional intensive newborn training using the neonatal ETAT+ were added to each neonatal unit.
How	A pragmatic approach with neonatal unit nurse managers deploying added nurses to improve nurse staffing as they deem fit.
Where	Additional nurses were placed in level 2 newborn units, which served as referral neonatal units from the community.
When and how much	Additional nurses were added for 15 months, with evaluations happening at baseline and then six months after the intervention.
Tailoring	Each neonatal nurse manager utilised extra nurses as they deemed fit to increase the number of shift-level nursing staff.
Intervention modifications	None
How well	Stakeholder engagement and a memorandum of understanding were signed to promote intervention fidelity. I assessed intervention fidelity using changes in available nursing time.

5.3.7 Study variables.

5.3.7.1 Exposure variables

Main exposure variable

The primary exposure variable in this study is the participant recruitment period (pre-intervention or post-intervention). I compared observation of care data collected after the workforce intervention (post-intervention) to data collected pre-intervention.

Other variables

I considered other key variables as potential confounders to the relationship between additional nurse staffing and increased nursing care delivery. These were nursing shift type (weekday, weekend, night, or day), patient severity and the number of nursing students present on a nursing shift. The first two were from my literature review in Chapter 3B, while the third was identified post-hoc from an exploratory analysis of my data in Chapter 4. These variables were used in model building in addition to the primary exposure variable. I adjusted for the effects of the three potential confounders. Other variables not included in the model building but included in the descriptive data are the nurse staffing variables – total nursing hours per 12-hour shift and nursing hours per patient per 12-hour shift. The former is the combined nursing care hours provided by the nursing team over a standard 12-hour shift, while the latter is derived by dividing the total nursing hours by the number of patients on a nursing shift. These variables were not included in model building as from my logic model (described in Chapter 2); they are central and are likely to mediate how the intervention leads to a change in nurse-delivered care.

5.3.7.2 Outcome variable

The outcome variable for this study is the nursing care index (NCI), described in detail in Chapter 4. Briefly, this is a patient-level aggregate score, expressed as a proportion of expected tasks conducted for a baby. For this score, when care is interpreted as carried out, it is given a score of 1; when it is missed, it is given a score of 0. An unweighted combined score of observed care is then expressed as a proportion of expected care. For this chapter, I have three different measures of the NCI as outcome measures - the nurse-delivered NCI (nNCI) is the primary outcome measure. The nursing care delivery by anyone (aNCI) and the priority NCI (pNCI) are used as exploratory outcome measures. Both nNCI and aNCI have been discussed in detail in Chapter 4, while the pNCI was developed for this chapter. I provide a rationale for the use of these measures below:

Primary outcome

The nurse-delivered NCI (nNCI), which considers tasks as performed when a nurse completes them, is used as a primary measure to determine the direct effect of adding extra nurses. As it directly measures work done by nurses, it is thus likely to be most sensitive to a change in nurse staffing. For this analysis, it was not possible to use some structured observational tool domains for example oxygen care, phototherapy intravenous medication, kangaroo mother care and care of babies under

CPAP as we did not collect data on who conducted this care in the baseline analysis (This was explained in Chapter 4). Additionally, I could not add documentation as observed effects contrasted actual documentation (this was also alluded to in Chapter 4).

Exploratory outcomes

The aNCI, which considers a task as performed if it was undertaken regardless of who carried it out, was used to determine the indirect effect of the intervention on all measured neonatal unit care in this study.

The pNCI (the newly added metric) was used in further exploratory analysis and was developed post-hoc following my analysis in Chapter 4. My analysis showed that nurses implicitly deprioritised some forms of care they commonly delegated to students and mothers of babies. To measure the effect of the intervention on prioritised nursing tasks, the pNCI was restricted to the ten most prioritised nursing tasks. I selected the top ten nursing tasks to identify the effect of the intervention on prioritised tasks as this was roughly a third of possible nursing tasks used in my analysis and would be a good number for a subset analysis. The idea was to explore the influence of norms on the intervention, i.e. does adding extra nurses mean nurses keep focusing on the tasks they prioritise and can perform just this set of activities more frequently?

5.3.8 Statistical methods and data analysis

I use descriptive statistics – frequency, percentages, median and interquartile range to compare baby and shift-level variables between pre-and post-intervention periods. I also employ dot plots to examine visually how nurse staffing changed across pre- and post-intervention periods and to compare changes in nNCI (my primary outcome).

Using multilevel modelling, I explore the intervention's impact on the nNCI as a primary outcome and its impact on aNCI and pNCI as exploratory outcomes. I use Akaike's Information Criteria, Bayesian Information Criteria, and likelihood ratio tests to determine the best-fit model, similar to the methods described in Chapter 4.

5.4 Results

5.4.1 Participant characteristics across pre- and post-intervention periods.

Across the four intervention neonatal units, we recruited 290 babies between February and March 2022 (the pre-intervention period) across 80 nursing shifts (Figure 4.1) and 300 babies from the same neonatal units between October and December 2022, six months after the nursing workforce intervention across 76 nursing shifts.

In Table 5.3, I compare the characteristics of babies recruited across both recruitment periods. These babies were broadly similar in gender, patient illness severity, neonatal unit of recruitment and recruitment shift type, demonstrating how well stratified random shift selection worked.

Table 5.3– Baby characteristics across pre- and post-intervention periods (n=590)

Participant characteristics	**Pre-intervention (%) (n=290)**	**Post-intervention (%) (n=300)**
Gender		
Male	139 (47.9)	150 (50.0)
Female	151 (52.1)	150 (50.0)
Patient illness severity		
Category A	101 (34.8)	102 (34.0)
Category B	88 (30.3)	98 (32.7)
Category C	101 (34.8)	100 (33.3)
Neonatal unit of recruitment~		
H1	75 (25.9)	79 (26.3)
H2	75 (25.9)	75 (25.0)
H3	66 (22.8)	73 (24.3)
H4	74 (25.5)	73 (24.3)
Recruitment shift type		
Weekday day	93 (32.1)	90 (30.0)
Weekday night	101 (34.8)	116 (38.7)
Weekend day	47 (16.2)	57 (19.0)
Weekend night	49 (16.9)	37 (12.3)

*-Data from non-intervention units was post-intervention - at one-time point

~- H1 to H4 represent individual neonatal units.

5.4.2 Nursing shift characteristics and nurse staffing across pre- and post-intervention periods.

Nursing shift characteristics, including patient numbers on the shift, the nursing staff hours, were largely similar across pre-intervention and post-intervention periods in pooled data from the four intervention neonatal units (Table 5.4). There was a 16.4% increase in median total nursing hours between the pre-intervention and post-intervention data collection periods.

Table 5.4 – Nursing shift characteristics across pre- and post-intervention periods across four intervention neonatal units (n=156)

Nursing shift characteristics	**n**	**Pre-intervention Median (IQR)**	**n**	**Post-intervention Median (IQR)**
Patient numbers on shift	80	27 (21.5 to 50)	76	33 (25 to 49)
Patient numbers by intervention	80		76	
CPAP		0 (0 to 1)		0 (0 to 1)
Oxygen		6 (4 to 10)		4 (1.5 to 6)
Intravenous therapy		17 (12 to 25)		18 (10 to 23.5)
Phototherapy		2 (1 to 5)		4 (3 to 5.5)
Nasogastric and orogastric tube feeding		11 (7 to 16)		8 (5 to 12)
Incubator care		6.5 (4 to 9)		4 (2 to 8.5)
Kangaroo mother care		3 (0 to 5)		3 (2 to 6)
Nurse student numbers	80	5 (3 to 9)	76	5 (3 to 11)
Total nursing hours per 12-hour shift**	80	20.7 (12.0 to 24.1)	76	24.1 (24.0 to 29.4)

** Combined nursing care hours provided by the nursing team across all nursing shifts

5.4.3 Nurse staffing levels were compared between pre-intervention and post-intervention periods.

Figure 5.1 compares nursing input measured as nursing hours per patient per 12-hour shift before the addition of extra nurses and after their addition. Median nursing hours per patient per 12-hour shift across all four intervention neonatal units increased from a median nursing time available for patient care of 0.56 hours (33.6 minutes) before the intervention to 0.72 hours (43.2 minutes) after the intervention (a 28.5% increase in median shift nursing time per patient).

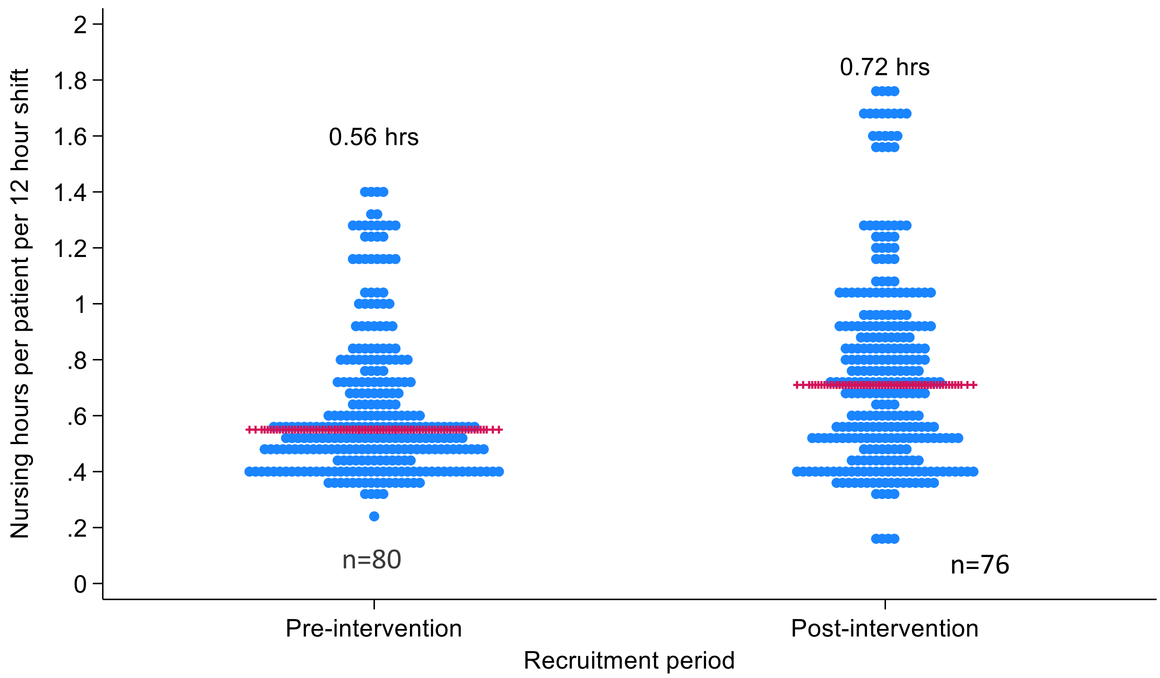

Figure 5.1– Dot plot comparing nursing hours per patient per 12-hour shift between nursing shifts in the pre-and post-intervention period (n=156).

Red lines across the plot represent the median.

Legends above the graphs are median values.

Nursing hours per patient per 12-hour shift is a measure of nursing time derived by dividing total nursing hours by patient numbers.

Values of n under the graphs represent the number of shifts

5.4.4 Primary analysis – Change in nurse-delivered care.

5.4.4.1 Change in nurse-delivered care (nNCI) between pre-intervention and post-intervention periods.

The median nNCI score between the pre-intervention and the post-intervention period did not differ considerably (Figure 5.2). In the pre-intervention period, the median (Interquartile range) nNCI was 0.33 (0.28 – 0.41), while in the post-intervention period this was 0.35 (0.30 – 0.44). Median scores also did not vary significantly across patient severity categories or shift types (Table 5.5).

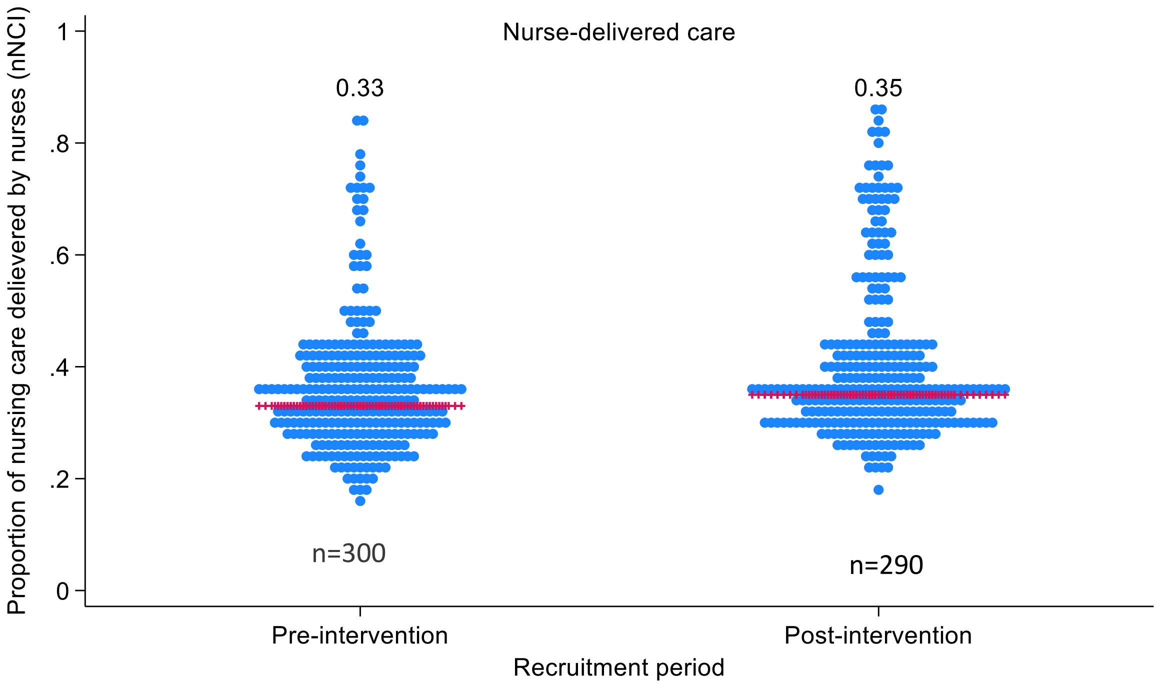

Figure 5.2– Dot plots comparing nurse-delivered care (primary analysis) between pre- and post-intervention periods for recruited babies (n=590).

Red lines across the plot represent the median.

Legends above the graphs are median values.

Values of n under the graphs represent the number of shifts

Table 5.5 – Nurse-delivered nursing care index (nNCI) compared across pre-intervention and post-intervention periods for recruited babies (n=590).

Nurse-delivered nursing care index (nNCI)*	**n**	**Pre-intervention Median (interquartile range)**	**n**	**Post-intervention Median (interquartile range)**
Median (IQR)	290	0.33 (0.28 – 0.41)	300	0.35 (0.30 to 0.44)
nNCI by shift type				
Weekday day	93	0.29 (0.26 – 0.38)	90	0.33 (0.29 – 0.39)
Weekday night	101	0.37 (0.33 – 0.44)	116	0.37 (0.33 – 0.44)
Weekend day	47	0.32 (0.27 – 0.41)	57	0.36 (0.30 – 0.48)
Weekend night	49	0.33 (0.29 – 0.37)	37	0.33 (0.32 – 0.44)
nNCI by patient illness severity				
Category A	101	0.32 (0.27 – 0.39)	102	0.33 (0.28 – 0.63)
Category B	88	0.29 (0.27 – 0.33)	98	0.33 (0.30 – 0.36)
Category C	101	0.39 (0.35 – 0.44)	100	0.39 (0.35 – 0.44)

*- This is the proportion of care delivered by nurses measured as an aggregate score of expected care that nurses provide

5.4.4.2 *Multilevel modelling on the effect of nurse staffing intervention on nurse-delivered care*

Table 5.6 shows a multilevel modelling analysis of the effect of the nurse staffing intervention on the proportion of care nurses deliver. It shows two models, a crude unadjusted multilevel model and the best-fit model, which both model the effect of the intervention on nurse-delivered care (nNCI). The best-fit model was adjusted for patient illness severity and number of nursing students. Using the best-fit adjusted model, on average, when compared to the pre-intervention data collection period, there was a 4.2% increase in nurse-delivered nursing care index score, and this was statistically significant (B-coefficient – 0.042 (95% CI 0.010 to 0.074, Table 5.6). Model fit statistics for best-fit model selection are shown in Appendix 18.

Table 5.6 - Multilevel models comparing nurse-delivered care between the pre-intervention and post-intervention periods for recruited babies (n=590).

Nurse-delivered care	**Unadjusted three-level random intercept**	**Best-fit model**
Recruitment period		
Post-intervention period	0.036 (0.003 to 0.069)	0.042 (0.010 to 0.074)
Pre-intervention period	Reference	Reference
Patient category		
Category A		Reference
Category B		-0.075 (-0.110 to -0.039)
Category C		-0.004 (-0.041 to 0.033)
Number of nursing students		-0.004 (-0.007 to -0.001)

5.4.5 Exploratory analysis

5.4.5.1 Change in the amount of care delivered by anyone (aNCI) between pre-intervention and post-intervention periods.

The median aNCI increased from 0.71 in the pre-intervention to 0.73 in the post-intervention (
).

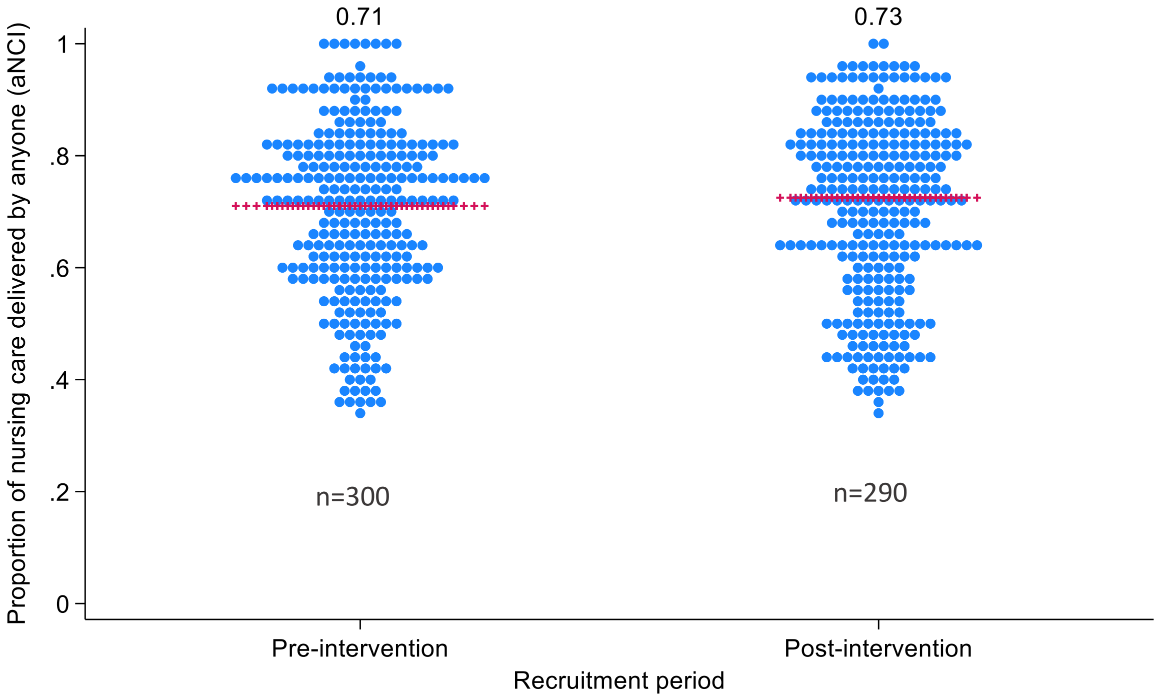

Figure 5.3– Dot plots comparing the amount of care provision between pre- and post-intervention periods for recruited babies (n=590).

Red lines across the plot represent the median.

Legends above the graphs are median values.

Values of n under the graphs represent the number of shifts

5.4.5.2 Multilevel modelling on the effect of nurse staffing intervention on the amount of nursing care delivered by anyone.

Table 5.7 shows the multilevel model analysis of the effect of the nurse staffing intervention on the total measured nursing care (amount of nursing care) in the neonatal units, irrespective of who undertook these tasks. It shows two models: a crude unadjusted multilevel model and the best-fit model. The best-fit model is a three-level hierarchical model adjusted for patient illness severity and the number of nursing students. Using the best-fit adjusted model, on average, the intervention did not result in a significant increase in care delivered by anyone (Model B-coefficient – 0.003 (95% CI -0.086 to 0.091, Table 5.7). Model fit statistics for best-fit model selection are shown in Appendix 19.

Table 5.7 - Multilevel models comparing the amount of care delivered between the pre-intervention and post-intervention periods for recruited babies (n=590).

Amount of care delivered by anyone.	**Unadjusted three-level random intercept**	**Best-fit model (adjusted model)**
Recruitment period		
Post-intervention period	0.003 (-0.073 to 0.080)	0.003 (-0.086 to 0.091)
Pre-intervention period	Reference	Reference
Patient category		
Category A		Reference
Category B		0.033 (-0.004 to 0.069)
Category C		0.078 (0.041 to 0.115)
Number of nursing students		0.004 (0.001 to 0.007)

5.4.5.3 Change in implicitly prioritised nursing care (pNCI) between pre-intervention and post-intervention periods.

Nursing care provision was compared between the pre-intervention and post-intervention periods using implicitly prioritised nursing care.

Table 5.8 compares nurse-delivered care using implicitly prioritised across recruitment periods. The table documents the top ten most carried out (prioritised) in the pre-intervention period and examines how this changed following the intervention. The top ten prioritised nursing tasks all increased by an absolute value of at least 3.2%, except for conducting nursing handovers, which appeared to demonstrate a ceiling effect (Carried out a 100% of times in the pre-intervention period and also measuring pulse oximetry which decline marginally (1%) (Table 5.8). In general, nursing tasks that nurses deprioritised remained either unchanged or minimally changed across intervention periods (not shown).

Table 5.8– Implicitly prioritised nursing tasks compared across pre-intervention and post-intervention periods (n=590).

	Pre-intervention				**Post-intervention**				**Change across pre- and post-intervention period**	
	n	**Nurse (95% CI)**	**Others (95% CI)**	**Missed (95% CI)**	**n**	**Nurse (95% CI)**	**Others (95% CI)**	**Missed (95% CI)**	**Change in nurse-delivered care**	Change in missed care
Implicitly prioritised nursing tasks*										
Patient handover	290	100.0 (-)	NA	0.0 (-)	300	99.7 [92.9,100.0]	NA	0.3 [0.0, 7.1]	- 0.3	+0.3
Patient assessment before a shift	289	76.1 [11.3, 98.8]	NA	23.9 [1.2, 88.7]	300	96.0 [75.2, 99.5]	NA	4.0 [0.5, 24.8]	+19.9	-19.9
Hand washing	290	70.7 [11.3, 97.9]	NA	29.3 [2.1, 88.7]	296	79.4 [8.8, 99.4]	NA	20.6 [0.6, 91.2]	+8.7	-8.7
Checking incubator settings	32	46.9 [2.3, 97.1]	34.4 [1.9, 93.5]	18.8 [1.3, 79.7]	48	62.5 [1.7, 99.4]	4.2 [0.2, 46.1]	33.3 [0.7, 97.3]	+15.6	+14.5
Patient communication	289	42.2 [7.5, 86.8]	NA	57.8 [13.2, 92.5]	294	51.4 [12.5, 88.7]	NA	48.6 [11.3, 87.5]	+9.2	-9.2
Measuring pulse oximetry	290	22.4 [15.2, 31.6]	37.3 [5.1, 86.9]	40.4 [5.3, 89.1]	295	21.4 [1.9, 79.4]	41.7 [6.3, 88.4]	36.9 [2.7, 92.4]	-1.0	-3.5
Measuring pulse rate	290	16.6 [5.2, 41.9]	50.0 [7.4, 92.6]	33.4 [3.9, 86.0]	300	21.0 [1.7, 80.3]	44.7 [6.0, 91.1]	34.3 [2.1, 92.7]	+4.4	+0.9
Measuring respiratory rate	290	15.9 [5.2, 39.5]	39.3 [6.2, 86.4]	44.8 [14.2, 79.9]	299	19.1 [1.2, 82.6]	30.8 [4.2, 81.9]	50.2 [7.3, 92.8]	+3.2	+5.4
Measuring temperature	290	14.8 [3.9, 42.8]	54.8 [18.4, 86.7]	30.3 [6.3, 73.8]	300	19.3 [2.4, 69.7]	41.0 [4.5, 91.1]	39.7 [3.4, 92.4]	+4.5	+9.4
Ward round attendance	83	14.5 [10.9, 18.9]	NA	85.5 [81.1, 89.1]	55	25.5 [3.8, 74.6]	NA	74.5 [25.4, 96.2]	+11.0	-11.0

*-Highest priority tasks in the pre-intervention period

Prioritised nurse-delivered care was compared between the pre-intervention and post-intervention periods using patient aggregate scores (Nursing Care Index).

Figure 5.4 compares patient aggregate scores for prioritised nursing tasks (using the ten most prioritised tasks) across pre-intervention and post-intervention periods. The median proportion of these tasks performed in the post-intervention period (0.50, Figure 5.4) was higher than the pre-intervention period (0.39, Figure 5.4).

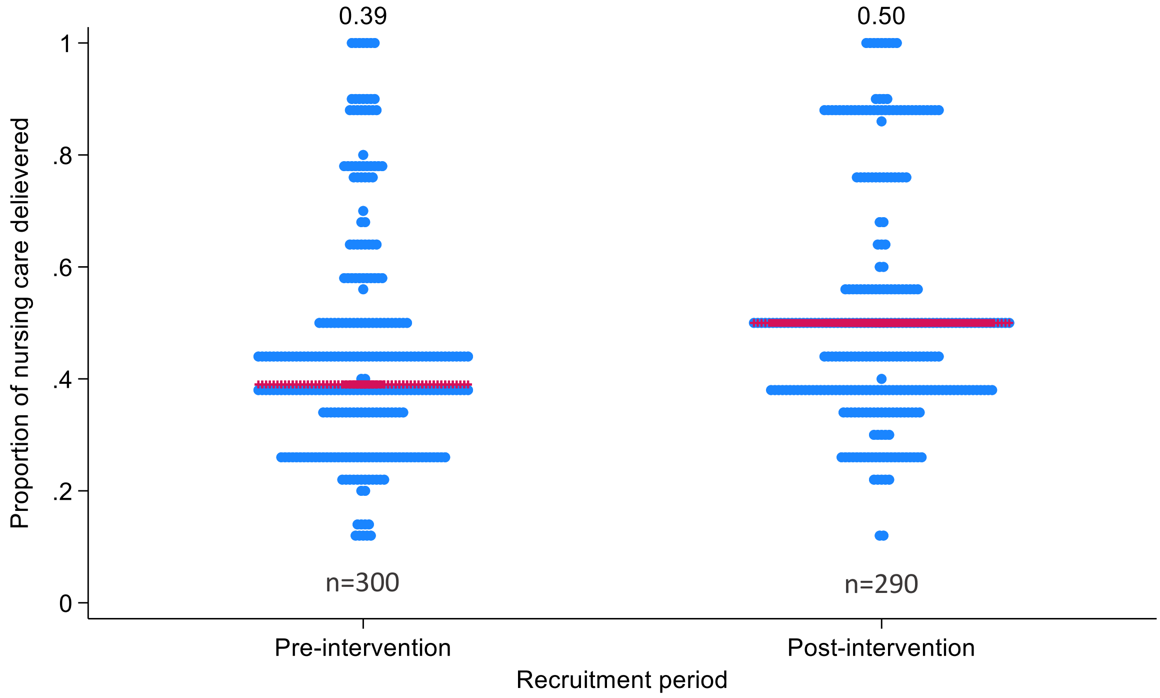

Figure 5.4– Dot plots comparing priority nursing care provision (pNCI) between pre- and post-intervention periods for recruited babies (n=590).

Red lines across the plot represent the median.

Legends above the graphs are median values.

Multilevel modelling of the effect of the nursing staff intervention on prioritised nursing tasks.

The nursing intervention resulted in a 5.9% increase in the delivery of prioritised nursing tasks (B-coefficient: 0.059, 95% CI: 0.011 to 0.107, Table 5.9). Model fit statistics for best-fit model selection are shown in Appendix 18.

Table 5.9 - Multilevel models comparing prioritised nursing tasks delivered between the pre-intervention and post-intervention periods for recruited babies (n=590).

Priority nursing care delivered	Unadjusted three-level random intercept	Best-fit model (adjusted model)
Recruitment period		
Post-intervention period	0.057 (0.005 – 0.110)	0.059 (0.011 to 0.107)
Pre-intervention period	Reference	Reference
Patient category		
Category A		Reference
Category B		-0.151 (-0.204 to -0.099)
Category C		-0.133 (-0.188 to -0.079)

5.5 Discussions

5.5.1 Summary of findings

In this chapter, I examined the effect of a modest increase in the number of ward nurses (the addition of three extra nurses) on indicators of the quality of newborn care in Kenyan neonatal units. As indicators of quality care, I use three proxy measures of nursing care delivery – nurse-delivered care (nNCI), which measures all nursing care that nurses specifically deliver to babies; nurse-delivered care on a subset of nursing tasks that are prioritised by nurses (pNCI) and nursing care provided by anyone (nurses, students and mothers, aNCI).

5.5.2 Effect of the intervention on nurse-delivered care

In the context of limited staffing and wider resource constraints, this study found that the nursing workforce intervention, which increased shift-level nursing time by about 28.5%, led to a 4.2% increase in overall nurse-delivered care (patient-facing nursing tasks) in models adjusting for the effect of clustering and potential confounders. This builds on the analysis in Chapter 4, which shows that increasing nurse staffing is likely associated with increased nurse-delivered care. This is also consistent with the existing literature on the positive impact of increasing nurse staffing on care delivery and patient care outcomes (111,223). My intervention design, which evaluates an intentional change in nurse staffing numbers, further builds on earlier work, which has come from largely observational studies (11,74,75,77,196). Although the nursing workforce intervention in this study increased nurse-delivered care, the observed increase was small (4.2%). This is likely linked to the small change observed in nursing hours per patient per 12-hour shift (the effective dose of the intervention) when considering the absolute change value (9.6 minutes per patient). One explanation for this is that the intervention was underdosed, and a considerable change at the shift level will likely require a much higher dosage of nurse staffing than adding three nurses. As shown in my exploratory analysis from the previous chapter (Chapter 4), the likely effect of a nurse staffing increase on care delivery depends highly on the dosage of additional nurses.

5.5.3 Impact of norms on nurse workforce intervention

In contrast to the nNCI measuring nurse-delivered, the pNCI, which was based on a subset of the ten most frequently carried out nursing tasks in the pre-intervention period, suggested a greater effect of the intervention (5.9% improvement in pNCI compared to 4.2% for the nNCI). This finding implies that the intervention resulted in nurses doing more of the tasks that they felt were of greater importance, further underpinning the strong impact of norms and informal systems within the neonatal units. This was further supported when I disaggregated the data and examined individual tasks. I observed that nursing tasks that nurses least prioritised during the pre-intervention period remained so after the intervention. For example, the proportion of babies with the top 5 most deprioritised nursing tasks (cord care, nasogastric tube feeding, cleaning of babies, changing diapers and linen change) did not change at all or only changed by less than 1%. In contrast, prioritised nursing tasks showed more significant changes, with four of the top five most prioritised nursing tasks experiencing a significant increase in the proportion of babies who had these tasks undertaken by a nurse. This depicts the deep rootedness of norms in the study context and might imply that the provision of holistic nursing care is likely to lag any nurse staffing investments.

5.5.4 Effect of the intervention on all nursing care

This study found no effect of the intervention on nursing care provided by anyone (aNCI). Therefore, the intervention did not indirectly affect increasing the volume of care provided by others. This might be explained by role transfer between student nurses and nurses. The disaggregated data showed a shift in care following the intervention rather than an overall increase in care provision. Nurses took back nursing care from nursing students and/or provided more nursing student supervision. For example, while the proportion of babies who had most of their vital signs measured by a nurse increased, the proportion of those conducted by unsupervised nursing students declined. This buttresses the point that using unsupervised nursing students as workforce support is likely a maladaptation to chronic understaffing in these neonatal units. The current Kenyan task-shifting strategy does not recognise any formal (or legal) role for unsupervised nursing students in neonatal care or any other hospital care (224). It is perhaps worth noting that nursing students may spend only between 2 to 6 weeks on neonatal units in their entire training in Kenya and that a single neonatal unit might be linked to more than one nurse training institution, thereby receiving students on clinical attachment at different times of the year.

As mentioned in Chapter 2, from the beginning of the HIGH-Q study, the programme had advocated for counties to retain the added nurses long term following expiration of their study contracts and signed a Memorandum of Understanding for counties to do their best to honour this in principle. Following the completion of the intervention, one of the four intervention counties retained two out of the three addition nurses following a recruitment process.

Additionally, an objective of the HIGH-Q programme is conducting an economic evaluation of the workforce intervention (see Chapter 2). This is a crucially important not only to support advocacy efforts but also to provide cost-benefit justifications for additional neonatal nurse staffing, particularly in a resource-constrained setting such as Kenya where there are multiple healthcare demands on a limited health budget. Such cost-benefit analyses are also likely to be important for other resource-constrained LMIC settings attempting to increase neonatal nurse staffing.

5.6 Strengths and limitations.

One strength of the study was the use of multilevel modelling, which adjusted for clustering and common confounders, such as patient case mix and shift timings. This study also used an objective assessment of real-time nurse-delivered care using direct observations of patient care provision; previous research in this area has largely relied on subjective nurse self-reports of care they had missed in their previous shifts (96) (111).

One limitation of this study was the absence of a control group to serve as a counterfactual. Not having a control group was linked to study budgetary constraints and the ethics of having a control group for a likely beneficial intervention such as nurse staffing increase.

The data presented in this study is derived from repeated cross-sectional data collection across the recruitment periods. The implication is that the data represents multiple snapshots and does not examine the effect of longitudinal changes across the intervention. Although post-intervention assessments were conducted six months after the intervention (when it was thought that the added nurses would be fully integrated), I might have found a different result if an assessment had been carried out, for example, at three or nine months.

I also did not take data on who conducted tasks in the pre-intervention period for key nursing tasks, for example, Intravenous medication administration, so I could only add this variable to the index that considered care provision for everyone but not to nurse-delivered care.

5.7 Conclusion

While the original intention in the addition of three nurses by the parent project (the HIGH programme) was to trial an intervention with a nursing number that might be feasible for an under-resourced government to employ, the evidence in this study suggests that considerable nurse staffing investments may be required to achieve high-quality neonatal care. Such investments in the nursing workforce would need to be holistic, targeting hospital facilities rather than specific units, as pressures from one part of the system will likely affect the balance in other parts (I explore this in the next chapter, Chapter 6). They might also need to involve other members of the health workforce other than nurses. A broader question is linked to who pays for such workforce expansions in a setting with resource constraints and multiple competing demands (noting that the NEST-360° programme is making important investments in technology, training, and quality improvement). Having less expensive nursing assistants has been suggested previously and employed in high-income countries. This should, however, be considered in addition to existing nurses rather than as a replacement for nurses, as data and research from high-income countries suggest that replacing nurses results in poor-quality care. The role and effect of such nursing assistants would need to be studied in resource-constrained settings, which is already a separate focus of the parent HIGH-Q research programme.

Chapter 6- Fidelity evaluation of the nursing workforce intervention

6.1 Background

In the previous chapter (Chapter 5), I observed a small effect of the intervention on nurse-delivered care (a 4.2% increase in the post-intervention period relative to the pre-intervention period). I also introduced the concept that the nursing workforce intervention was deployed pragmatically. In each intervention neonatal unit, nursing and hospital managers were given autonomy to allocate the additional nurses they received to increase shift-level nurse staffing in a manner they deemed fit. These managers were sensitised about the study's goals, and their buy-in into the project was sought. Such a pragmatic approach to the study's implementation likely mirrors what would occur in a real-world environment where additional new nursing staff were posted to neonatal units.

Recognising the complexity of this research and appreciating that nursing managers in each of the four neonatal units were likely to implement the nurse workforce intervention in different ways, it was essential to measure the fidelity of the intervention, i.e., how the intervention's uptake varied across the neonatal units (225). This is a crucial part of the process evaluation of any intervention, and it is vital to improving the understanding and replicability of the study findings (225–227).

This chapter thus focuses on my measurement of intervention fidelity as a possible explanation for the intervention's observed effect on nurse-delivered care in Chapter 5.

6.2 Methods

6.2.1 Study setting.

This study was conducted in the four intervention neonatal units. Within these units, neonatal nursing managers plan for shift-level nurse staffing in the months preceding a work month. They usually produce paper-based rotas detailing nurses' monthly work plans and indicating those on leave or away from the neonatal unit for other reasons. Figure 6.1 shows an anonymised version of one of the neonatal unit rotas.

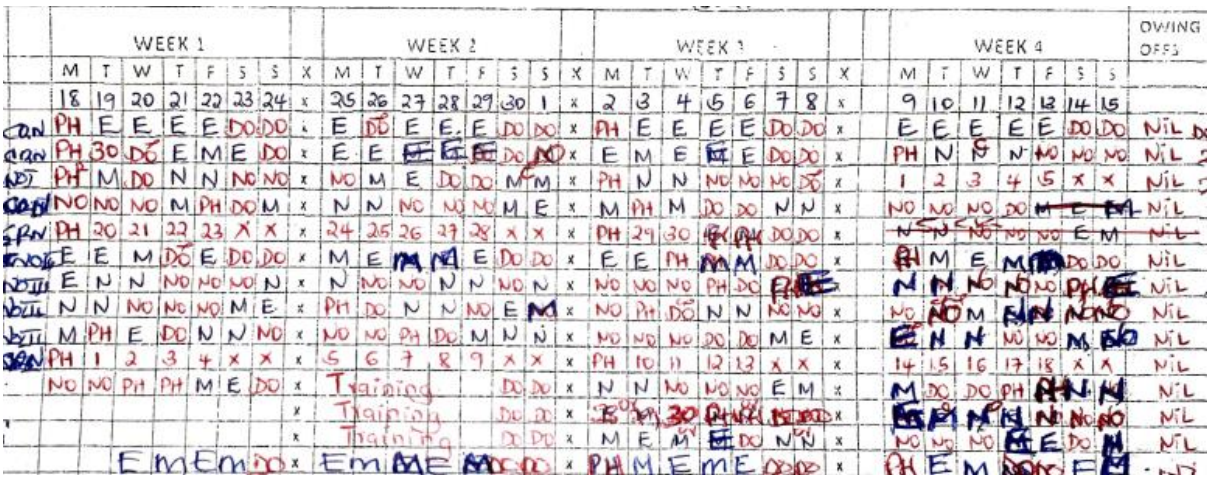

Figure 6.1– Anonymised paper-based example of a neonatal unit nursing rota.

PH – Public holiday, E- evening shift, M- Morning shift, N- Night shift, D0 – Day off, NO – Night off, numbers -1,2,3… (Nurse on leave)

6.2.2 Fidelity measures

Central to my logic model described in 2.4.3, I proposed that increasing nursing numbers will lead to increased nursing time available for patient care and ultimately increased nursing care delivery. Thus, nursing care time was central to my hypothesis as it is expected to mediate the intervention's effects on nurse-delivered care and care provision in general. In theory, increased intervention uptake will likely lead to increased nurse shift-level presence and, therefore, an increase in the nursing time available for patient care. In Chapter 3A, following my umbrella review, I identified two nurse staffing metrics that I adapted to measure intervention fidelity in this chapter (see Table 3.3).

These are the total nursing hours per day and nursing hours per patient per day (NHPPD). The definitions of these variables and the source of data to derive them are summarised in Table 6.1

Table 6.1– Definitions of the various intervention fidelity variables used in the analysis.

Fidelity nomenclature	Definition	Data sources
Total nursing hours per day	Total planned nursing hours (nursing care allocated on nursing rotas) per 24 hours	Paper nursing rotas
Nursing hours per patient day	Total planned nursing hours (nursing care allocated on nursing rotas) per 24 hours / Total number of patients admitted in the same 24-hour period.	Paper nursing rotas Patient numbers from daily bed returns*

*—These are daily data on bed occupancy and the number of patients resident in the neonatal ward. They are usually collated daily and reported to the hospital bed manager.

6.2.2.1 Collection of data for fidelity

We collected nursing rota data and daily bed returns (neonatal admission headcount) from each intervention neonatal unit between October 2021 and December 2022. This period was at least six months before the HIGH-Q workforce intervention and six months after. The HIGH-Q programme intervened in the first week of May 2022 by adding extra nurses to the four intervention units simultaneously. The intervention period was preceded by primary data collection of nursing care data (between February and March 2022) using the structured observational checklist (described in Chapters 2.4.4) and followed by a repeat evaluation of the intervention's impact using the same checklist six months after the intervention (between November and December 2022). Following the workforce intervention, the team continuously collected data from each neonatal unit on nurse staffing transfers, retirements and other significant events affecting the neonatal unit nurse work schedule. The nursing rotas also provided information on staff on annual or prolonged leave, such as maternity leave.

One of the research officers and I entered details from the nursing rotas and daily bed returns into an Excel sheet, which I exported into STATA for analysis. Details entered included hospital name, year, month and day of each shift, number of nurses in the neonatal unit, number of nurses rostered to be on each shift, number of nurses on any form of leave and details of the daily bed returns. I conducted random crosschecks of this data from the source document to ensure accuracy and used descriptive statistics to observe for any outliers. When I noted any outliers, we (the research officer and I) revisited the primary data source to crosscheck this.

6.2.2.2 Fidelity variable derivation

In this subsection, I discuss how I practically derive the two fidelity variables – total nursing hours per day and the nursing hours per patient day (NHPPD). To determine the total nursing hours per day from the nursing rota, I summed up all hours contributed by individual nurses on a particular day. For example, if five nurses were rostered on a particular day (two on the night shift and three on various shifts during the day), the individual hours contributed by each nurse within the 24 hours were summed up across both night and day. Thus, the time contribution of a nurse was equivalent to the individual length of shift the nurse was to attend and was unique to the specific neonatal unit shift pattern.

The NHPPD was derived by dividing total nursing hours per day by the number of patients on admission (derived from neonatal unit daily bed returns, which are reported daily by each neonatal unit after considering both discharges and admission for the particular day). In contrast to the total nursing hours per 12-hour shift and nursing hours per patient per 12-hour shift employed in Chapters 4 and 5, which were based on a standard 12-hour shift, the total nursing hours per day and the NHPPD are based on 24 hours. Because the total nursing hours per day and NHPPD aggregate nursing hours on a 24-hour rota schedule, they are not influenced by variations in shift patterns across specific hospitals or data periods. However, two underlying assumptions are implicit to these metrics: that nurses turn up and stay on their shifts for the period they were meant to work and that all nursing time is used for patient care.

6.2.2.3 Fidelity evaluation design.

I used interrupted time series analysis (ITS) to explore the intervention's effect on nurse staffing. ITS is used to evaluate the impact of an intervention, policy change, or quality improvement program on repeated observations of a specific event collected over time (230). The data used in this chapter consisted of day-to-day unit-level nurse staffing available over time from nursing rotas, and the date of the workforce intervention was distinct, making it suitable for ITS analysis.

I used ITS analysis to examine changes in the total nursing hours per day and NHPPD across pre- and post-intervention periods. Pre-intervention periods in my ITS analysis were all data points before the intervention, while post-intervention periods were data points after the intervention. These are distinctly different from pre- or post-intervention primary data collection periods using the structured checklist, which essentially involved bedside observations for six-week periods (referred to in Chapter 5). Therefore, primary data collection periods were specific time points in both pre-and post-intervention periods described in the ITS analysis. I distinguish between both these terms in subsequent sections, using the term primary data collection when specifically referring to the bedside observation period.

For my ITS analysis, the total nursing hours per day measures planned shift-level nursing change without considering variations in patient numbers at the ward level. It is thus less influenced by a change in patient load and is thus more reflective of a change in nursing input at the unit level. The NHPPD, on the other hand, is likely to fluctuate depending on changes in patient numbers but can, however, be seen as the effective dose of the intervention at unit level.

6.2.3 Data analysis

6.2.3.1 Descriptive statistics

I report median available nurse staffing numbers before and after the intervention using staffing data from the paper nursing rotas. Available nurse staffing was defined as the actual number of nurses available for work at a particular period, and I derived this by subtracting the number of nurses that were on any form of leave (terminal, annual, maternity and prolonged sick leave) from the number of nurses on the neonatal unit. I also show a timeline of significant events (any event outside of annual leaves) that might have affected nurse staffing.

To visually examine changes in planned nursing time, I plot descriptive time series line graphs of the two nurse staffing metrics - total nursing hours per day and NHHPD. I do this for all the combined data and each neonatal unit. In each of these plots, I plot actual week-to-week changes using daily data to calculate a 7-day average, thereby reducing fluctuations due to lower weekend staffing. I also plot additional line graphs using a 9-point moving average. This was chosen over a 5-point or 7-point moving average as it allowed for smoother graphs, reducing data fluctuations and allowing for better observation of trends. The 9-point moving average uses data from the preceding and subsequent four weeks to calculate the value of each week (creating a rolling average across the time series). The downside is that it also borrows data from before and after the intervention around the intervention point. Alongside these trends, I have also displayed data from the raw time series that did not include any week-to-week averaging, so actual weekly changes in the nursing metrics over time could also be observed. In each of these graphs, I also clearly indicate the intervention period and primary observation of care data collection period before and after the intervention.

6.2.3.2 Interrupted time series (ITS) analysis.

My ITS analysis assesses whether adding extra nurses to the intervention neonatal units resulted in an immediate change in planned shift-level nurse staffing (level change) sustained over time (ITS trend). Figure 6.2 provides a graphical depiction of the level and trend change associated with ITS analysis. For analytic purposes, nurse staffing data before the 1st week of May 2022 (when the new nurses reported to the unit) was recognised as pre-intervention and data after were identified as post-intervention.

For my primary analysis, I model daily nurse staffing data using Stata's 'itsa' command. The *'itsa'* uses segmented linear regression to model data and estimates the B-coefficients of the linear regression using the ordinary least square (OLS) approach (228). The following equation was used to specify the ITS model (228) –

$$Y_t = \beta_0 + \beta_1 * time_t + \beta_2 * Nursing\ workforce\ intervention_t + \beta_3 * time\ after\ intervention + e_t$$

Where Yt (The dependent variable) is the nurse staffing metric – total nursing hours per day or nursing hours per patient day (Figure 6.2), the independent variables included time as a continuous indicator of time in weeks from October 2021, the nursing workforce intervention which was the treatment variable coded as nursing workforce intervention, equal to 0 for dates before the intervention and equal to 1 for the periods after the intervention. B_0 estimates the baseline nurse staffing level in the specified model at time zero, while β_1 estimates the weekly change in nurse staffing metrics pre-intervention, i.e., the pre-existing trend in planned shift-level nurse staffing (Figure 6.2). β_2 estimates the immediate (level) change in planned shift-level nurse staffing in the immediate post-intervention period (Figure 6.2). β_3 estimates the change in planned shift-level nurse staffing trend in the post-intervention compared with the pre-intervention trend (Figure 6.2). The error term, e_t, represents the random variability at time t.

I report β-coefficients and the corresponding 95% confidence interval for each of the three parameters - β_1, β_2 and β_3. A β coefficient was deemed significant when its 95% confidence interval did not cross 0.

I carried out two primary ITS analyses. In the first analysis, I used the combined data for all neonatal units to examine the overall intervention effect on unit-level nurse staffing. I then conducted further analyses on individual intervention neonatal units to examine for any variations in intervention fidelity.

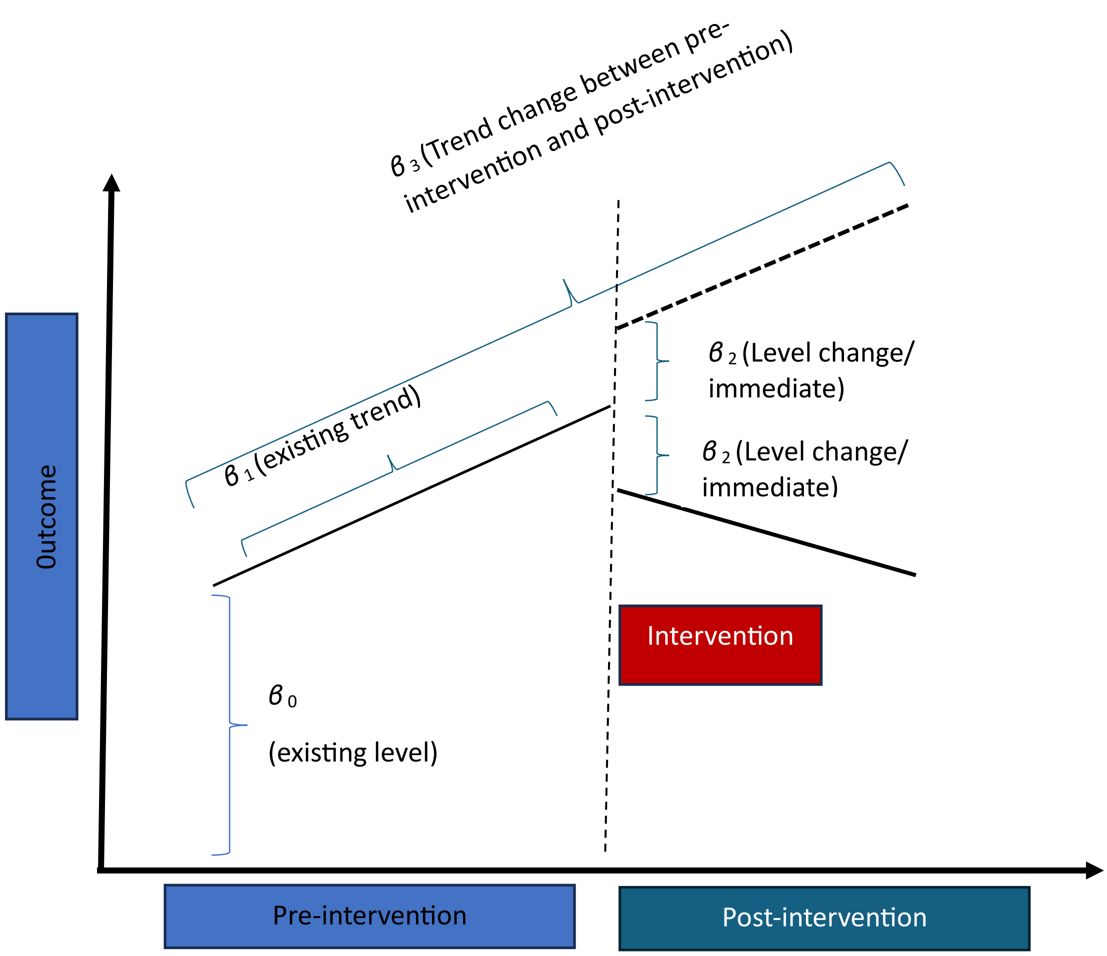

Figure 6.2– Diagram explaining interrupted time series and meaning of β-coefficients.

6.3 Results

6.3.1 Changes in nurse staffing across intervention units.

Across the four intervention neonatal units, H1 had the highest baseline nurse staffing with 17 nurses, while H3 had the least with eight nurses (Table 6.2). The median number of nurses available for work on the nursing rotas (i.e. not on any form of leave and not transferred) changed the least from the pre-intervention to the post-intervention period in H1 and H2. H2 was also the neonatal unit that had the most nurses on leave at any point in the post-intervention period (Figure 6.3). It was one of two units (including H1) where the number of nurses on leave during the post-intervention primary data collection period had not returned to pre-intervention levels (Figure 6.3). Overall, on average, more nurses were on leave following the intervention compared to the period before the intervention across all four neonatal units (Figure 6.3).

Table 6.2–Changes in nurse staffing numbers following the addition of extra nurses to the neonatal unit.

Neonatal units	Number of nurses in the neonatal unit before the intervention*	Median (IQR) available nurses' pre-intervention[&]	Predicted number of nurses after the intervention with three additional nurses**	Median (IQR) available nurses' post-intervention[&]
H1	11	11 (10 to 11)	14	12 (12 to 12)
H2	17	14 (14 to 15)	20	15 (15 to 16)
H3	8	7 (7 to 7)	11	9 (8 to 10)
H4	10	9 (8 to 9)	13	11 (10 to 12)

*- This is the number of nurses on the neonatal unit before the intervention was derived from baseline health facility assessments

& - Available nurses are those who are not on any form of leave and are available to be rostered for duty.

**This is the predicted number based on adding three extra nurses to the baseline neonatal nurse staffing

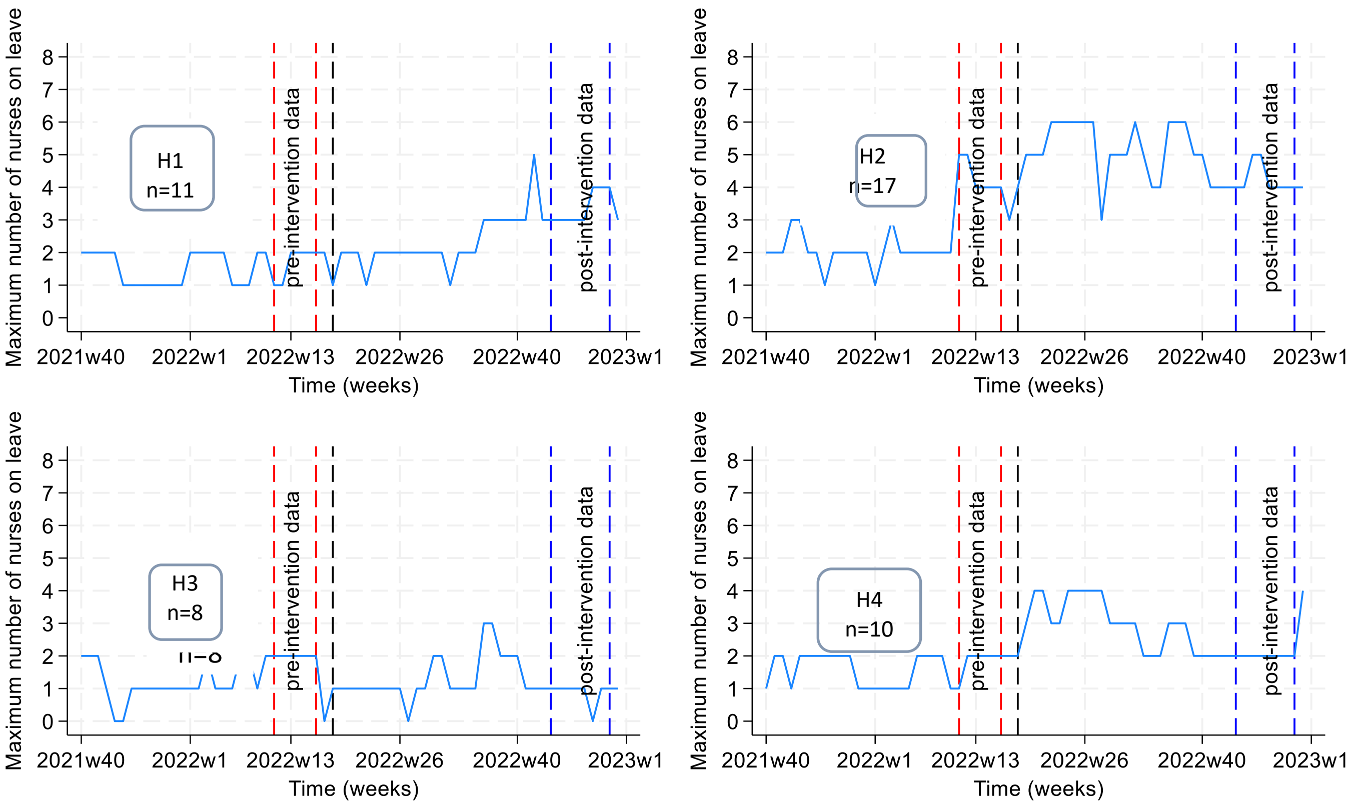

Figure 6.3– Line graphs showing week-to-week change in the maximum weekly number of nurses on any form of leave across the four intervention neonatal units.

The period between the vertical red dotted lines represents the pre-intervention observation of care primary data collection period. The vertical black dotted line represents the intervention week - 2022, week 18. The period between the blue dotted lines is the post-intervention observation of care primary data collection period.

H1 to H4 represent the individual neonatal units. The reported values within the boxes in the graphs are the number of nurses in the neonatal unit before the intervention.

6.3.2 Events related to nurse staffing affecting intervention fidelity.

Multiple staffing events (outside of nurses going on annual leave) affected nurse staffing levels following intervention across the neonatal units during the intervention period. Figure 6.4 provides a timeline of some of these events. One notable event was a change in nursing shift rotas from a 3-shift nursing rota to a 2-shift rota in H3. Other staffing events affecting shift-level nurse staffing were linked to increased nurses taking other forms of leave (maternity, pre-retirement and sick leave) and nurses being transferred away from the neonatal unit (Figure 6.4).

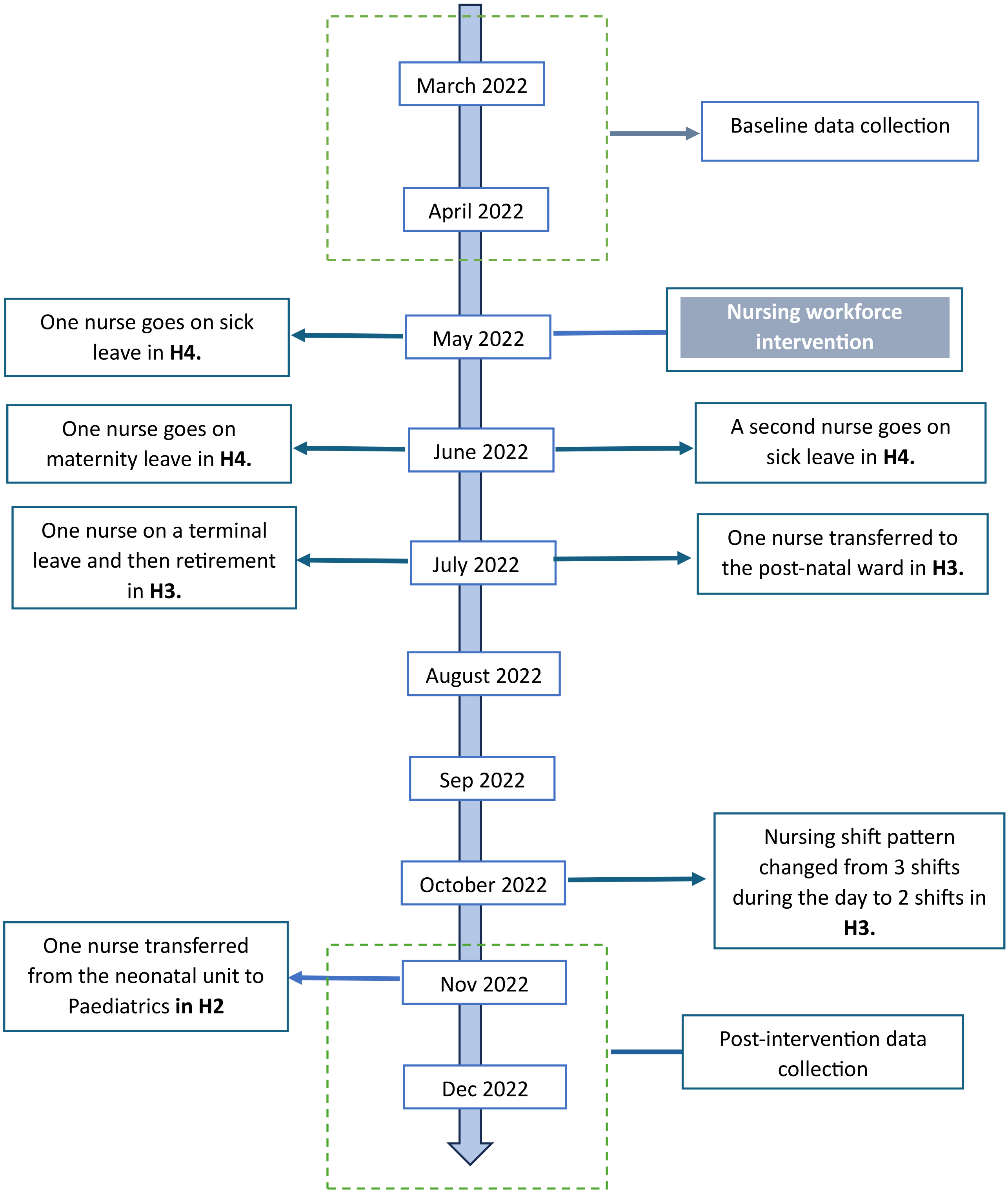

Figure 6.4– Timeline of significant nurse staffing events around the nursing workforce intervention.

6.3.3 Nursing staffing metrics (total nursing hours and NHPPD) compared between pre- and post-intervention.

Both total nursing hours per day and the nursing hours per patient per day (NHPPD) had skewed distributions (Figure 6.5 and Figure 6.6). Across all neonatal units combined, neither of the two metrics differed considerably between the pre-intervention and post-intervention periods (Table 6.4).

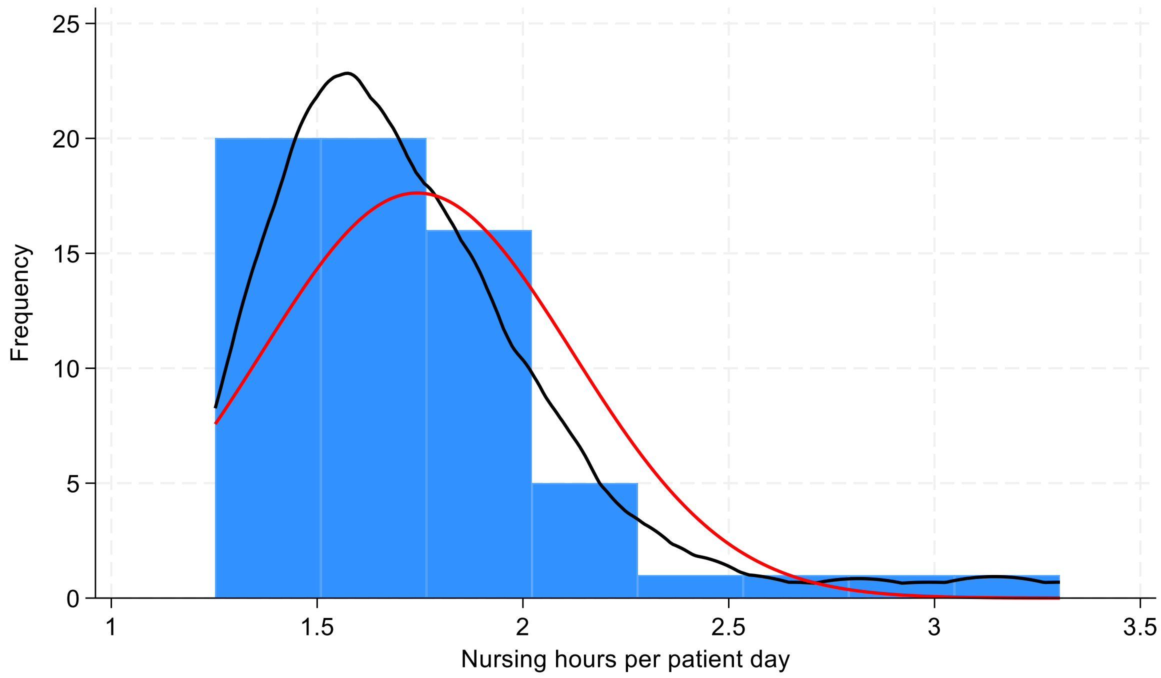

Figure 6.5– Plot showing histogram and kernel density plot (black) of nursing hours per patient day and a superimposed normal distribution plot (red).

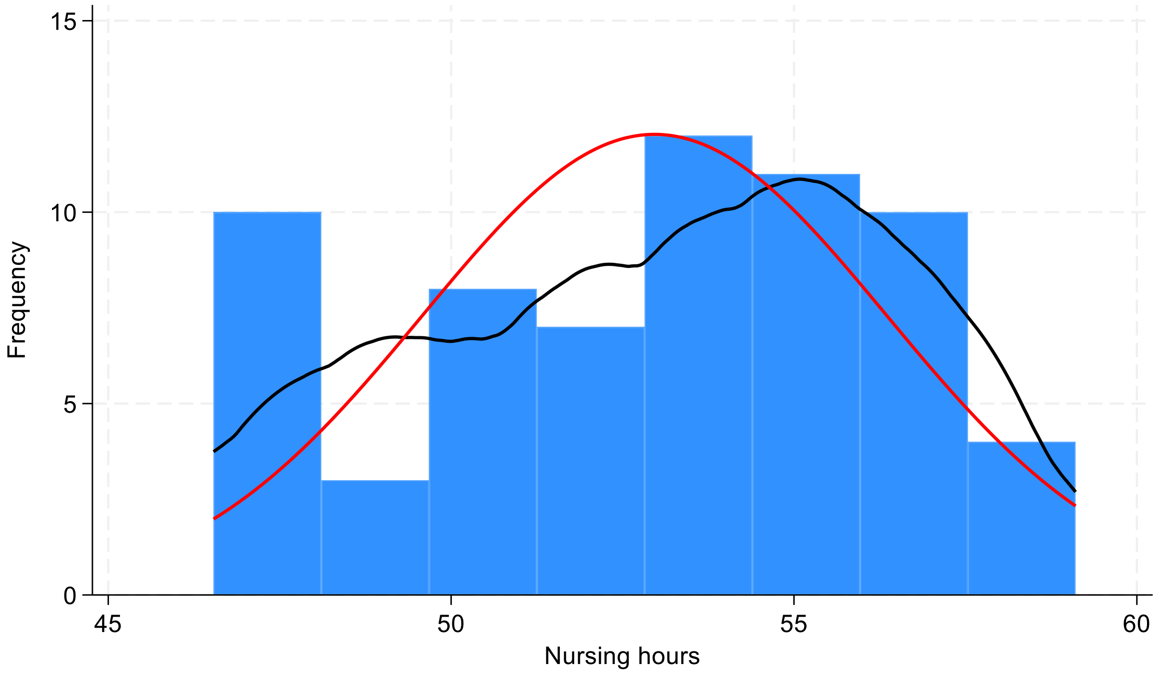

Figure 6.6– Plot showing histogram and kernel density plot (black) of total nursing hours per 24 hours and a superimposed normal distribution plot (red).

6.3.3.1 *Total nursing hours per day*

Examining individual neonatal units, the average total nursing hours per day changed differently across the neonatal units between the pre- and post-intervention periods (Table 6.3). The least absolute median difference was seen in H1 with 0.6 hours, and the greatest was seen in H3 with 11.0 hours (The change in H3 was a combination of the intervention effect but also a change in nurse staffing hours, which resulted in a move from a three-shift nursing structure to a two-shift structure).

6.3.3.2 *Nursing hours per patient day (NHPPD)*

The greatest change in NHPPD across pre- and post-intervention was seen in H4, with an absolute median difference of 0.67 hours per patient and a 34.1% change relative to the pre-intervention period (Table 6.3). The least change in this metric was seen in H2 (Absolute median difference of 0.04 and relative change in medians of 2.8%, Table 6.3)

Table 6.3 – Nurse staffing metrics compared in the pre- and post-intervention period.

Variable		Median (IQR) pre-intervention staffing (hours)	Median (IQR) post-intervention staffing (hours)	Absolute median difference (hours)	Relative change in medians (%)
Total nursing hours per 24-hour day	All neonatal units	49.8 (47.8 to 51.4)	55.8 (54.3 to 56.8)	6.0	12.0
	H1	57.6 (50.9 to 59.4)	60.9 (59.4 to 63.7)	3.3	5.7
	H2	63.1 (62.1 to 64.0)	63.7 (60.9 to 64.6)	0.6	0.9
	H3*	36.4 (33.1 to 39.6)	47.4 (45.1 to 50.0)	11.0	30.2
	H4	43.6 (41.0 to 47.2)	50.1 (47.4 to 53.4)	6.5	14.9
Nursing hours per patient per day	All neonatal units	1.48 (1.43 to 1.67)	1.79 (1.65 to 1.97)	0.31	20.9
	H1	1.00 (0.90 to 1.07)	1.04 (0.96 to 1.13)	0.04	4.0
	H2	1.44 (1.26 to 1.62)	1.48 (1.29 to 1.81)	0.04	2.8
	H3*	1.55 (1.34 to 1.81)	1.86 (1.49 to 2.59)	0.31	20.0
	H4	1.96 (1.69 to 2.29)	2.63 (2.30 to 2.90)	0.67	34.1

*The staffing change in H3 from 3 nursing shift rotas to 2 had an additional effect on the change in hours.

6.3.3.3 Change in weekly average unit-level nurse staffing metrics over time.

Figure 6.7 and Figure 6.8 depict time series line graphs showing weekly average changes in total nursing hours per day and nursing hours per patient per day (NHPPD) over time, while Figure 6.9 shows the weekly average change in the daily bed returns for the number of babies resident on the neonatal units. Narrow fluctuations were observed in both measured nursing metrics over time and across pre- and post-intervention periods (Figure 6.7 and Figure 6.8), the average total nursing hours per day ranged from 46.5 to 59.1 hours, while the average weekly NHPPD (a 24-hour measure of nursing time per patient) ranged from a nadir of 1.3 to a maximum of 3.30. Fluctuations in the number of admitted patients (Figure 6.9) across the entire data collection period were not matched with a change in total nursing hours (Figure 6.7).

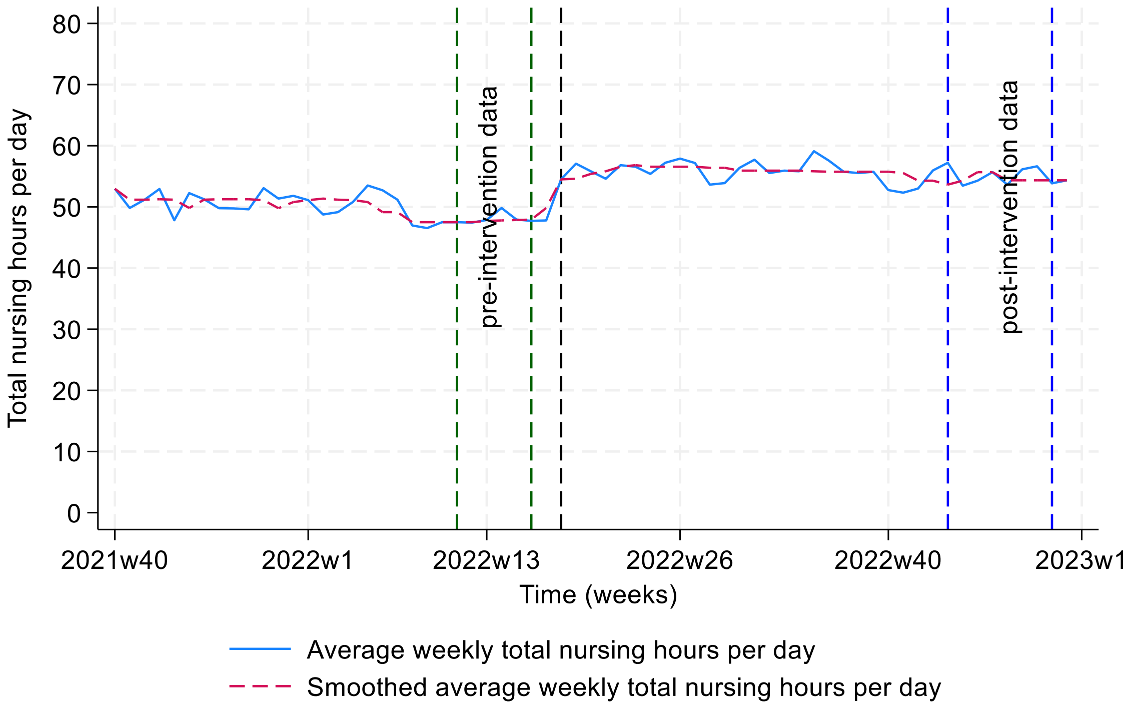

Figure 6.7– Time series line graph showing the change in weekly average total nursing hours per day (24 hours) before and after the workforce intervention plotted as actual weekly data points (blue line graph) and nine-week moving averages (dotted red line graph).

The period between the vertical dark green dotted lines represents the pre-intervention observation of care primary data collection period. The vertical black dotted line represents the intervention week - 2022, week 18. The period between the blue dotted lines is the post-intervention observation of care primary data collection period.

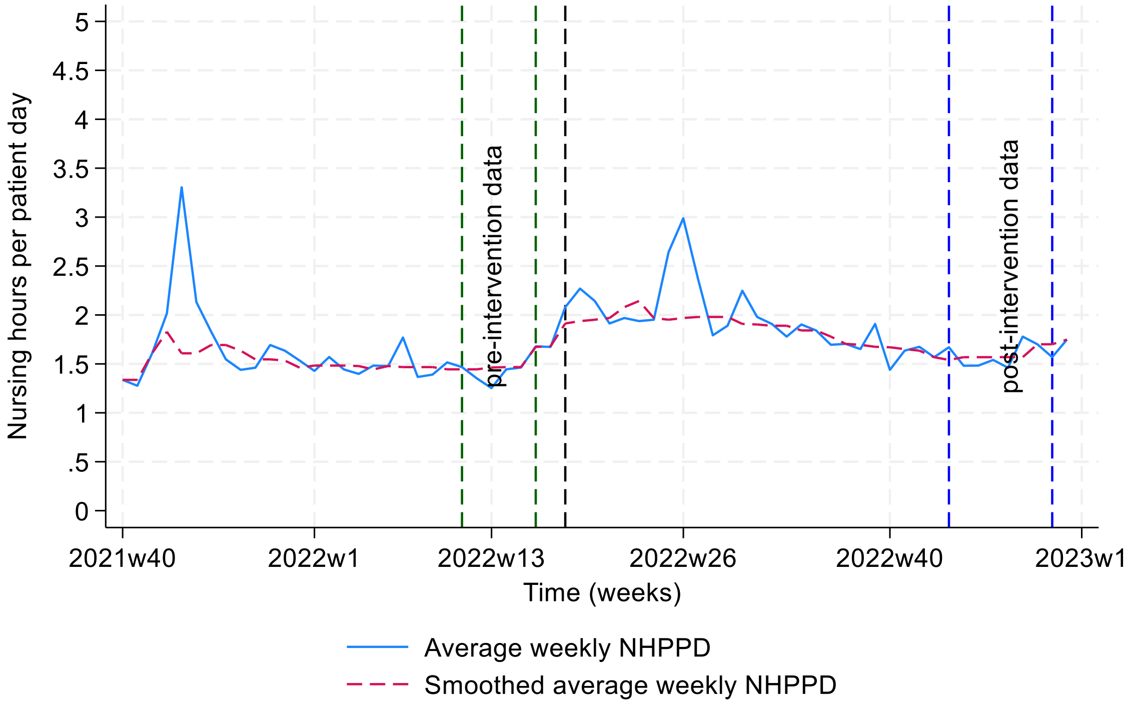

Figure 6.8– Time series line graph showing the change in Nursing hours per patient per day (NHPPD) before and after the workforce intervention plotted as actual weekly data points (blue line graph) and nine-week moving averages (dotted red line graph).

The period between the vertical dark-green dotted lines represents the pre-intervention data collection period. The vertical black dotted line represents the intervention week - 2022, week 18. The period between the blue dotted lines is the post-intervention data collection period.

The spike in the pre-intervention period is linked to a drop in patient numbers in one of the neonatal units due to COVID-19, while the smaller spike in the post-intervention period is linked to a drop in neonatal admissions.

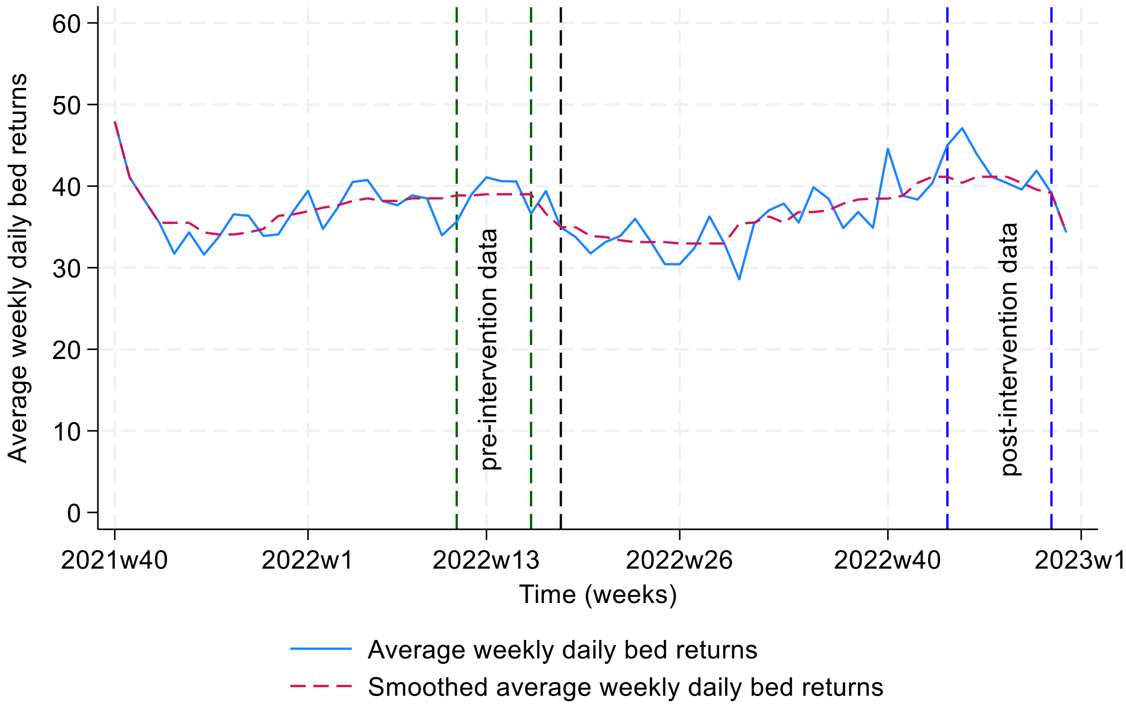

Figure 6.9– Time series line graph showing the change in weekly average daily bed returns (number of babies admitted in all neonatal units) before and after the workforce intervention plotted as actual weekly data points (blue line graph) and nine-week moving averages (dotted red line graph).

The period between the vertical dark green dotted lines represents the pre-intervention observation of care primary data collection period. The vertical black dotted line represents the intervention week - 2022, week 18. The period between the blue dotted lines is the post-intervention observation of care primary data collection period.

6.3.4 Interrupted time series analysis

Across all neonatal units combined, there was a small average week-to-week decline in planned total nursing hours per day before the nursing workforce intervention (β-coefficient: -0.14 (95% CI: - 0.20 to -0.08), p-value <0.001, Table 6.3) Immediately following the intervention, there was on average a statistically significant increase in planned pooled total nursing hours per day of about 8.62 hours (p<0.001, Table 6.4). Following this, there was a small week-to-week decline in planned nursing hours per day (β-coefficient: -0.05 (95% CI: - 0.09 to -0.005), p-value <0.03, Table 6.4). The trend for the interrupted time series from this analysis is visually presented in Figure 6.10.

Across individual neonatal units, the greatest level change was observed in H3 (the neonatal unit with the change in nursing shift structure), with an increase in planned total nursing hours per day of 16.5 hours (Table 6.4). This was followed closely by H1, which was about 12.9 hours per day. The least level change in planned total nursing hours was seen in H2 (0.29 hours), and this was not statistically significant (β-coefficient: 0.29 (95% CI: -2.20 to 2.78), p-value 0.82, Table 6.4). Across individual neonatal units, there was no statistically significant change in the post-intervention trend (Table 6.4). The individual neonatal unit interrupted time series are presented graphically in Figure 6.11.

Similar to the total nursing hour per day metric, across all neonatal units combined, there was a significant level change in NHPPD (β-coefficient: 0.86 (95% CI: 0.58 to 1.15), p-value <0.001, Table 6.5) followed by a statistically significant decline in the post-intervention trend (β-coefficient: -0.02 (95% CI: -0.03 to -0.01), p-value <0.001, Table 6.5). In contrast to the total nursing hours per day, the NHPPD is also sensitive to variation in patient volumes; for example, in Figure 6.8, spikes in the line graphs were seen as linked to low patient volumes. Time trends for the intervention effects on the NHPPD across all neonatal units combined and across individual neonatal units are shown in Figure 6.12 and Figure 6.13, respectively. These graphs show the output from Table 6.5.

Table 6.4– Results of times series analysis comparing intervention fidelity measured as total nursing hours across pre- and post-intervention periods.

	Total nursing hours	B-co-efficient	95% CI	P-value
All neonatal units combined	Pre-intervention trend	-0.14	-0.20 to -0.08	<0.001
	Immediate impact	8.62	7.21 to 10.03	<0.001
	Post-intervention trend	-0.05	-0.09 to -0.005	0.03
	Post-intervention trend compared to pre-intervention	0.09	0.01 to 0.16	0.02
H1	Pre-intervention trend	-0.47	-0.58 to -0.36	<0.001
	Immediate impact	12.89	10.12 to 15.65	<0.001
	Post-intervention trend	-0.02	-0.12 to 0.09	0.72
	Post-intervention trend compared to pre-intervention	0.45	0.30 to 0.60	<0.001
H2	Pre-intervention trend	-0.02	-0.08 to 0.04	0.48
	Immediate impact	0.29	-2.20 to 2.78	0.82
	Post-intervention trend	-0.001	-0.106 to 0.104	0.98
	Post-intervention trend compared to pre-intervention	0.02	-0.10 to 0.14	0.75
H3	Pre-intervention trend	-0.21	-0.38 to -0.04	0.01
	Immediate impact	16.49	12.91 to 20.08	<0.001
	Post-intervention trend	-0.13	-0.27 to 0.02	0.08
	Post-intervention trend compared to pre-intervention	0.08	-0.14 to 0.30	0.46
H4	Pre-intervention trend	0.15	0.02 to 0.28	0.02
	Immediate impact	4.81	1.49 to 8.13	0.005
	Post-intervention trend	-0.05	-0.18 to 0.08	0.45
	Post-intervention trend compared to pre-intervention	-0.20	-0.38 to -0.02	0.03

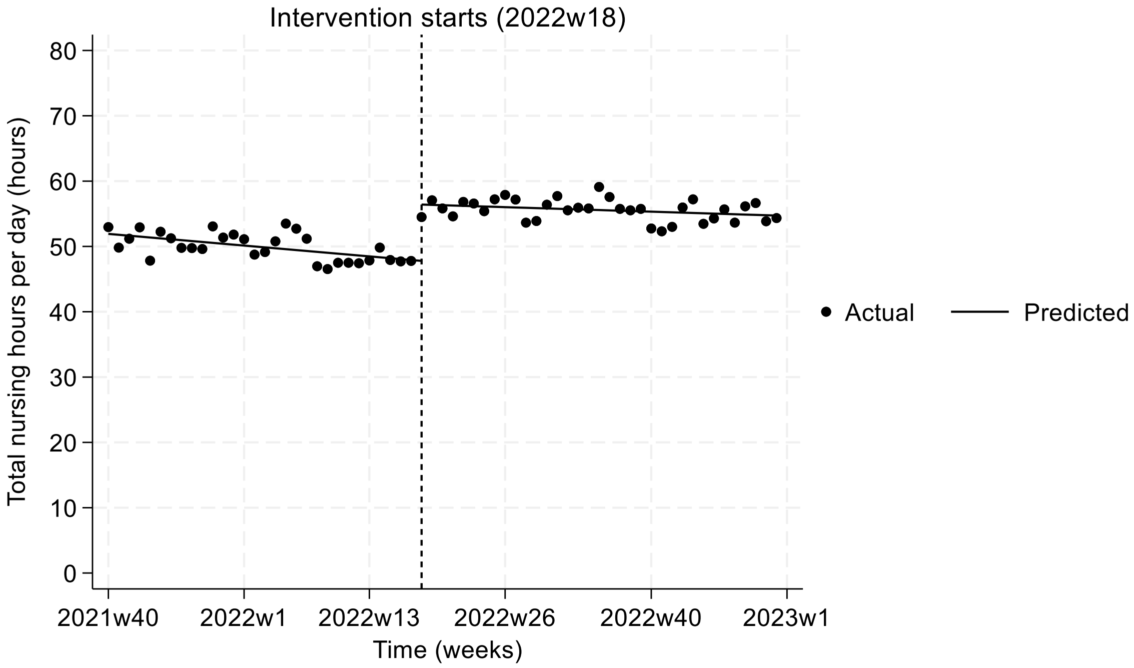

Figure 6.10– Effect of workforce intervention on planned nursing time measured as total nursing hours per day across all neonatal units and based on weekly averages.

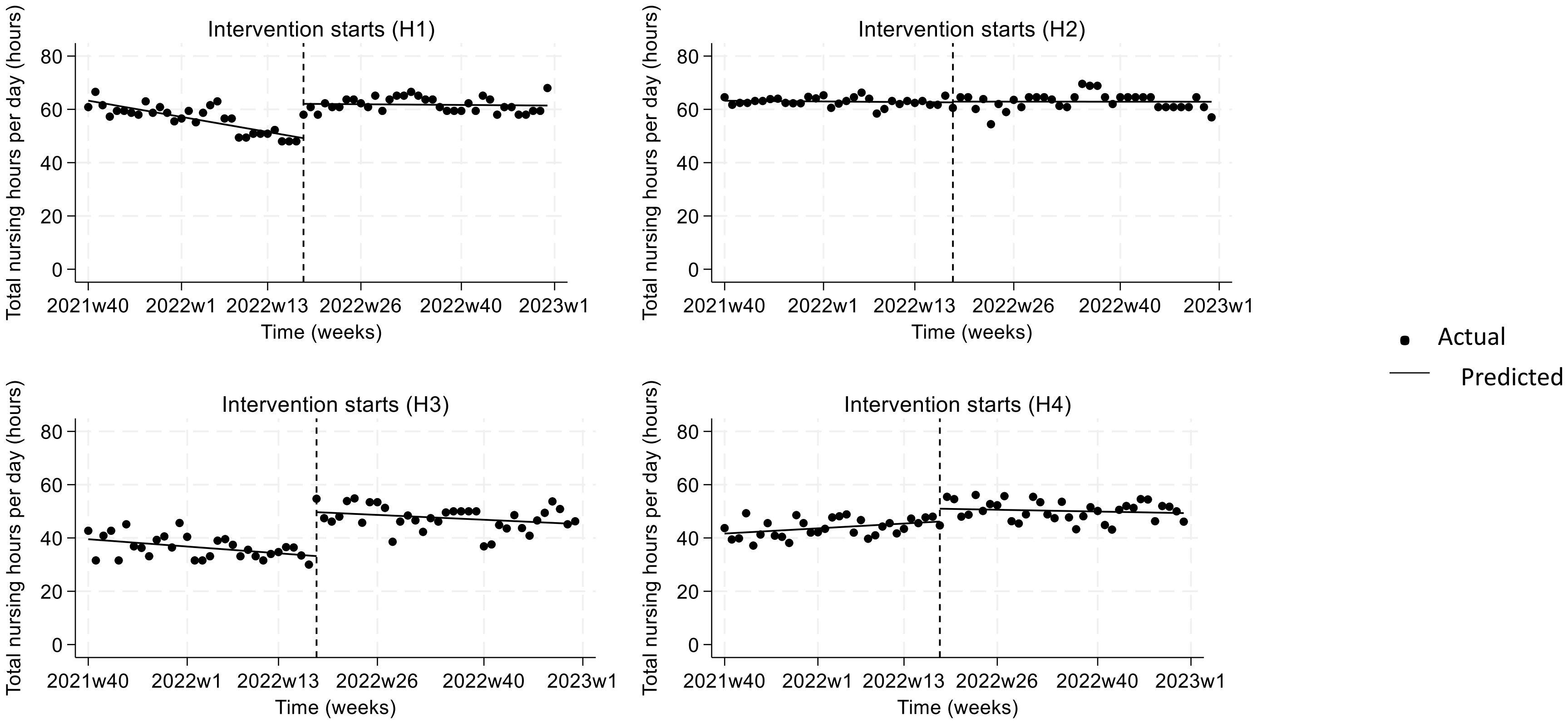

Figure 6.11- Effect of workforce intervention on planned nursing time measured as weekly average total nursing hours per day across individual neonatal units.

Intervention at 2022w18. H1 to H4 represent the individual neonatal units.

Table 6.5- Times series analysis comparing intervention fidelity measured as Nursing hours per patient day across pre- and post-intervention periods.

Neonatal units	Nursing hours per patient day	B-co-efficient	95% CI	P-value
All neonatal units combined	Pre-intervention trend	-0.01	-0.03 to 0.005	0.15
	Immediate impact	0.86	0.58 to 1.15	<0.001
	Post-intervention trend	-0.02	-0.03 to -0.01	<0.001
	Post-intervention trend compared to pre-intervention	-0.01	-0.03 to 0.01	0.43
H1	Pre-intervention trend	-0.007	-0.015 to 0.001	0.08
	Immediate impact	0.22	0.08 to 0.37	0.003
	Post-intervention trend	-0.003	-0.007 to 0.002	0.24
	Post-intervention trend compared to pre-intervention	0.004	-0.005 to 0.013	0.95
H2	Pre-intervention trend	-0.016	-0.023 to -0.008	<0.001
	Immediate impact	0.63	0.41 to 0.84	<0.001
	Post-intervention trend	-0.018	-0.026 to -0.009	<0.001
	Post-intervention trend compared to pre-intervention	-0.002	-0.014 to 0.009	0.72
H3	Pre-intervention trend	-0.057	-0.131 to 0.017	0.13
	Immediate impact	2.20	1.22 to 3.18	<0.001
	Post-intervention trend	-0.06	-0.09 to -0.04	<0.001
	Post-intervention trend compared to pre-intervention	-0.007	-0.085 to 0.072	0.87
H4	Pre-intervention trend	0.02	0.009 to 0.038	0.002
	Immediate impact	0.40	0.01 to 0.79	0.04
	Post-intervention trend	-0.005	-0.019 to 0.008	0.44
	Post-intervention trend compared to pre-intervention	-0.03	-0.05 to 0.01	0.005

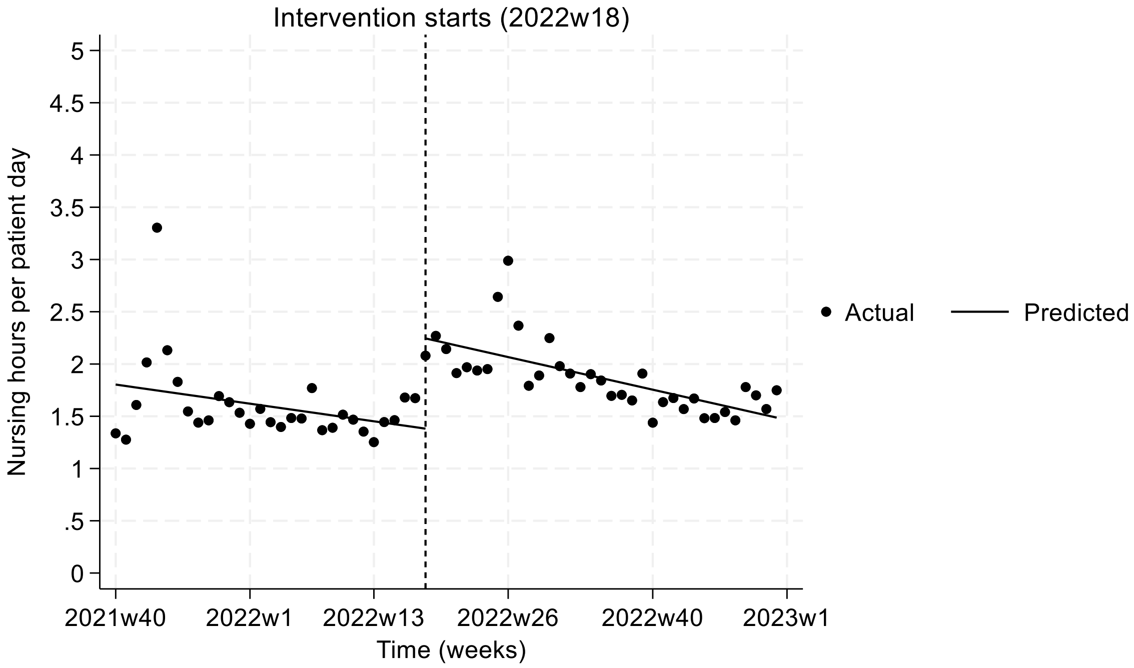

Figure 6.12– Effect of workforce intervention on planned nursing time measured as Nursing hours per patient per day across all neonatal units.

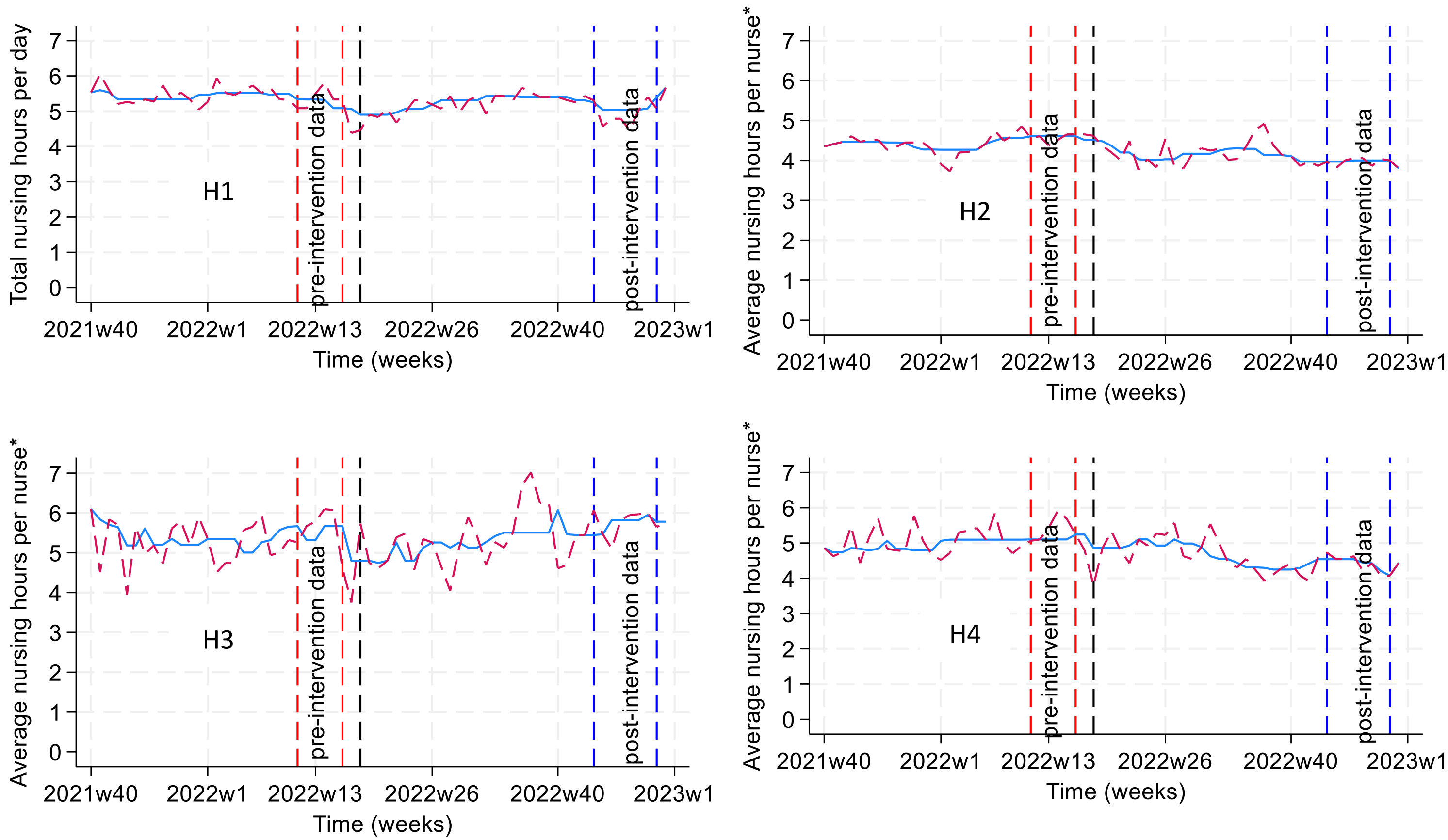

Figure 6.13–Time series line graph showing the change in nursing workload measured as average nursing hours per patient day plotted as actual weekly data points (blue line graph) and nine-week moving averages (dotted red line graph) across the four intervention units.

The period between the vertical red dotted lines represents the pre-intervention observation of care primary data collection period. The vertical black dotted line represents the intervention week - 2022, week 18. The period between the blue dotted lines is the post-intervention observation of care primary data collection period.

6.4 Discussions

6.4.1 Summary of findings

In the current chapter, I examined intervention fidelity across all the intervention neonatal units combined and in individual neonatal units to explain the observed effect in Chapter 5. Overall, the workforce intervention resulted in a moderate step change in available nursing time across all neonatal units, with some variation in the magnitude of change observed across individual units. Over time, there was also a slow and gradual waning of the intervention effect.

6.4.2 Intervention fidelity across time

A review of nurse staffing across the four neonatal units showed that average pre-intervention nursing staffing varied across the units, ranging from 8 to 17 staff nurses. This translated to a median total nursing hours per day and NHPPD of 49.8 hours and 1.48 hours, respectively, across the four intervention neonatal units combined in the pre-intervention period.

My interrupted time series analysis showed a moderate step change in average weekly total nursing hours per day (8.62 hours) following the workforce intervention. This value was less than was hoped for (8.62 is, for example, perhaps equivalent to having one additional nurse for one 8-hour shift in 24 hours). This was further exacerbated by a steady but slow fall in nursing hours over time. This was also observed with the NHPPD, which was affected by a rise in patient volume at the same time as there was a decline in nursing hours in the post-intervention period. Thus, the intervention did result in a moderate step change in both nursing metrics, but this was followed by a significant increase in staff who took some form of leave and a small but gradual attrition in nursing staff across most units. For example, in H2 and H3, nurses were transferred to support activities in other related departments, such as Paediatrics and the post-natal ward. These events were out of the control of the neonatal unit nursing managers as they were linked to pressures in other parts of the hospital. In some neonatal units, other unpredictable events such as retirements, sickness, and nurses going on maternity leave, occurred before the post-intervention primary data collection exercise (using the structured checklist) without these units replacing such nursing staff. These events led to declining nurse staffing numbers despite the HIGH-Q programme's best intentions of instituting multiple measures (signing a memorandum of understanding (MoU) and consistent hospital and neonatal unit engagement) to maintain the intervention fidelity.

Similar findings of difficulty sustaining Human Resources for Health interventions in high-work-pressure health systems have also been documented in an earlier study investigating the prospective addition of nursing assistants to a few units within a hospital setting (229). There is minimal research based on prospective intervention studies, such as the current workforce intervention study that could provide stronger evidence of the causal association between safe staffing and quality of care (79). My findings highlight the challenges with targeted prospective staffing interventions, particularly in high-pressure resource-constrained settings, where the influence of the external environment is likely to play an important role in the outcome of such interventions. They also underscore the need for whole-system improvement in staffing to prevent staff from being moved from the units to which they are deployed.

There was also an increase in the number of nurses who went on leave in the post-intervention period in some neonatal units. This was partly explained by nurses who had been owed accumulated leave being granted their leave after the extra nurses resumed. One emerging finding from a larger HIGH-Q programme process evaluation is that leave postponement was a coping strategy for some of the more short-staffed neonatal units to maintain staffing numbers in the pre-intervention period. This increase in the number of nurses on leave was recognised as a potential unintended consequence of the intervention in my logic model described in Chapter 2 (Methodology Chapter). To address this, I tailored the intervention to include signing an MoU, sensitising and engaging existing staff to get their buy-in and allowing them to see the current workforce enhancements as a new way of working differently from the previous, more limited nurse-to-staffing ratios (see 2.4.3). The larger HIGH-Q process evaluation is currently attempting to determine and evaluate what influenced nurse staffing decision-making and practice that can help explain further the challenges to intervention fidelity I document.

6.4.3 Differential fidelity across neonatal units

The uptake of the workforce intervention varied across neonatal units, which were measured using average weekly total nursing hours per day. While H1 and H3 had the greatest level changes of 12.9 and 16.5 nursing hours respectively, H2 had only a change of 0.29 nursing hours. Although part of the change in H3 is explained by a move from a three-shift to a two-shift nursing schedule, it is likely that neonatal unit norms of working with a specific number of nursing staff might have played out in the neonatal units and might explain some of the observed differences. For example, H2 consistently had many nurses on leave during the post-intervention period. Throughout the current thesis, the influence of norms has been prominent across the care nurses provide and is also likely to be crucial in how work is planned within the units. Improving staff-to-patient ratios in these settings might not necessarily mean only increasing the number of nurses but also encouraging work culture change so better staff-to-patient ratios are viewed as a norm. Alternatively, it is also feasible that delaying the post-intervention primary data collection period beyond six months might have allowed most of the staff accumulated leave to be taken and nursing staff to return to work before the data collection period. The data shows that the number of nurses on leave in H3 and H4 had returned to pre-intervention levels by the post-intervention primary data collection period but not in H1 and H2.

Differences in intervention fidelity linked to NHPPD (the effective dose of the intervention) across neonatal units were also linked to differential patient load. While H2 had a higher number of nurses and hence total nursing hours than H3 and H4, it was also a busy neonatal unit with a higher patient load. H2 thus had comparatively lower NHPPD than H3 and H4.

6.4.4 The relationship between intervention fidelity and newborn care quality.

In Chapter 5, I observed the workforce intervention, which added three extra nurses in each of the four intervention neonatal units, resulted in a small effect of the intervention on nurse-delivered care (4.2% increase). Central to my logic model described in Chapter 2, the intervention was likely to act by increasing available nursing time for patient care after adding extra nurses. My findings of limited uptake of the intervention linked to multiple earlier described events affecting neonatal unit nurse staffing provide some explanation of the observed change in care delivery.

6.4.5 Limitations

One limitation of this study is that I did not measure the nurse practice environment, i.e., overall local factors enabling or hampering nurses in delivering quality care, such as the leadership capacity or management styles of each neonatal nursing manager. Such differences might have provided an additional explanation for the variation in intervention uptake across the neonatal unit.

The time series analysis was based on planned staffing from neonatal unit rotas rather than actual staffing. While planned staffing might often equal actual staffing, there are occasional instances where these might differ due to last-minute changes in nursing rotas.

6.4.6 Conclusion

Despite the efforts to encourage intervention fidelity across the study units, implementation of the nursing workforce intervention was generally less than intended across all units, with initial observed changes that slowly waned over time. This partly explains the reduced effect of the intervention on nurse-delivered care and highlights the complexity that arises from conducting prospective workforce interventions. It also suggests that holistic staffing intervention at the hospital level rather than the unit level is required, as this will limit the impact of shortages in other parts of the hospital on staffing interventions.

Chapter 7- Discussion

This discussion chapter broadly synthesises research findings from my four results chapters (Chapters 3, 4, 5, and 6). I also discuss how my research links with the global evidence on nursing and quality of care, and I review the implications of my work for policy and practice. Additionally, I discuss the relevance of my work to the global agenda of reducing newborn mortality, and I conclude this chapter by discussing my research limitations and areas for future research.

7.1 Summary of key findings and comparison with global literature

In this thesis, I have described the evidence gaps for nurse staffing and quality of patient care using systematic literature reviews (Chapter 3). I also described nursing care provision in resource-constrained Kenyan newborn units (Chapter 4). In my later two results chapters (Chapters 5 and 6), I evaluate if and how a prospective workforce intervention to increase the number of neonatal unit nurses' results in improved quality of newborn care. The results of my thesis fall under three broad categories, which I discuss in the following subsections: (1) Examining existing evidence, (2) Nurse staffing and nursing care provision in resource-constrained Kenyan newborn units, (3) Evaluating a nursing workforce intervention to improve quality of newborn care.

7.2 Examining existing evidence for nurse staffing and quality of care in low-middle-income countries

My research underscores the crucial gap in understanding the relationship between nurse staffing and quality of care in LMICs. In Chapter 3A, my umbrella review revealed that a mere 6.6% of studies in previously published systematic reviews on this area of research were from LMICs, and these focused on a limited range of quality measures and were from mainly middle-income countries. My focused, systematic review of missed nursing care (care wholly or partially missed by nurses during the conduct of their duties) in LMICs, presented in Chapter 3B, highlighted a substantial proportion of nursing care being missed, with crucial factors including staff-to-patient ratios, nurse work environment, and nurses' sense of well-being and job satisfaction being linked with missed nursing care.

My literature review findings show an absence of evidence on the effect of nurse staffing on the quality of care in LMIC settings. They contribute significantly to knowledge as they highlight the critical evidence gaps on quality-of-care issues currently being ignored by global health researchers, for example, the relationship between nurse staffing and quality of care in LMICs. My findings agree with a previously published LMIC-focused systematic review on nurse staffing and quality of care by Assaye *et al.,* demonstrating a dearth of evidence and low-quality studies (230). My findings build on this earlier review by not only stating the absence of evidence but also going a step further to show the extent of the evidence gaps.

7.3 Nurse staffing and nursing care provision in resource-constrained newborn units

My research findings from Chapter 4 provide a comprehensive examination of ward-level neonatal nurse staffing and nursing care provision in resource-constrained newborn unit settings and link this to a multi-dimensional index comprising process indicators of quality of care: nurse-delivered care/ missed nursing care. In Chapter 4, I show extremely poor staffing levels at the neonatal unit level, with variations occurring across different county hospitals. Poor nurse staffing levels are not unique to only public sector neonatal care services in Kenya; they also happen in other departments and among other staffing cadres (231). It is also not peculiar to Kenya, as nurse staffing shortages have been described in other resource-constrained LMIC settings (2,150,232). A survey of 68 neonatal units across Nigeria, Malawi, Tanzania and Kenya found similar poor staffing levels (233).

In this study, I documented a strong association between the number of ward-level nurses and how much care nurses can deliver to newborns. I also found evidence of nurses deciding what patients to see and what tasks to undertake due to scarce nurse staffing. In this high-pressure, poorly staffed setting, I noted some critical patient-facing nursing tasks were not done or, in some instances, were delegated to parents or students without supervision. In an earlier study by Omondi et al., which used a task analysis approach to determine the complexity and critical nature of nursing tasks in Kenyan units, intravenous drug administration and nasogastric tube feeding were ranked as very critical nursing tasks by nurses (234). My study found that nasogastric tube feeding was essentially a caregiver's role in these units. At the same time, more than 40% of intravenous drug administration was carried out by nursing students who were not supervised. This raises patient safety concerns that will need to be addressed. Task sharing by nurses to laypersons is not unique to the Kenyan setting and has been documented in other LMIC settings where nurses prioritise clinical care over patient physical care due to time constraints (96). The current level of informal task sharing in the observed neonatal units makes a strong case for increasing ward-level nurse staffing but also strongly considering formal nursing support roles in the form of nursing assistants already used in some settings (235). This cadre might improve the quality of care in a multitude of ways, including taking up some roles from nursing students and supporting and supervising mothers in providing safe care to their newborns (rather than the current situation where they have minimal support) and also supporting nurses with less critical tasks, so nurses have time for more critical tasks. Most of the previous evidence on the role of nursing assistants in care has been carried out in high-income countries (235).

While there is previously published qualitative research that examines nursing care provision in low-resource settings, examining themes such as limited nursing time, heavy nursing workload and coping strategies using qualitative methods, my research adds to the existing dialogue by providing quantitative estimates of workloads and actual nursing care in such environments. I present data on average nursing workloads using a measure of nursing time (the nursing hour per patient per 12-hour shift) not previously documented in low-resource setting research. I found that neonatal unit nurses have on average, only 30 minutes per patient, and this assumes they have no breaks and includes time for non-patient facing tasks such as documentation and administration. In contrast, a nurse might have 325.8 mins per patient on equivalent units in a high-income setting (206). Prior LMIC research has largely employed nurse-to-patient ratios, which, although easy to understand, might not completely convey the nursing workload to health policymakers (130,133,150). In addition, using ratios becomes complex and less reflective of actual nursing time when there are multiple overlapping nursing shifts, for example, in the current neonatal care settings. I also show the unreliability of nursing input measures such as nurse-to-bed ratios (this assumes one bed per patient, which is usually largely not the case in this setting). My research thus proves that it is possible to have a more accurate staffing input estimation in future nursing workforce research.

7.4 Evaluating a nursing workforce intervention to improve quality of newborn care.

7.4.1 Effect of the intervention on quality of newborn care

In Chapter 5, I evaluate the first prospective study to determine the effect of increasing nursing numbers on the quality of care in a low-resource setting. The workforce intervention was deployed across four neonatal units within larger hospital contexts. The intervention setting could thus be viewed as a complex system, with the neonatal unit interacting with the wider hospital and organisational context and all its competing demands.

Post-intervention, my study showed that, on average, there was an increase in the available shift nursing time by 28% (absolute value of 9.6 mins per patient on a 12-hour shift). Using multilevel models, this translated to a 4.2% increase in the proportion of patient-facing nurse-delivered care and a 5.8 % increase in tasks that nurses prioritise relative to the pre-intervention period. The observed effect of increasing nursing time thus had a non-linear relationship with nurse-delivered care as assessed by the nursing care index. Non-linearity in cause-and-effect relationships, where interventions have either a bigger or smaller effect relative to the size of the intervention, is a key feature of complex systems (236).

This relates to how the intervention interacts with other component parts of the system (236). The HIGH-Q project added three extra nurses to each of the four intervention neonatal units, and this was meant to result in total nurse staffing increases of between 17.6% and 37.5% across neonatal units. Possible reasons for a small intervention effect (4.2% increase in nurse-delivered care) outside of the uptake of the intervention (which I discuss in the next subsection) are that the intervention resulted in greater changes in non-patient-facing tasks that were not measured by my structured observation tool. Another possibility is that nurses performed their tasks better and with greater attention to detail (an aspect of quality not measured by my tool) or that the addition of extra nurses resulted in a redistribution of previously heavy workloads.

My findings, using a prospectively designed before and after intervention study, build on the earlier body of work to support the important role of increasing nurse staffing in the quality of care (11,84). It also provides information that prospective workforce interventions in low-resource settings with low nurse-to-patient ratios are possible, although they have not been the focus of previous research. A prospective before and after design also builds a stronger case for causal inference between adequate nurse staffing and quality of patient care than the previous purely observational studies (76,127,197,237).

Previously, the global literature on the effect of nurse staffing has employed large administrative data to support the role of staffing in the quality of patient care and demonstrated the negative consequences of low nurse staffing numbers and not the effect of increasing numbers of nurse staffing (11,73–75,77,238) (I reviewed some of these evidence in Chapter 1). The available evidence for the effect of increasing numbers of nurse staffing comes from natural experiments investigating a change in nurse staffing following policy changes, for example, a change in the minimum nurse-to-patient ratio following the California minimum staffing regulations in the United States (239), the Australian Nursing Federation nurse-to-patient ratios enforced in Victorian hospitals (240), and one other study evaluating a policy decision to increase nurse staffing in general medical and surgical units in Seoul, South Korea (76). In China, researchers also conducted a pre-and post-intervention study following nurse staffing reallocation in medical and surgical units of a single tertiary hospital (241). My research is distinctively different from these works in that it is prospective and specific to neonatal unit contexts.

Globally, most of the world's population resides in LMICs, and these regions also have the greatest patient safety issues and the greatest burden of critical illness with the poorest patient outcomes (242). These regions have distinct organisational contexts and work environments from those of HICs and are likely to need context-specific solutions. My findings also provide much-needed evidence on the importance of adequate and safe nurse staffing levels for quality newborn care. This is needed to inform policymakers and make a real case for investments in nursing in Kenya and the need to implement nurse staffing policies. My findings are also potentially applicable to broader human resources for health investments and applicable to other resource-constrained LMIC settings.

7.4.2 Intervention fidelity and quality of newborn care

In Chapter 6, I evaluate the intervention fidelity of the workforce intervention, i.e., how the actual uptake of the intervention compares to the planned uptake. After adding three extra nurses to each of the four intervention neonatal units, there was an average weekly change in total nursing hours per day of 8.62 hours (roughly one nurse working the equivalent of one extra 8-hour shift in 24 hours) in the immediate post-intervention period. This was followed by a gradual fall in nursing hours over time. The limited intervention effect on nursing time was linked to multiple events, including nurses going on leave and being transferred to other units within the intervention hospitals. Pre-intervention, part of the adaptive responses to cope with chronic nursing shortages in some of these neonatal units, had been to defer nurse leaves and off-duty periods. Following the addition of extra nurses, the intervention thus had an unintended consequence of increasing the number of nurses on leave at a particular period (as deferred leave was now taken), thereby limiting the effective intervention dose. Challenges with intervention fidelity have also been described in much earlier work by Neidlinger *et al.,* who investigated the prospective addition of nursing assistants to a setting that had previously not had such a cadre (229). My findings underscore the challenges and unpredictability of intervening within complex adaptive systems, which are heavily influenced by context (243). The HIGH-Q programme intervened in a difficult healthcare environment with high work pressures and wider resource constraints, including human resources for health constraints. The intervention was ultimately affected by internal pressures within the neonatal units and external pressures and needs in other parts of the intervention hospitals. These pressures influenced the intervention despite constant engagement by the HIGH-Q programme and signing a memorandum of understanding (described in Chapter 6) between the county leadership, intervention hospitals and the HIGH-Q programme to maintain staffing levels.

7.5 Linkage of my research with current HIGH -Q programme research and future works

In Chapter 2, I introduced the HIGH-Q programme and showed a schematic of how my work related to other ancillary research being carried out in the project work package which housed my research. While my findings from Chapter 4 showcase care by nurses around babies. There is so much that happens away from babies that I was unable to measure. Within the wider HIGH-Q programme, there is an ancillary time in motion study being conducted and this examines how nurses spend their time during shifts (See Figure 2.1). This data is complementary to my study as it looks at non-patient facing tasks within study neonatal units and examines overall nursing activities within a nursing shift. There is some evidence from this work that a lot nursing time is taken up indirect patient care activities such as the management and ordering of supplies, preparation of feeds and housekeeping, cleaning and equipment functionality checks. Some of these activities potentially take up time for direct nursing care and there is a potential for task shifting these tasks with the neonatal units. As this study was not powered to investigate the effect of the workforce intervention on indirect care, future studies will need to investigate specifically how prospective nursing workforce interventions affect non-patient-facing tasks.

While in in Chapter 5, I showed how the nursing workforce intervention affected nursing care. A second HIGH-Q study looked at how adding ward assistants to the neonatal units specifically changed the dynamics of care. This study is showing that a lot of indirect patient care that took nurses time, for example supplies retrieval, cleaning and feed preparation are being taken up by ward assistants and hence freeing nurses time for more direct patient care.

A process evaluation of the workforce intervention which was also undertaken alongside the intervention also strongly complements by work on intervention fidelity and using a qualitative approach is providing reasons for some of my more quantitative findings. For example, an increase in annual leave following the intervention was linked to deferral of leave has a coping strategy by understaffed units which was documented by the process evaluation.

There is future work currently being planned to take forward nurse staffing metrics I have identified from by umbrella review process in Chapter 3A and operationalised in Kenya and relate this to more outcome-based measures of quality such as neonatal mortality. In addition, there is also ongoing work to use data from my research that shows how increasing nurse staffing affects care delivery to conduct a health economic evaluation of the intervention.

7.6 Policy recommendations to improve nursing care delivery in Kenya.

In this subsection, I propose three policy recommendations to improve nursing care delivery in Kenya based on my research findings.

7.6.1 Focus on improving nursing workforce numbers as a fundamental pillar of the health agenda.

While the long-term Kenyan strategic health policy documents all mention human resources for health, including nurses, as central to the Kenyan health agenda, the reality is public sector nursing workforce is depleted . The current data in my thesis demonstrate severe understaffing across all studied neonatal units and extreme nursing workloads. There is literature to show how increased workloads are associated with increased patient mortality and adverse patient outcomes (26,83,244). The current workforce inadequacies described in this research are likely to hamper the effective delivery of several interventions to improve the quality of newborn care, including those of technologies to improve newborn care. Kenya as a country is thus unlikely to achieve the Sustainable Development Goals for newborn mortality without considerable investments in the nursing workforce and human resources for health in general.

To be successful at improving the quality of neonatal nursing care in the medium to long term, an increase in the nursing workforce would need to be complemented by preventative strategies to reduce the small and sick newborn care burden in neonatal units, including strengthening antenatal care practices and community care of the newborn, thereby improving nurse staffing to patient ratios and resulting in decreasing stress and burn-out and improvements in nurses' overall well-being. Nursing workforce increases would need to consider the nursing skill mix (although not explored in this research), as there is evidence that a higher skill mix leads to better patient care outcomes .

7.6.2 Need for a Kenyan nursing workforce standard.

Increasing nursing numbers will need to be supported by standards that inform frontline nursing practice. Although the Kenyan National Nursing and Midwifery Policy sets out long-term strategic policy for nursing in Kenya (17), there is currently no policy that sets standards for day-to-day nursing in Kenya. This is also similar in many resource-limited settings (33). In earlier work, Keene *et al.* proposed standards for staffing neonatal units following stakeholder and local expert engagements and considering the local Kenyan context (208). These have, however, not been reflected or considered in official Kenyan health strategy or policy. My thesis shows extremely poor nurse staffing and variability in nurse staffing across different county neonatal units, highlighting some key gaps in policy to support day-to-day nursing in Kenya. While devolution has placed powers in the hands of counties to manage their public health systems, realities remain that counties have different financial capabilities, and they invest differently in public health services and human resources for health. Earlier works by Zhao *et al.* have also demonstrated marked variability in hospital staffing across Kenyan counties and differential absorption of doctors into medical service post-internship (246,247). The situation makes a case for some uniformity or minimum standard across counties that is supported by a policy from the Kenyan National Ministry of Health, and that is also backed by legislation and funding.

A national nursing workforce standard will support the delivery of safe, quality, and effective nursing care provision (18). Such standards will need to be supported by local or contextually applicable evidence that takes into cognisance challenges related to funding and health budgets in Kenya but also considers practical and important issues related to patient safety. It should also serve as a guide to all stakeholders involved in delivering nursing services, including county leadership who oversees hiring nurses, planning and designing nursing services, hospital managers who manage nursing staff and the Nursing Council of Kenya who regulate nursing activities (46)**.** In addition, it should serve as a blueprint for development partners wanting to support the extension and expansion of health services including programmes such as NEST-360^{o}, which are upgrading neonatal units in Kenya. In practice, the national government through partnerships might need to support poorer counties to achieve the minimum set standards.

Amongst other things the standard should spell out fair compensation for nurses, a quality workplace environment and specify minimum nursing work hours (18). It should also specify escalation thresholds when additional nurse staffing is needed with increasing patient load and case-mix severity (18). Currently the data suggests nurse staffing remains the same irrespective of patient load.

The nursing standards would also need to address the role and supervision of nursing students (who currently feature prominently in Level 2 neonatal unit care provision), and this would need to be supported by research evidence. Additionally, the role and support of caregivers in the neonatal units to provide family-centred care would need to be considered, including the necessary neonatal nurse staffing required to deliver this. From my research, caregivers do not have the required levels of support (linked in part to poor nurse staffing) for family-centred care. It is crucial for the proposed standards to address this, as global policy direction is moving towards involving families more in the care of small and sick newborns with policy directions such as immediate kangaroo mother care for small and sick newborns and also mother-baby neonatal units (248,249).

Overall, this standard is likely to compliment the Kenyan National Nursing and Midwifery Policy which sets out long-term strategic policy for nursing in Kenya (17).

7.6.3 Need for long-term nursing workforce planning and strategy.

Kenya has a double jeopardy problem where a limited production of nurses exists side by side with nurse unemployment and underemployment (37). This arises from a malignment between nursing workforce supply and demand (37). The government of Kenya has taken a practical step towards this by conducting a health labour market analysis to understand health labour workforce demand, need, and supply at national and subnational levels (41). In addition to increasing the number of nursing graduates, there is a need for strategic financing and job creation to absorb nursing graduates and meet population needs. In addition to this, the government needs a nursing workforce retention policy that creates pull factors for nurses in Kenya through competitive pay, good working environments and social welfare packages (2). Currently, the out-migration of nurses is a significant problem in Kenya; for every

4.5 nurses added to the pool of nurses available to work but mostly not in the workforce, one nurse out-migrates from Kenya (51). At the sub-national level, the ability to retain nurses is variable across counties, and this is linked mostly to financing but also variations in the work environment and human resource management practices (17).

The current nursing workforce shortages cannot be addressed by increasing nurses alone. In the medium term, Kenya needs to consider a long-term workforce strategy that involves task-shifting to lower cadres to support (and not replace) the work nurses do in neonatal units and other hospital units with careful consideration of the nursing skill mix. Nursing assistants are a key feature in many high-income countries, with the nursing workforce encompassing these cadres (11) (250). For example, in the UK, the nursing workforce comprises nursing assistants, nurses, maternal support workers and healthcare assistants who have no formal qualifications (18). Although there is still some resistance among a few policy implementers on the need for assistants (207), the reality is task shifting is already occurring to lay persons and unqualified students in these contexts. The strategy would, however, need to be pragmatic and linked to the judicious use of health funding, which is a key consideration for the optimal skill mix to provide quality newborn care (251).

7.7 Implications of my findings for global policy direction on improving newborn survival

The WHO global strategy on human resources for health (HRH) rightly points out that ending preventable newborn deaths will remain aspirational if challenges with the health workforce are not addressed (252). It also recognises that to attain the health-related Sustainable Development Goals (SDGs) and other global targets linked to quality of care, HRH would need to take centre stage in health in the global development agenda (252).

The SDG has a clear target of reducing preventable newborn deaths to below 12 per 1000 live births by 2030, and improving the quality of care for small and sick newborns has featured as a key strategy to attaining these goals (14). This is reflected in key global initiatives aimed at attaining the SDG targets for newborn health, for example, Every Newborn Action Plan (ENAP), the WHO standards for improving the quality of small and sick newborns in health facilities and Survive and Thrive report all emphasising the need for care of small and sick newborns (89–91). These initiatives all have improved access to quality newborn services as central themes, including access to adequate and skilled multidisciplinary staff, live-saving interventions and technology, and harnessing the power of family-centred care (89–91).

In recent years, the ENAP has extended its original targets to include increasing access to Level 2 special care baby units (similar to those in my studies) to improve universal health coverage and close the neonatal mortality gap (93). Current targets are that by 2025, 80% of districts in every country should have at least one Level 2 newborn unit providing care to small and sick newborns (93). In Kenya and some other LMICs, efforts are being made to upgrade existing facilities and equip them with essential newborn technologies (such as CPAP, Phototherapy machines, and oxygen) through programmes like NEST360 to function as Level 2 neonatal units and improve access for small and sick newborns (70).

My findings show extremely poor nurse staffing, increased missed nursing care, and large-scale provision of care by unsupervised students and caregivers, suggesting that the enhancement of the neonatal unit workforce has not kept pace with the rollout of technology across Level 2 neonatal units. It also suggests that access to a Level 2 neonatal unit is not synonymous with access to quality care by trained HRH, in this case, quality nursing care. This is corroborated by literature in other LMIC settings, which also describe inadequate facility-based care and an increase in care provision by largely unsupported caregivers (212,213). While technology and access to care is one piece of the puzzle in addressing neonatal mortality, technology alone cannot address the neonatal mortality gap to achieve the SDG targets in resource-constrained LMICs and will need to act synergistically with progress in improving HRH. This is recognised and reflected in global policy documents (89–91), but does not appear to manifest in current real-life implementation.

The current gap between theory and practice when it comes to neonatal unit HRH is recognised in recent reviews of the ENAP targets for the post-2025 period (unpublished), which plan to include specific shift-level nurse staffing ratios for neonatal units managing small and sick newborn care that are close to nurse staffing standards in high-income countries. This revision is led by the WHO and UNICEF to determine staffing norms in neonatal settings in LMIC settings. My research suggests that the current nurse staffing realities are far from the proposed standards and would require significant investments in HRH, which might be difficult to attain before 2030. The reality in Kenya and other resource-constrained LMICs is that budget cuts and limited health spending are a constant feature of health financing (253,254). Concerted efforts will, however, need to be made to improve the nursing workforce and HRH numbers as a priority through increased budgetary allocation towards HRH, including nursing, optimisation of current health spending and innovative strategies for health funding. There is some evidence from the literature of some LMIC health systems enacting bold policies to increase nursing numbers in the years preceding the 2030 SDG targets. Rwanda, for example, has committed to the 4X4 health reform, which is aimed at quadrupling the health worker and nursing workforce by 2030 (255).

Outside of improving the quality of facility care, another common strategy in global health policy for improving neonatal survival has been leveraging families to provide care for small and sick newborns through family-centred care (89–91). The recent comprehensive model for scale up of small and sick newborn care (SSNC) at district level (Level 2) neonatal units by WHO/UNICEF highlights the crucial role that family involvement and support play as a core global strategy for improving neonatal survival (256). My research shows that implementation of this is hampered by poor nurse staffing, leading to care provision by families (mothers) largely unsupported by nurses in many cases, with nurses having to rely on mothers as a form of workforce support rather than supporting them to be involved in care of their newborns. Additionally, adequate human resource for health, particularly nurses are key to other crucial components of SSNC scale up, for example, having functional referral systems extends beyond just transportation and requires the needed human resources to function. Linkages between maternal and newborn care is not only about health system hardware but would also require the software which includes an adequate number of staff (including nurses) to enhance communication between maternity and newborn units.

With barely six years left to the SDG deadlines (as of the year 2024) and a global acceleration of four times the current pace in improvements of neonatal mortality rates needed (257), the importance of achieving adequate numbers of competent, well-trained staff and having a well-equipped health workforce including nurses cannot be understated.

7.8 Limitations and future research

The majority of limitations were linked to my study design, and I have discussed some of these that are specific to particular methodologies in each of the relevant thesis chapters. A few limitations linked to my broad research worth mentioning are highlighted below.

Firstly, my selection of intervention study sites for this research was non-random. As mentioned in my methodology chapter (Chapter 2), this was in part linked to the Covid-19 pandemic and the movement restrictions around that period. It was also important to have sites with administrative buy-in to this study. The HIGH-Q project also considered the ethics of randomising an intervention perceived as beneficial and the costs associated with the nursing workforce intervention. Randomisation would have meant a much larger number of facilities and considerable costs associated with the nursing workforce intervention, and it may have been unethical to withhold the intervention from control sites post-intervention contributing to costs. Ultimately, randomisation is unlikely to control for every potential confounder for complex interventions when an intervention is targeted at a more complex level than the individual (in this thesis, the target of the intervention was at the neonatal unit level). This is because there are likely to be a large number of baseline characteristics, including both individual and unit-level characteristics, that could potentially confound results (258). It is thus possible that my selected sites might not be representative of all public hospitals in Kenya. I have, however, reviewed contextual data from an additional four non-intervention neonatal units (in Chapter 4), which appear similar in context to the four intervention neonatal units. I also ensured random shift selection for observation as it was important to collect data across the week and at night and for nursing staff not to be able to predict observation shifts.

A second limitation worth mentioning is that because of my quantitative approach to addressing my research questions, I could not measure differences in organisational culture or workplace environments. Such differences might provide a deeper understanding of how and why the intervention led to its effect and of differential intervention uptake across the four intervention neonatal units. There is, however, a much broader HIGH-Q programme process evaluation that takes a deeper dive into these issues and is likely to complement my research.

A third limitation is that my work focused only on a process indicator of quality of care (although a multi-dimensional one with indicators across 14 domains). This, in part, was linked to the nature of the workforce intervention, which was expected to improve nursing processes before outcomes. Traditional outcomes, such as mortality, are usually downstream to process interventions on the causal pathway to effect. Nevertheless, there is a need for future research to show how a nursing workforce intervention in a resource-limited context might affect outcome-based measures of quality of patient care.

A fourth limitation is that although I standardised the training of observers to ensure that data was being collected in a consistent manner across sites and conducted group pilot training, I did not conduct any testing to assess inter-rater agreement between observers in their observations. This would be important to formally prove that the training had had the desired effect. Although this might have been difficult to check with actual bedside observations, in hindsight it might have been possible to do this using data extraction from patient documentation.

A fifth limitation is that the nursing care index used to measure nurse-delivered care in my study was based only on patient-facing tasks. This is because observations were made on nursing activities happening to and around particular patients. Nurses are involved in both patient-facing and non-patient-facing tasks (as described in Chapter 1). For example, within neonatal units, they are involved in medication preparation, supply inventory, billing, meetings, nursing planning, conversation with neonatal unit visitors, and admission and resuscitation of other patients, all of which happen away from the patient being observed. My structured observation tool is thus limited in that it does not reflect the sum of nursing activities and cannot also capture how well a task was performed. It is possible that the intervention might have affected non-patient-facing tasks in a different pattern.

7.9 Conclusion

In this thesis, I investigated nursing care delivery in Kenyan neonatal units and evaluated the effects of a workforce intervention to increase the number of frontline neonatal unit nurses on the quality of newborn care provided. Using largely quantitative methods, I show that neonatal nurse staffing is poor in Kenyan public Level 2 neonatal units with heavy reliance on caregivers and nursing students in training to support patient care. I also show that increasing the number of nurses is likely to increase the proportion of care delivered by nurses (an indicator of quality of care), although there is not a 'like for like' link between increased nursing time and directly observed patient-facing nursing care tasks performed. My systematic literature reviews also show that poor nurse staffing is not common to Kenya alone but also occurs in other resource-constrained LMICs.

As most of the low-income Kenyan population receives neonatal care from public hospitals, I argue that Kenya needs a long-term nursing workforce strategy that addresses extreme frontline nursing workforce shortages in neonatal services and other departments in the public sector. This strategy would need to be practical and consider sustainability at its core in terms of the skill mix of the nursing workforce and the linked neonatal care team. Also, a foundational principle of this strategy should be ensuring the quality of patient care and upholding the tenets of patient safety as underlying principles.

In the absence of considerable investments in the nursing workforce and human resources for health in general, even if investments in more advanced neonatal technologies are made, Kenya is unlikely to achieve the SDG targets of ending preventable newborn deaths.

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Appendices

Appendix 1– Adapted structured observational checklist.

Date of completion	|__|__|/|__|__|/|__|__|__|__| **(DD/MM/YYYY)**		
Observer code	|__|__| (e.g., 01)		
Subject ID	|__|__|- |__|__|__| (5-digit code (first 2 digits, hospital code and last 3-digit, patient number e.g., 010 or 100)	In-patient number ☐	
Recruitment period (Tick as appropriate)	Baseline (Pre-intervention) ☐ Post-intervention_1 (nurses) ☐ Post-intervention_2 (ward clerks) ☐		
Part A – Shift information (Tick as appropriate)			
Q 1. Shift type			
Weekday day ☐	Weekday night ☐		
Weekend day ☐	Weekend night ☐		
Q 2. Observation period			
Start Date |__|__|/|__|__|/|__|__|__|__| **(DD/MM/YYYY)**	Start time |__|__| :|__|__| (Please use 24-hour timing e.g., 23:59, not 11:59pm)		
End Date |__|__|/|__|__|/|__|__|__|__| **(DD/MM/YYYY)**	End time |__|__| :|__|__| (Please use 24-hour timing e.g., 23:59, not 11:59pm)		
Q 3. Total number of patients in the ward (Include all babies including those in KMC and acute rooms)	|__|__|__|	Number of babies on CPAP	|__|__|
		Number of babies on Oxygen	|__|__|
		Number of babies on IV therapy (medications/ fluids)	|__|__|
		Number of babies on Phototherapy	|__|__|
		Number of babies requiring nasogastric tube/orogastric feeding	|__|__|

		Number of babies requiring incubator care		|__|__|	
Q 4 Is there an extra KMC Ward/ room managed by the NBU nurses?	Yes ☐ No ☐		Number of babies on the KMC ward |__|__|		
Q 5 Is there an acute room present in the NBU?	Yes ☐ No ☐		How many babies are present in this room? |__|__|		
Q6. Number of nurses on current 12-hour shift	Actual (Based on observations)				
	Morning shift (07:30 – 12:30)	☐	Night shift (18:30 – 07:30)	☐	
Comment:	Evening shift (07:30 – 16:30)	☐	Others ___________	☐	
	Afternoon shift (12:30 – 18:30)	☐			
Q 7. Device check. On the current shift, how many of the following devices below are present and functional					
Glucometer **(If no strips, put as 0)**	☐	Weighing scale	☐	Pulse oximeter	☐
Thermometer **(owned by the unit)**	☐	Stethoscopes **(owned by the unit)**	☐		

Instruction: Please reconcile the following information below at end of the shift

Q 8. How many of the following processes occurred during the shift?	Admissions	|___|
	Discharges	|___|
	Referrals	|___|
	Deaths	|___|
Q 9. How many of the following staff cadres where present on this shift?	Medical officer	|___|
	Clinical Officer Interns	|___|
	Medical officer interns	|___|
	Nursing officer interns	|___|
	Nursing students	|___|
	Others _____________	|___|

	Others ____________	|___|
Q 10. Was the ward-in-charge or deputy ward-in-charge present at any time during the 12-hour observation period	Yes ☐	
	No ☐	
Part B – Baby's biodata (Tick as appropriate)		
Q 11. Care category		
Category A (Critical/HDU) ☐	Category B (Acute) ☐	Category C (Stable) ☐
Q 12. Date of admission |__|__|/|__|__|/|__|__|__|__| **(DD/MM/YYYY)**		
Q 13. Current age (write in days if above 24 hours old, if less than please write in hours)	Hours |__|__|	Days |__|__|
Q14. Gender		
Male ☐ Female ☐		
Q 15. Current diagnosis	Diagnosis 1 (Primary diagnosis) ______________________________	
	Diagnosis 2 (Secondary diagnosis) ______________________________	
	Diagnosis 3 (Secondary diagnosis) ______________________________	
	Other diagnosis ______________________________	
Q 16. Birth weight (grams) |__|__|__|__|		
Q 17. Current weight (Most recent weight in grams) |__|__|__|__|		
Q 18. Which of the following medical devices/interventions is the baby on? **(Tick yes if any device applies and tick no if it does not)**		
CPAP	Yes ☐ No ☐	
Incubators	Yes ☐ No ☐	
Intravenous fluids	Yes ☐	

	No ☐
Intravenous cannula (without fluid attached)	Yes ☐ No ☐
Nasogastric/Orogastric tube	Yes ☐ No ☐
Oxygen	Yes ☐ No ☐
Phototherapy	Yes ☐ No ☐

Nursing tasks	Task frequency	Expected number within current 12-hour shift	Tasks done (Insert Y, if yes and N if no)	Time tasks done	Comment
Routine nursing care					
Nurses handing over patient		1			
Patient assessment before shift		1			
Nurse washes / sanitises hands before patient assessment (Assess the first patient contact)		1			
Nurse attends the ward round with doctor (s) to see patient. (If nurse student, mark as no)		1			
Nurse communicates with caregiver details of care/ counsels the caregiver		1			

Nursing tasks	Task frequency (Circle option)	Expected number within current 12-hour shift	Tasks done (Insert Y, if yes and N if no)	Task performed by (N for nurse, NS* –Student nurse, M-Caregiver/ Mother, W-ward clerk)	Time tasks done	Comment
Temperature check	4/6/12 hourly	1 /2 /3	☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
Pulse/heart rate check	4/6/12 hourly	1 /2 /3	☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
Respiratory rate	4/6/12 hourly	1/ 2 /3	☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
Pulse oximetry	4/6/12 hourly	1/ 2 /3	☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	

*- Task performed by a nursing student under supervision should be termed as done by a nurse

Nursing tasks (Routine newborn care)	**Task frequency (Circle option)**	**Expected number within current 12-hour shift**	**Tasks done (Insert Y, if yes and N if no)**	**Task performed by (N for nurse, NS* –Student nurse, M-Caregiver/ Mother, W-ward clerk)**	**Time tasks done**	**Comment**
Cleaning baby		1	☐	☐		
Linen change		1	☐	☐		
Weight check		1	☐	☐		
Checking incubator settings		1	☐	☐		
Diaper change		1	☐	☐		
Cord care		1	☐	☐		
Turning the baby		4	☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		

*- Task performed by a nursing student under supervision should be termed as done by a nurse

Nursing tasks (Feeding)	Task frequency (Circle option)	Expected number within current 12-hour shift	Tasks done (Insert Y, if yes and N if no)	Task performed by (N for nurse, NS* –Student nurse, M-Caregiver/ Mother, W- ward clerk)	Time tasks done	Comment
Breastfeeding ☐ Cup/spoon feeding ☐ Nasogastric/ Oro-gastric tube ☐ No oral feeding ☐	3-hourly	4	☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
NG Tube feeding process &						
Check tube positioning	3-hourly	4	☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		
Measure feeds	3-hourly	4	☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		

Position the baby after feeding	3-hourly	4	☐	☐		
			☐	☐		
			☐	☐		
			☐	☐		

& - Complete for only NG-tube fed babies

IV Medication						
Is the baby on IV medication? (Tick as appropriate) Yes ☐ (complete section below) No ☐ (cross-out section below)						
Nursing tasks (Medication)	**Task frequency (Please circle)**	**Expected number within current 12-hour shift**	**Tasks done (Insert Y, if yes and N if no)**	**Time tasks done**	**Task performed by (N for nurse, NS* –Student nurse, M-Caregiver/ Mother, W- ward clerk)**	**Comment**
Drug name ____________________	6/8/12/24 hourly	|___|	☐ ☐	☐ ☐	☐ ☐	
Drug name ____________________	6/8/12/24 hourly	|___|	☐ ☐	☐ ☐	☐ ☐	
Drug name ____________________	6/8/12/24 hourly	|___|	☐ ☐	☐ ☐	☐ ☐	
Drug name ____________________	6/8/12/24 hourly	|___|	☐ ☐	☐ ☐	☐ ☐	

6 hourly – QDS/QID, 8 hourly – TDS/TID, 12 hourly – BD, 24 hourly - OD						
Oral Medication						
Is the baby on oral medication? (Tick as appropriate)	**Yes** ☐ **(complete section below)** **No** ☐ **(cross-out section below)**					
Nursing tasks (Medication)	**Task frequency**	**Expected number within current 12-hour shift**	**Tasks done (Insert Y, if yes and N if no, E if not determined)**	**Time tasks done**	**Task performed by (N for nurse, NS* –Student nurse, M-Caregiver/ Mother, W- ward clerk)**	**Comment**
Drug name ______________________________	12/24 hourly	|___|	☐	☐	☐	
Drug name ______________________________	12/24 hourly	|___|	☐	☐	☐	
Drug name ______________________________	12/24 hourly	|___|	☐	☐	☐	
Drug name ______________________________	12/24 hourly	|___|	☐	☐	☐	

IV Medication delivery process (Perform this observation for first round of medications)				
Nursing tasks (Medication)	**Tasks done (Insert Y, if yes and N if no, E if not determined)**	**Not applicable e.g., if patient not on IV medication**	**Task performed by (N for nurse, NS* –Student nurse, M-Caregiver/ Mother, W- ward clerk)**	**Comments**
Review of treatment sheet	☐	☐	☐	
Cannula flush with saline before drug administration	☐	☐	☐	
Cannula flush with saline after drug administration	☐	☐	☐	
Supervision of mother during Kangaroo Mother Care (KMC)				
Is the baby on KMC? (Tick as appropriate)	**Yes** ☐ **(complete section below)** **No** ☐ **(cross-out section below)**			
Supervision of mother during KMC	☐		☐	

Phototherapy

Is the baby on oral medication? (Tick as appropriate) **Yes** ☐ **(complete section below)**

No ☐ **(cross-out section below)**

Nursing tasks (Special newborn care)	**Task frequency**	**Expected number within current 12-hour shift**	**Tasks done (Y-yes, N-no)**		**Task performed by (N for nurse, NS* –Student nurse, M-Caregiver/ Mother, W- ward clerk)**	**Comment**
Turning/positioning	4 hourly	3				
Skin assessment	6 hourly	2				
Eye care	12 hourly	1				
Changing eye pads	12 hourly	1				

Continuous Positive Airway Pressure					
Is the baby on Continuous Positive Airway Pressure? (Tick as appropriate)			**Yes** ☐ **(complete section below)** **No** ☐ **(cross-out section below)**		
Nursing tasks (Medication)	**Task frequency**	**Expected number within current 12-hour shift**	**Tasks done (Insert Y, if yes and N if no, E if not determined)**	**Task performed by (N for nurse, NS* –Student nurse, M- Caregiver/ Mother, W- ward clerk)**	**Comment**
Checking nasal prong position	4 hourly	3	☐	☐	
			☐	☐	
			☐	☐	
Checking oxygen flow rate	4 hourly	3	☐	☐	
			☐	☐	
			☐	☐	

Oxygen therapy					
Is the baby on oxygen therapy? (Tick as appropriate) Yes ☐ (complete section below) No ☐ (cross-out section below)					
Nursing tasks (Medication)	**Task frequency**	**Expected number within current 12-hour shift**	**Tasks done (Insert Y, if yes and N if no, E if not determined)**	**Task performed by (N for nurse, NS* –Student nurse, M- Caregiver/ Mother, W- ward clerk)**	**Comment**
Checking nasal prong position	4 hourly	3	☐	☐	
			☐	☐	
			☐	☐	
Checking oxygen flow rate	4 hourly	3	☐	☐	
			☐	☐	
			☐	☐	

Documentation					
Documentation of tasks (source)	**Done (Please tick)**	**Not Done (Please tick)**	**Not applicable (Please tick)**	**If done, how many times (Please write number)**	**Comments**
Neonatal assessment by nurse (Nursing cardex)	☐	☐	☐	☐	
Nursing care plan (Nursing cardex/ care plan)	☐	☐	☐	☐	
Temperature measurements	☐	☐	☐	☐	
Heart rate	☐	☐	☐	☐	
Respiratory rate	☐	☐	☐	☐	
Oxygen saturation	☐	☐	☐	☐	
Ward round details	☐	☐	☐	☐	
Frequency and volume of feed	☐	☐	☐	☐	
Health talks/ Communication to parents	☐	☐	☐	☐	
Volume of IV fluids	☐	☐	☐	☐	
Weight check	☐	☐	☐	☐	

NB – sections highlighted in yellow are DPhil modifications to the original tool.

Appendix 2 – Health facility assessment tool

Date of completion		|__|__|/|__|__|/|__|__|__|__| **(DD/MM/YYYY)**	
Interviewer code		|__|__| (e.g., 01)	
Site code		|__|__|__|	
Who was interviewed to complete this Health Facility Assessment		Head nurse ☐	
		Delegate ☐	
UNIT CHARACTERISTICS			
Q1. What type of newborn unit is your unit?			
Discrete (**Standalone**) NBU (Separate from other units) ☐	Ward on a maternity unit ☐	Combined with other Paediatric patients ☐	Other ________
Q2. How many neonatal beds does this unit have? This is the unit's capacity. Please, count beds, both occupied and not occupied. Incubators and cot beds are both classified as beds			
|__|__|__|			
Q 3. Does this unit admit referrals?			
Yes ☐			
No ☐			
Q4. If yes, to Q3., does this unit have a separate section for referrals?			
Yes ☐			
No ☐			

Q5. If yes to Q 4. How many neonatal beds does this separate referral section have? **Please count beds, both occupied and not occupied. Incubators and cot beds are both classified as beds**				
|__|__|__|				
Q6. Which of the following nursing shifts do you run in your unit? (Please tick all that apply)				
Morning shift ☐ Start: |__|__|:|__|__| Stop: |__|__|:|__|__|	Afternoon shift ☐ Start: |__|__|:|__|__| Stop: |__|__|:|__|__|	Evening shift ☐ Start: |__|__|:|__|__| Stop: |__|__|:|__|__|	Night shift ☐ Start: |__|__|:|__|__| Stop: |__|__|:|__|__|	Specify other shift type with timing _____________
Q7. Is there a Kangaroo Mother Care ward present in your unit?				
Yes ☐				
No ☐				
Q 8. Is there an acute room present in your unit?				
Yes ☐				
No ☐				
UNIT STAFF RESOURCES				
A. NURSES				
Q 9. How many nurses work in this neonatal unit (Probe for locum)? **Please include the ward-in-charge to this figure but do not include student nurses.**				
|__|__|				

Q 10. Of the nurses in Q 9, how many have their highest qualification as the following?

Certificate	Diploma	Higher diploma	BSc	BSc + Higher diploma combined	MSc
|__|__|	|__|__|	|__|__|	|__|__|	|__|__|	|__|__|

Q 11. As of today, how many student nurses are posted to your neonatal unit?

|__|__|

Q 12. What are the categories of students in Q 11?

Degree students	Diploma students
|__|__|	|__|__|

Q 13. In your unit, how often do you get requests to provide staff cover to other units in a month? (e.g., maternity, paediatrics, out-patients, MCH)

Never	At least once a month	2- 3 times a month	>3 times a month
☐	☐	☐	☐

B. NON-NURSING STAFF RESOURCES

Q 14. At present, how many consultant Paediatrician-led (Major) ward rounds do you have in your newborn unit in a week?

|____|

Q 15. How many consultants are specifically assigned to your NBU

|____|

Q 16. At present, how many medical officers (excluding interns) are assigned to your NBU?

|____|

Q 17. At present, how many medical officer interns are posted to your unit?

|____|

Q 18. At present, how many nursing officer interns work in your unit?

|____|

Q 19. At present, how many clinical officer interns are posted to your unit?

|____|

Q 20. At present, how many nutritionists work in your unit?

|____|

Q 21. At present how many support staff/ ward clerks are in your unit

|____|

UNIT SCHEDULES (Please complete in 24-hour format, e.g., write 19:00 and not 07:00pm)

Q 22. What are the scheduled medication administration times for each of this medication times in your unit ?

Medication type	Times (e.g., 09:00)					
Daily (24 hourly) medications						
12-hourly						

8-hourly				
6-hourly				

Q 23. How often do you schedule vital sign monitoring for critically ill babies in your unit and at what times?

Write frequency (e.g., twice)

Q 24. How often do you schedule vital sign monitoring for moderately ill babies in your unit and at what times?

Write frequency (e.g., twice)

Q 25. How often do you schedule vital sign monitoring for stable babies in your unit and at what times?

Write frequency (e.g., twice)

Q 26. What are the scheduled times for conducting the following nursing tasks in your unit?

Nursing tasks	Frequency (Daily/ every two days)	Time (e.g. 15:00 or 08:00)
Cleaning baby		
Linen change		
Weight check		
Diaper change		
Cord care		

C. DOCUMENTS AVAILABLE ON THE UNIT

Q 26. Are the following documents listed below available and in use within the NBU?

Newborn Admission Record	Yes	
	No	
Admission register	Yes	
	No	
Referral notes/forms	Yes	
	No	
Vital signs chart	Yes	
	No	
Treatment sheets	Yes	
	No	
Comprehensive newborn monitoring chart	Yes	
	No	
Fluid and feeding charts	Yes	

	No	☐
Newborn resuscitation guideline (wall chart)	Yes	☐
	No	☐
Protocols for managing common newborn conditions – Basic paediatric protocol and comprehensive newborn protocol.	Yes	☐
	No	☐

D. TECHNOLOGIES RESOURCES

Of the technologies listed below, can you please list the number you have currently and the number that are functional. (*Interviewer should do a manual count and if possible, examine these devices*).

Functionality of a device refers to numbers that are working properly and that are currently in use. Equipment locked up and that have never been used are not functional. For material resources, count the number available for use.

Q 27. Of the equipment below, how many of these are available and how many are functional?

Device	Total number available in the neonatal unit (Include those in storage)	Number that are functional and in use
Equipment for conducting vital signs and anthropometry		
Respiratory counters	☐	☐
Thermometers	☐	☐
Stethoscopes	☐	☐
Pulse oximeters	☐	☐
Weighing scales	☐	☐

Equipment for essential newborn care and neonatal resuscitation		
Radiant warmers	☐	☐
Suction machines	☐	☐
Glucometers	☐	☐
Incubators	☐	☐
Equipment for providing respiratory support		
CPAP machines	☐	☐
Ventilators	☐	☐
Laryngoscopes	☐	☐
Laryngoscope blades	☐	☐
Equipment for providing phototherapy		
Phototherapy machines	☐	☐
Phototherapy irradiance measure (Light meter)	☐	☐
OTHER EQUIPMENT AND DEVICES		
Bilirubin meter	☐	☐
Hemoglobinometer	☐	☐
Syringe pump	☐	☐
Q28. Are the following equipment available on the neonatal unit (Yes/No)		
	Yes	**No**
Endotracheal tubes	☐	☐

Bag and mask device	☐	☐
Nasal prongs	☐	☐

Comments:

Appendix 3– Glossary of nursing tasks

Domain	Nursing tasks	Definition
Routine nursing care	Patient handover	This is the handover which happens before a shift. it involves the incoming nurses on a shift receiving details on every newborn in the previous shift. Its structure is hospital dependent.
	Patient assessment before a shift	This is a patient-level head-to-toe assessment of a baby carried out by the nursing team after or during the handover before the commencement of a shifting
	Hand washing	This was defined as hand washing or hand sanitising before the first patient contact in a child who was being observed
	Ward round attendance	Patient-level attendance by a nurse when a ward round was being conducted on the baby being examined
	Patient communication	Nurse taking time to talk to and counsel the mother regarding patient care or the patient's condition at any time during a shift
Vital sign monitoring	Temperature check	This involved all methods for checking temperatures including placing a thermometer under the axilla of a neonate or non-contact measurements or the nurse reading off temperatures from a continuous baby monitoring device
	Pulse/ heart rate	This was defined as either the nurse using their fingers to palpate the pulse of a baby or using a pulse oximeter to read the heart or pulse rate value or placing a stethoscope on the baby's chest and manually counting the pulse/ heart rate or reading off the heart rate from a continuous monitoring device on a baby.
	Respiratory rate	This involved the nurse counting the respiratory cycles of a baby being observed
	Pulse oximetry	This was defined as the nurse either using a monitor with a probe to the baby's digits or reading off oxygen saturation readings from a monitor connected to a baby under observation
Routine newborn care	Cleaning baby	Systematic head-to-toe cleaning of a baby using cotton/cloth and warm water
	Linen change	This involved changing the linen that was used in a previous shift/ the previous day or linen that was soiled during a shift
	Weight check	This involved placing the baby on a weighing scale and recording the baby's weight
	Checking incubator settings	This involved checking on the settings of incubators in observed babies who were preterm. The nurse would adjust settings by pressing the buttons or checking if the recommended setting was in place

	Diaper change	This is cleaning and wiping the baby following a soiled nappy or during a shift
	Cord care	This involves exposing the umbilicus and wiping it with a ball of cotton wool soaked with a cleaning solution such as chlorhexidine.
	Physical turning	Deliberately changing a baby's position from one side to another
Feeding	3-hourly feeding	Giving a baby 3 hourly feeds. This can be breastfeeding, cup feeding or nasogastric tube feeding
Nasogastric tube feeding processes	Check tube positioning	Continuous checking of the nasogastric tube (NGT) position is done by assessing the gastric aspirate, in this case, the nurse before feeding, will attach a syringe to the NGT and aspirate then assess the aspirate contents and determine if the contents are from the stomach(gastric)
	Measure feeds	This done by confirming the amount of feed prescribed and calculating the volume of feed
	Position the baby after feeding	Putting the baby in lateral position to avoid aspiration in cases of regurgitation/ vomiting
Medication	Intravenous medication given	Actual administration of intravenous drug through the cannula using a syringe
	Oral medication given	Actual administration of oral medication
Intravenous medication delivery process	Review of treatment sheet	Reading through the treatment sheet to confirm right drug dosage and frequency
	Cannula flush with saline before drug administration	Pushing into the cannula a small amount of water for injection or normal saline through the cannula to check for patency
	Cannula flush with saline after drug administration	Pushing through water for injection or normal saline through the cannula after administering intravenous medication using a syringe.
Kangaroo mother care	Supervision of Kangaroo mother care	Kangaroo mother care involves a mother carrying her by infant using skin to skin contact. This involves nurse supervising this process

Phototherapy	Turning/positioning	Done at least every 4 hours, involves the turning the neonate to a lie on a different side/position while on phototherapy
	Skin assessment	Physical check of babies' skin to assess the yellow jaundice tinge, by slightly indenting skin mostly on the back or abdomen or checking on the eyes.
	Eye care	This is done each time the eye pad is changed normally 12 hourly and involves the nurse checking the eyes and cleaning them with cotton swab and warm water, at times TEO (tetracycline eye ointment) is prescribed to apply before padding up again
	Changing eye pads	Done by uncovering the eye pad the neonate is currently wearing and covering with a clean one at least 12 hourly
Continuous positive airway pressure	Checking nasal prong position	This is performed every 3 hours, and involves nurse physically examining the nostrils and cleaning it if need be, with cotton wool soaked with water
	Checking oxygen flow rate	Opening oxygen flow and titrating to require rate per minute, by adjusting the nob on the oxygen flow meter.
Oxygen therapy	Checking nasal prong position	This is performed every 3 hours, and involves nurse physically examining the nostrils and cleaning it, if need be, with cotton wool soaked with water
	Checking oxygen flow rate	Opening oxygen flow and titrating to require rate per minute, by adjusting the nob on the oxygen flow meter.
Documentation	Neonatal assessments	Documented physical/ systematic examination in the Kardex, this could include among others the state of each system such as cardiovascular, respiratory, central nervous system and so forth. At least once at start of shift.
	Nursing care plan	Documented plan of care for the shift in the Kardex, can include plan for monitoring of vital signs, feeding. At least once in the start of shift
	Temperature measurements	Documented temperature in observation chart. Frequency depends on baby's category – A, B or C.
	Heart rate	Documented heart rate in observation chart. Frequency depends on baby's category – A, B or C.
	Respiratory rate	Documented respiratory rate in observation chart. Frequency depends on baby's category – A, B or C.

	Oxygen saturation	Documented oxygen saturation in observation chart. Frequency depends on baby's category – A, B or C.
	Ward round details	Documented plan from ward round on the nursing Kardex.
	Frequency and volume of feed	Documented in feeding chart and or nursing Kardex, includes time fed and amount of feed. Number of times feeding was done
	Health talks/ Communication with parents	Notes on caregiver communication or specific health talk given documented in nursing Kardex
	Intravenous fluids volumes	Documented in input and output chart including time the fluid was started and amount given
	Weight check	Documented weight in nursing notes or monitoring chart

Appendix 4 – Training standard operating procedures

Standard operating procedure for observation of care

SSP Title	**OBSERVATIONS OF CARE**		
SSP Number:	01	Version and date:	v0.1, 24 FEB, 2021
SERU approval number			
Prepared by **(Name, title)**	Abdulazeez Imam (DPhil candidate)		
Signature and date	…………………………………		……………………………………..
Reviewed by **(Name, title)**	David Gathara, Michuki Maina, Vincent Kagonya and Onesmus Onyango		
Signature and date	…………………………………		……………………………………..

Background

As part of the wider Harnessing Innovations for Global Health Quality (HIGH-Q) program, this study will conduct observations of care across newborn units in Kenya in before and after supplementing these units with extra nurses. The focus of these observations is to determine the type, frequency and timing of care received by newborn infants in these hospitals before and after the intervention.

Purpose

This SSP describes the process for conducting observations of care using the nursing care index tool which is a structured checklist employed by non-participatory observers to determine the type, frequency and timing of care administered to admitted newborn infants.

Scope

This SSP applies to all members of the study team including Observers, Research Officers (ROs), Assistant Research Officers (AROs), DPhil students, Post-doctoral Researchers (PR), Study Co-ordinator (SC) who will be involved in the recruitment of study participants

Equipment/ Materials

- Observational checklist/tool
- Pen
- Field notebook
- Identity badge/name tag
- Copy of letter of approval to conduct study (ethical and hospital approval letter)
- Study information sheet
- Consent forms
- Wristwatch

Responsible persons

The SC, PR, and the DPhil are responsible for:

- Ensuring all AROs, ROs and observers are duly trained in conducting observations
- Ensuring there is consistency in measurements across all observers
- Managing, planning and co-ordinating observations across sites

- Training the research team on identifying eligible newborns for observation and ensuring this is consistent across the research team
  - Conduct random spot-checks of observations across hospital sites including participant selection and general conduct of observations

The RO and ARO are responsible for:

- Directly supervise observers during the conduct of observations
- Cross-checking returned observation tool for completeness
- Conduct random spot-checks of observations across hospital sites including participant selection and general conduct of observations
- Available to temporarily fill in for observations of care in the rare event an observer is unavailable.

The observers are responsible for:

- Conducting patient observations
- Escalating and discussing challenges related to observations promptly

Procedures

Section	**Description**	**Responsible persons**
1.1	**Pre-observation period**	
1.1.1	Planning and developing a schedule for observations across sites, shift types (weekday, weekends, day, and night) and patient severity	SC, PR, DPhil
1.1.1	Co-ordinating the pilot of the observation tool to ensure there is good internal consistency in the measurements taken by the research team	SC, PR, DPhil
1.1.2	Training the research team on identifying different patient severity categories using care packages/interventions delivered to infant	SC, PR, DPhil
1.1.3	Meeting with the hospital authorities and neonatal unit Paediatrician and nurse in-charge prior to conduct of observations	SC, PR, DPhil, RO, ARO

1.1.4	Conducting a CME session with neonatal unit nurses and other unit staff working on the study and what this entails	SC, PR, DPhil
1.1.5	Conducting a familiarisation period in hospitals to learn layout, schedule of activities, identify newborn unit staff and allow staff to acclimatise to the team. Using this period to conduct dry runs of observations	All
1.1.6	Piloting and administering the health facility assessment tool to collect baseline facility data in neonatal units in the weeks before the intervention	SC, PR, DPhil, RO, ARO
1.2	**Observation period**	
1.2.1	Arrive early before the commencement of a randomly selected shift to: 1. Identifying babies to observed 2. Consent caregivers of identified babies 3. Identify appropriate location to conduct observations. This should not interfere with the unit flow 4. Determine expected tasks to be completed for each baby based on patient severity and interventions the baby is having 5. Attend the nursing handover. During the handover, important information that can be picked up and completed on the checklist include number of babies currently on admission in the unit and the number of unit devices (Glucometers – please put 0 if there are no glucometer strips available, weighing scales, Pulse oximeters, Thermometers, Stethoscopes (only count unit owned stethoscopes). The device handover book can be an alternate source to find these items. For a night shift, if feasible, arrive 2 hours before the commencement of the shift to carry out processes 1 to 5. This is because if you consent during a busy shift, it is highly likely you will miss most of the processes of care to be observed during your shift. For a morning shift, if practical, perform processes 1 to 3 the day before the shift .i.e., identify and consent mothers of babies to be examined on the following shift.	Observer
1.2.2	For each shift, we will observe babies of the same patient severity classification either A, B or C (An existing schedule of observations would be circulated across the research team). Category A babies are unstable babies who need closer monitoring and can be identified based on their requirements for	Observer

<table>
<tr><td></td><td>interventions such as CPAP, oxygen, IV Fluid, blood transfusion, needing radiant warmers or incubators to maintain their temperature

Category B babies have stabilised but are still ill and receiving care. They do not require interventions above but might still need care such as assistive feeding (nasogastric tube), intravenous medication, double phototherapy

Category C are stable babies. This category is limited in terms of observation and can include term babies on phototherapy, stable abandoned babies or babies accommodated due to maternal illness</td><td></td></tr>
<tr><td>1.2.3</td><td>Settle down to conduct observations of care using the structured checklist on 4 admitted babies of the same category. It is important this happens as soon as possible when the shift commences so as not to miss out on nursing processes that occur early in the shift.</td><td>Observer</td></tr>
<tr><td>1.2.4</td><td>Because care is usually bundled, time a ward walk around in periods outside times care is expected to be provide and complete the following portions of the checklist:

1. Determine the number of babies in the acute room and Kangaroo mother care room
2. Headcount of the number of babies on the following intervention (Note- a baby can be on 2 or more of the interventions below and should still be counted in each individual intervention):
a. Babies on continuous positive airway pressure (CPAP)
b. Babies on oxygen
c. Babies on phototherapy
d. Babies under incubator care
e. Babies on Intravenous therapy (IV fluids/ IV medication)</td><td>Observer</td></tr>
<tr><td>1.2.5</td><td>During less busy periods also review the case notes and treatment sheets of the 4 selected babies to be observed. Identify and complete the baby’s biodata and medication sections of the structured tool:

1. Current diagnoses
2. Current ages (please write this in days if above 24 hours old or in hours if less than 24 hours)
3. Date of admission
4. Gender
5. Birth weight
6. Intravenous and oral medications the child is on and the frequency</td><td>Observer</td></tr>
</table>

1.2.6	Within the 12-hour shift period, determine the number of nurses on the shift. Remember for day observation shifts there might be as many as 3 shifts, a morning (07:30 to 12:30), an afternoon (12:30 to 18:30) and an evening (07:30 to 16:30). Tally the total number of nurses on each shift. A nurse on morning shift cannot be included for the afternoon shift and vice-versa. Night observations are more straight forward as there is only 1 set of nurses	Observer
1.2.7	Within the 12-hour shift period, determine the number of the following non-nursing staff cadres who attended the shift. 1. Nursing students 2. Medical officers 3. Clinical officer interns 4. Medical officer interns 5. Nursing officer interns	Observer
1.2.8	Observe whether routine nursing processes were conducted and document the time, for example, whether a nurse attended ward rounds while the patient was being reviewed or whether a nurse assessed a patient	Observer
1.2.9	Observe and document whether vital signs (temperature, heart rate, respiratory rate, pulse oximetry) are conducted, by whom and at what time. Monitoring of vital sign frequency will depend on the patient care category, therefore, circle the expected frequency for vital signs before this (Category A babies should have at least 4 hourly vitals and this should happen twice in a 12-hour shift. Category B and C babies should be monitored at least 6 and 12 hourly respectively)	Observer
1.2.10	Keep field notes and make additional observations in them as guided by wider research team	Observer
1.2.11	DO NOT participate in care of newborn under any circumstances. If you notice an emergency call the attention of the nurse on duty	Observer, ARO, RO
1.2.12	Complete observations for entire 12-hour shift. Breaks can be taken with nursing staff during this period and should be avoid during busy unit periods.	Observer
1.2.13	At the end of the shift, crosscheck whether the following information were documented for the observed patients and complete the necessary portions of the checklist 1. neonatal nurse assessments, nursing care plans, health talk with parents and ward round details from the nursing cardex	Observer

	2. Temperature, heart rate, respiratory rate, oxygen saturation, weight check from the vital sign charts and patient monitoring charts 3. Frequency and volume of intravenous fluids or oral feeds from the input and output chart and patient monitoring chart.	
1.3	**General etiquette during observations**	
1.3.1	Treat families and staff with respect	All
1.3.2	Keep mobile phones on silent and keep usage to a minimum while conducting observations. Avoid personal calls while at work as this is likely to be a distraction.	Observer
1.3.3	Put on your name tag/badge	All
1.3.4	Dress appropriately for the newborn units (Short sleeves, fold your sleeves, minimal jewellery)	All
1.4	**Post-observation period**	
1.4.1	Put all observation sheets in a clear bag and place in a previously identified safe place for collections by research team	Observers
1.4.2	Regular debrief with supervising RO and ARO at least twice a week	Observers, ARO, RO
1.4.3	Retrieve completed observation checklists during supervision visits	DPhil, ARO, RO
1.4.4	Weekly debrief meetings on observations including challenges on the field	All

References

1. Serem G, Gathara D, English M, Murphy GA. Quantify nursing care delivered to sick newborns and its adherence to practice guidelines. SOP- Procedures for general study conduct.

Standard operating procedure **– Ensuring data quality**

SSP Title	**ENSURING DATA QUALITY**		
SSP Number:	01	**Version and date:**	V1.0, 03 FEB, 2021
SERU approval number	KEMRI/SERU/CGMR-C/229/4203		
Prepared by **(Name, title)**	Abdulazeez Imam (DPhil candidate)		
Signature and date	…………………………………		……………………………………..
Reviewed by **(Name, title)**	David Gathara, Michuki Maina, Vincent Kagonya and Onesmus Onyango		
Signature and date	…………………………………		……………………………………..

Background

Making valid inferences from our research requires that the data we collect should be of high quality and be credible. Traditionally, quality data has been determined by data possessing some characteristics, for example being error free, complete, and collected in a consistent manner **(259)**.

Purpose

This SSP describes how we will ensure the data we collect fulfil the traditional metrics of being free of error, complete and that they are collected in a consistent manner across hospital sites and across every member of the research team.

Scope

This SSP applies to all members of the study team including Observers, Research Officers (ROs), Assistant Research Officers (AROs), DPhil students, Post-doctoral Researchers (PR), Study Co-ordinator (SC) who will be involved in the recruitment of study participants.

Equipment/ Materials

- Wristwatches
- SOPs
- Study manual

Responsible persons

The SC, PR, and the DPhil are responsible for:

- Ensuring all AROs, ROs and observers are duly trained on conducting observations of care and health facility assessments
- Organising pilot exercises for AROs, ROs and observers to ensure there is internal consistency in data collection across the research team
- Developing a study manual that defines and explains the various nursing and patient processes that are being observed.
- Conducting random spot checks on field research activities
- Cross-checking data collected for errors

The RO and ARO are responsible for:

- Review of data collected from the field for errors and completeness
- Conducting random spot checks on observations of care being conducted in hospitals

The observers are responsible for:

- Ensuring the data, they collect is credible

Procedures

Section	Description	Responsible persons
1.1	**Overview**	
1.1.1	**Data quality metric definitions**	
1.1.1.1	**Credibility-** This is the extent to which data is believable	
1.1.1.2	**Completeness–** This is the extent to which data is not missing and is of sufficient quantity (breadth and depth) for the task being conducted.	
1.1.1.3	**Consistency –** The extent to which data is collected in the same manner and format.	
1.1.2	**Free of error-** The extent to which data is correct and reliable	
1.2	**Procedure for ensuring credibility**	
1.2.1	Collected data **SHOULD NEVER** be falsified or fabricated. Falsification means manipulating the data to give a false impression an example of this might be removing an inconvenient observation or falsely changing data collected during observations. Fabrication means making up research findings, for example, creating data that was not observed because of absence for any reason. If for some reason you could not determine or collect required data, write an 'E' in the data section, and put a note in the comment section of the observational checklist. Also, make use of the comment section to provide additional information for clarity where appropriate.	All
1.3	**Procedure for ensuring completeness**	
1.3.1	It is important we are collecting data that is complete. Incomplete data will weaken our ability to draw meaning from the data we are collecting	All
1.3.2	Ensuring all required data fields are filled completely during observations and health facility assessments.	Observer, ARO, RO
1.3.2	Writing an 'E' in the specific data section and writing a note in the comment section of the observational checklist if for any reason particular data could not be collected or determined. This will allow differentiation from data that could not be ascertained, and data was mistakenly omitted.	Observer, ARO, RO

1.3.3	cross-checking returned observation checklist for any missingness	ARO, RO
1.3.4	Cross-checking the observation checklist and health facility assessment tool during data entry for any missingness not observed in 1.3.3	Data entry clerk
1.4	**Procedure for ensuring consistency**	
1.4.1	It is important we are collecting data in the same manner across our research sites and between individuals as this will strengthen how valid the conclusions we draw are.	All
1.4.2	Piloting observational checklist and health facility assessment tools to ensure internal consistency among research team	All
1.4.3	Identify, if possible, a standard and uniform set of documents where observers should derive the information to complete the documentation section of the observational checklist	All
1.4.4	Generating a weekly schedule of observations, that will include the timing of observations (day/night or weekday/weekend) and the category of babies being observed (A, B or C)	SC, PR, DPhil
1.4.5	Conducting a set of observations with the observers during spot check visits to make sure data is being collected consistently	RO, ARO, DPhil
1.4.6	Conducting periodic retraining if significant deviations in methods are observed in the field	SC, PR, DPhil, RO, ARO
1.5	**Procedure for ensuring data collected is error free**	
1.5.1	Conducting random spot check visits. In addition to 1.4.3, these are to minimise errors in data collection and should include- a.) Reviewing whether the correct categories of babies were selected for observations by the observer. If there is any error observed, this is an opportunity to conduct re-training of the personnel. b.) Reviewing whether the correct frequency of observations was selected for the category of baby being observed. c.) Review whether the correct patient diagnosis and baby's other biodata were recorded. d.) Check the consent documents are completed appropriately	RO, ARO, DPhil
1.5.2	Have a wristwatch for your observations to determine the time activities were carried out.	Observer
1.5.3	Double check a random 10-20% of data entry to ensure there are no errors in the data entry process.	RO, ARO, Investigator

One page checklist for identifying patient categories

Category A (unstable) – can be on one or a combination of:

- CPAP
- Oxygen
- Intravenous fluids
- Blood transfusion
- Under radiant warmer
- Incubator care

Category B - stable but still ill

- **SHOULD NOT BE ON ANY THERAPY LISTED FOR CATEGORY A**
- On IV medication
- On NG-tube feeding
- On double phototherapy

Category C - stable baby

- **SHOULD NOT BE ON ANY THERAPY LISTED FOR CATEGORY A and B**
- Term baby on phototherapy alone
- Baby accommodated because the mother is ill.
- Stable preterm on KMC
- On oral medications only

Guidelines for hospital entry (Week 1)

The following guidelines should be followed on entry into the hospitals where the missed care study is to be conducted.

- Ensure all hospitals have consented to conduct the study in their hospital's newborn unit. The letter the hospital wrote to the principal investigator approving the study should prove this.
- The observers meeting the minimum qualification criteria outlined in the study protocol should have been fully trained on the study and the consenting process.
- On arrival at the hospital, the team should first meet the relevant administration (medical superintendent, medical director, depending on hospital protocols)
- The team shall then be introduced to the human resources/hospital administration to be given identification badges
- The team shall then be introduced to the hospital nurse manager/chief nurse, who will introduce them to the heads of the newborn unit (i.e. paediatrician and unit nurse in charge)
- The team shall give a CME about the study to the nurses in the newborn unit and address any concerns that might arise
- The team shall spend time in the newborn care area for not less than 3 days. During this period, the team shall:
  - Familiarize with the newborn unit surrounding
  - Familiarize with the routine procedures in the unit
  - Familiarize with unit nurses and other staff in the unit
  - Interact with parents/guardians
  - Do preliminary observations and consenting
- The team shall then meet to discuss any shortcomings and have them addressed

Goals for familiarisation week for observers

Goals	Performed (Tick)
Familiarise with the newborn unit layout including location of wards, where folders and files are kept etc	☐
Familiarise with the newborn unit schedule of activities and staff	☐
Interact with parent and guardians within the newborn unit	☐
Identify other important sections of the hospital such as the postnatal ward where mothers reside	☐
Conduct consenting of nurses	☐
Conduct preliminary consenting with caregivers and determine what best works for you	☐
Conduct at least **Two** 12-hour day shift observation of care. Perform all processes related to the NCI including consenting of patients for this process. Please keep your sheet and return it to the team	☐
Attend **One** night shift hand-over to observe transition between day and night shift	☐
Debrief with the research team on Thursday/ Friday	☐
Shadowing of a nurse – one day (intervention hospitals only – Embu, Nyeri, Machakos and Kiambu)	☐

Appendix 5– Ethical approvals

Figure – Oxford Tropical Research Ethics Committee approval letter

Oxford Tropical Research Ethics Committee

University of Oxford
Research Services, University Offices
Wellington Square, Oxford OX1 2JD
Tel. +44 (0) 1865 (2)82106
E-mail: oxtrec@admin.ox.ac.uk

UNIVERSITY OF OXFORD

Professor Mike English
Centre for Tropical Medicine and Global Health
Peter Medawar Building for Pathogen Research (PMB)
South Parks Road
Oxford OX1 3SY

25 November 2021

Dear Professor English,

Full Title of Study: Evaluating the effects of technology and workforce enhancement to support neonatal hospital care in Kenya (HIGH-Q)

OxTREC Reference: 26-21

Thank you for your letter of 15 November 2021 in which you have responded to the Committee's request for further clarification.

I am pleased to confirm that approval has now been granted for this study. This is valid for the first five years and is subject to receiving the local ethical approval (if this approval has not yet been received).

The documents approved for this study are as follows:

Documents:	**Version:**	**Date:**
OxTREC application form		
Protocol (including appendices)	V3.0	19/05/21
Addendum to protocol		10/08/21
Information Leaflet		
PI Signature Form		

Any subsequent changes to the application must be submitted to the Committee as an Amendment. This should include a letter to give the reasons for the proposed modifications and all revised documents with changes tracked.

Please ensure that you submit a completed Annual Report form on every anniversary of this approval and a final End of Study Report. The relevant forms can be found on the OxTREC website: https://researchsupport.admin.ox.ac.uk/governance/ethics/apply/oxtrec.

Finally, please note the following **important information**:

Data safety—all studies
It is the responsibility of the PI to ensure that all data collected during the course of the study is stored and transferred safely and securely. Further guidance and advice is available from the Research Data Team.

Only studies that will involve storing human tissue samples in Oxford
If you are planning to import the samples into England, you will need to make arrangements before the samples are transferred to store them under the governance of a Human Tissue Authority (HTA) licence. It is a legal requirement that any tissue or fluid made up of or containing human cells to be used for the purpose of research is stored on premises licensed by the HTA unless covered by an exemption. OxTREC approval is not a recognised exemption. Further information may be found on the University's human tissue governance web pages: https://researchsupport.admin.ox.ac.uk/governance/human-tissue.

Yours sincerely,

Rebecca A Bryant

Dr. Rebecca Bryant
Research Ethics Manager, OxTREC

Figure – Kenya Medical Research Institute approval letter

KENYA MEDICAL RESEARCH INSTITUTE

P.O. Box 54840-00200, NAIROBI, Kenya
Tel: (254) 2722541, 2713349, 0722-205901,0733-400003, Fax: (254) (020) 2720030
Email: director@kemri.org, info@kemri.org, Website. www.kemri.org

KEMRI/RES/7/3/1 **May 12, 2021**

TO: **DR. MICHUKI MAINA,**
PRINCIPAL INVESTIGATOR

THROUGH: **THE DEPUTY DIRECTOR, CGMR-C,**
NAIROBI.

Dear Sir,

RE: PROTOCOL NO. KEMRI/SERU/CGMR-C/229/4203 *(INITIAL SUBMISSION)*: LEARNING TO HARNESS INNOVATION IN GLOBAL HEALTH FOR QUALITY CARE (HIGH-Q)

This is to inform you that during the 310th Committee C meeting of the KEMRI Scientific and Ethics Review Unit (SERU) held on **April 29, 2021**, the above referenced application was discussed.

SERU acknowledges the receipt of the following documents:

1. SERU Submission Form
2. Letter from the Secretary, CSC
3. Response to CSC reviewers' comments
4. Study Protocol HIGH Q Version 2.0 29_03_2021
5. Participant information and Informed consent document(s) HIGH Q Version 2.0 29_03_2021
6. Study tools (Interview and FGD guides) HIGH Q Version 2.0 29_03_2021
7. CVs of non-KEMRI investigators
8. Investigator ethics certificate

The Committee noted that the above study aims to understand how technological and human resource interventions can be designed and implemented successfully to enhance the quality of inpatient and post-discharge neonatal care.

After careful consideration, the Committee concluded that more information is necessary before a final decision on the application can be reached:

1. Ethics certificates for Dr. Jalemba Aluvaala and Ms. Edith Gicheha are missing. Kindly provide.
2. Dr. Jalemba Aluvaala (Appendex 1 Investigators role) His role is missing. Please indicate his roles.
3. The title is very general and needs to be specific addressing the technologies in neonatal units. Please revise.
4. Please attach missing CVs for all non-KEMRI investigators.

In Search of Better Health

5. Please include the reimbursement fee range in the consent forms.
6. Reimbursement fee has not been included in the budget. Kindly include.

Please address the issues raised and submit soft copies of the revised application to the SERU Secretariat via email, seru@kemri.org and kemriseru18@gmail.com by **June 12, 2021** for further action.

Yours faithfully,

ENOCK KEBENEI,
THE ACTING HEAD,
KEMRI SCIENTIFIC AND ETHICS REVIEW UNIT.

Figure – National Commission for Science, Technology and Innovation research license

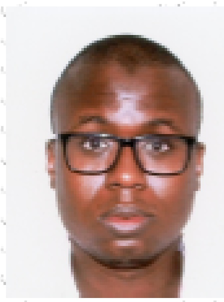
REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 251210

Date of Issue: 01/November/2022

RESEARCH LICENSE



This is to Certify that Dr.. ABDULAZEEZ IMAM of CENTRE FOR GEOGRAPHIC MEDICINE RESEARCH-COAST (CGMRC), has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Bungoma, Embu, Kakamega, Kiambu, Kirinyaga, Kisumu, Machakos, Nairobi, Nakuru, Nyeri on the topic: EVALUATING THE EFFECTS OF A HEALTH WORKFORCE INTERVENTION ON INDICATORS OF QUALITY OF NEWBORN CARE IN KENYAN NEONATAL UNITS for the period ending : 01/November/2023.

License No: NACOSTI/P/22/21337

251210

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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See overleaf for conditions

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013 (Rev. 2014)
Legal Notice No. 108: The Science, Technology and Innovation (Research Licensing) Regulations, 2014

The National Commission for Science, Technology and Innovation, hereafter referred to as the Commission, was the established under the Science, Technology and Innovation Act 2013 (Revised 2014) herein after referred to as the Act. The objective of the Commission shall be to regulate and assure quality in the science, technology and innovation sector and advise the Government in matters related thereto.

CONDITIONS OF THE RESEARCH LICENSE

1. The License is granted subject to provisions of the Constitution of Kenya, the Science, Technology and Innovation Act, and other relevant laws, policies and regulations. Accordingly, the licensee shall adhere to such procedures, standards, code of ethics and guidelines as may be prescribed by regulations made under the Act, or prescribed by provisions of International treaties of which Kenya is a signatory to
2. The research and its related activities as well as outcomes shall be beneficial to the country and shall not in any way;
   i. Endanger national security
   ii. Adversely affect the lives of Kenyans
   iii. Be in contravention of Kenya's international obligations including Biological Weapons Convention (BWC), Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Chemical, Biological, Radiological and Nuclear (CBRN).
   iv. Result in exploitation of intellectual property rights of communities in Kenya
   v. Adversely affect the environment
   vi. Adversely affect the rights of communities
   vii. Endanger public safety and national cohesion
   viii. Plagiarize someone else's work
3. The License is valid for the proposed research, location and specified period.
4. The license any rights thereunder are non-transferable
5. The Commission reserves the right to cancel the research at any time during the research period if in the opinion of the Commission the research is not implemented in conformity with the provisions of the Act or any other written law.
6. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research.
7. Excavation, filming, movement, and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
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13. The Licensee shall disclose to the Commission, the relevant Institutional Scientific and Ethical Review Committee, and the relevant national agencies any inventions and discoveries that are of National strategic importance.
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15. Relevant Institutional Scientific and Ethical Review Committee shall monitor and evaluate the research periodically, and make a report of its findings to the Commission for necessary action.

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Appendix 6 – search strategy and strings for Umbrella review

Table - Umbrella review - Medline and Embase search strategy

1.	Nursing Staff, Hospital/
2.	Nurse's Role/
3.	Specialties, Nursing/
4.	Nurse-Patient Relations/
5.	((nurse* or nursing) adj3 (staff* or ratio or ratios or workforce or workload or sensitive or mix or practitioner* or assistant* or practice* or performance)).ab,kw,ti.
6.	1 or 2 or 3 or 4 or 5
7.	"Personnel Staffing and Scheduling"/
8.	Health Care Rationing/
9.	"Quality of Health Care"/
10.	Quality Indicators, Health Care/
11.	Patient Safety/
12.	Outcome Assessment, Health Care/
13.	(outcome* or impact* or safety or quality or evidence or indicator* or advers* or mortality or death* or omission* or missed or missing or unmet or undone or rationed or rationing).ti.
14.	"missed nursing".ab,kw,ti.
15.	"missed care".ab,kw,ti.
16.	7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15
17.	(systematic and review).ti.

18. ("meta analysis" or metaanalysis).ti.
19. "Systematic Review"/
20. Meta-Analysis/
21. 17 or 18 or 19 or 20
22. 6 and 16 and 21

Table – Umbrella review search strategy in CINAHL

S1	MH "NURSING STAFF, HOSPITAL"/ OR MH "NURSE'S ROLE"/ OR MH "SPECIALTIES, NURSING"/ OR MH "NURSE-PATIENT RELATIONS"/ OR (TI "nurse*" N3 "STAFF*") OR (AB "nurse*" N3 "STAFF*") OR (TI "nurse*" N3 "RATIO") OR (AB "nurse*" N3 "RATIO") OR (TI "nurse*" N3 "RATIOS") OR (AB "nurse*" N3 "RATIOS") OR (TI "nurse*" N3 "WORKFORCE") OR (AB "nurse*" N3 "WORKFORCE") OR (TI "nurse*" N3 "WORKLOAD") OR (AB "nurse*" N3 "WORKLOAD") OR (TI "nurse*" N3 "SENSITIVE") OR (AB "nurse*" N3 "SENSITIVE") OR (TI "nurse*" N3 "MIX") OR (AB "nurse*" N3 "MIX") OR (TI "nurse*" N3 "PRACTITIONER*") OR (AB "nurse*" N3 "PRACTITIONER*") OR (TI "nurse*" N3 "ASSISTANT*") OR (AB "nurse*" N3 "ASSISTANT*") OR (TI "nurse*" N3 "PRACTICE*") OR (AB "nurse*" N3 "PRACTICE*") OR (TI "nurse*" N3 "PERFORMANCE") OR (AB "nurse*" N3 "PERFORMANCE") OR (TI "nursing" N3 "STAFF*") OR (AB "nursing" N3 "STAFF*") OR (TI "nursing" N3 "RATIO") OR (AB "nursing" N3 "RATIO") OR (TI "nursing" N3 "RATIOS") OR (AB "nursing" N3 "RATIOS") OR (TI "nursing" N3 "WORKFORCE") OR (AB "nursing" N3 "WORKFORCE") OR (TI "nursing" N3 "WORKLOAD") OR (AB "nursing" N3 "WORKLOAD") OR (TI "nursing" N3 "SENSITIVE") OR (AB "nursing" N3 "SENSITIVE") OR (TI "nursing" N3 "MIX") OR (AB "nursing" N3 "MIX") OR (TI "nursing" N3 "PRACTITIONER*") OR (AB "nursing" N3 "PRACTITIONER*") OR (TI "nursing" N3 "ASSISTANT*") OR (AB "nursing" N3 "ASSISTANT*") OR (TI "nursing" N3 "PRACTICE*") OR (AB "nursing" N3 "PRACTICE*") OR (TI "nursing" N3 "PERFORMANCE") OR (AB "nursing" N3 "PERFORMANCE")
S2	MH "Personnel Staffing and Scheduling"/ OR MH "Health Care Rationing"/ OR MH "Quality of Health Care"/ OR MH "Quality Indicators, Health Care"/ OR MH "Patient Safety"/ OR MH "Outcome Assessment, Health Care"/ OR TI(outcome* OR impact* OR safety OR quality OR evidence OR indicator* OR advers* OR mortality OR death* OR omission* OR missed OR missing OR unmet OR undone OR rationed OR rationing) OR TI ("missed nursing") OR AB ("missed nursing") OR TI ("missed care") OR AB ("missed care")
S3	TI (systematic AND review) OR TI ("meta analysis" OR metaanalysis) OR MH "Systematic Review"/ OR MH "Meta-Analysis/")
S4	S1 AND S2 AND S3

Appendix 7 – AMSTAR-2 criteria for evaluation risk of bias in systematic reviews.

Question number	Questions
Question 1	*Did the research questions and inclusion criteria for the review include the components of PICO?*
Question 2	*Did the review report explicitly state that the review methods were established before the review was conducted, and did the report justify any significant deviations from the protocol?*
Question 3	*Did the review authors explain their selection of the study designs for inclusion in the review?*
Question 4	*Did the review authors use a comprehensive literature search strategy?*
Question 5	*Did the review authors perform study selection in duplicate?*
Question 6	*Did the review authors perform data extraction in duplicate?*
Question 7	*Did the review authors provide a list of excluded studies and justify the exclusions?*
Question 8	*Did the review authors describe the included studies in adequate detail?*
Question 9	*Did the review authors use a satisfactory technique for assessing the risk of bias in individual studies included in the review?*
Question 10	*Did the review authors use a satisfactory technique for assessing the risk of bias in individual studies included in the review?*
Question 11	*If meta-analysis was performed, did the review authors use appropriate methods for statistical combination of results?*
Question 12	*If meta-analysis was performed, did the review authors assess the potential impact of risk of bias in individual studies on the results of the meta-analysis or other evidence synthesis?*
Question 13	*Did the review authors account for the risk of bias in primary studies when interpreting/discussing the results of the review?*
Question 14	*Did the review authors provide a satisfactory explanation for and discussion of any heterogeneity observed in the results of the review?*
Question 15	*If they performed quantitative synthesis, did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?*
Question 16	*Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?*

Appendix 8 – Data abstraction tool template for umbrella review

Question 1: a. What proportion of studies in published systematic reviews were conducted in LMICs (answered by column G)

Table 1: Descriptives of included systematic reviews

First author (year)	Review Objectives	Review period	setting	Number of primary studies included*	List of countries where primary studies were conducted	LMICs/ HICs (%)
						LMIC – HIC –
				* – In reviews considering multiple outcomes e.g. Patient and nurse outcomes, only studies reporting patient outcomes will be included		

Table 2 : Primary studies and overlaps between systematic reviews

	Systematic reviews				
Primary study	Review 1	Review 2	Review 3	Review 4	Review 5
Study 1 et al	X				
Study 2 et al			X		X
Study 3 et al		X			

Q 1b : What is the range of nurse staffing levels that have been researched across care settings and how do this differ from conventional staffing in LMICs?

Table 3 : Synthesis from primary studies retreived from reviews

Staffing Metric : Nurse to patient ratios					Outcomes			
First author (year)	Country	LMIC (YES/NO)	Standard staffing	enhanced staffing	outcome A	out b	out c	out d
Linda et al (2020)	Namibia	YES	x:y	a:b	x	x		x
Greg et al (2019)	Singapore	NO	r:s	t:l		x	x	
Staffing Metrics: Nursing Hours per patient day								
Gout et (2001)	US	NO	2.6	4.8		x		x

Question 1a: what patient care outcomes do primary studies report and how do this differ between HICs and LMICs?

Table 4 : Comparison of outcomes from primary studies conducted in LMICs and HICs

Patient Outcome	Number of studies conducted in HICs (row %	Number of studies conducted in LMICs (row %)	Total

Appendix 9 – Excluded systematic reviews and reasons for exclusion

First Author	Year	Citation	Reason for exclusion	Explanation
Bae et al	2014	Bae SH, Fabry D. Assessing the relationships between nurse work hours/overtime and nurse and patient outcomes: systematic literature review. Nursing outlook. 2014 Mar 1;62(2):138-56.	Wrong intervention	Intervention was nurse working hours which is not a metric of nurse staffing level
Butler et al	2019	Butler M, Schultz TJ, Halligan P, Sheridan A, Kinsman L, Rotter T, Beaumier J, Kelly RG, Drennan J. Hospital nurse-staffing models and patient-and staff-related outcomes. Cochrane Database of Systematic Reviews. 2019(4).	Wrong intervention	Intervention was nurse staffing models not ratio change or change in other metrics of nurse staffing
Wilson et al	2010	Wilson S, Bremner A, Hauck Y. Association between nurse staffing and hospitalised children's health outcomes: A systematic review. JBI Evidence Synthesis. 2010 Jan 1;8(8):1-5.	Protocol paper	
Recio-Saucedo et al	2018	Recio-Saucedo A, Dall'Ora C, Maruotti A, Ball J, Briggs J, Meredith P, Redfern OC, Kovacs C, Prytherch D, Smith GB, Griffiths P. What impact does nursing care left undone have on patient outcomes? Review of the literature.	Wrong intervention	Impact of missed nursing care on patient care outcomes and not the impact of staffing

		Journal of clinical nursing. 2018 Jun;27(11-12):2248-59.		
Shekelle et al	2013	Shekelle PG. Nurse–patient ratios as a patient safety strategy: a systematic review. Annals of internal medicine. 2013 Mar 5;158(5_Part_2):404-9.	Literature review	Narrative literature review
Papastavrou et al	2014	Papastavrou E, Andreou P, Efstathiou G. Rationing of nursing care and nurse–patient outcomes: a systematic review of quantitative studies. The International journal of health planning and management. 2014 Jan;29(1):3-25.	Wrong intervention	Impact of missed nursing care on patient care outcomes and not the impact of nurse staffing
Driscoll et al	2018	Driscoll A, Grant MJ, Carroll D, Dalton S, Deaton C, Jones I, Lehwaldt D, McKee G, Munyombwe T, Astin F. The effect of nurse-to-patient ratios on nurse-sensitive patient outcomes in acute specialist units: a systematic review and meta-analysis. European Journal of Cardiovascular Nursing. 2018 Jan 1;17(1):6-22.	Wrong study setting (non-ward setting)	All papers from intensive care unit
Garcia et al	2010	García F, Sampietro-Colom L. Nursing staff and patient results: systematic review about the existing relationship.	Non-English paper	Spanish

		Revista de enfermeria (Barcelona, Spain). 2010 Jan 1;33(1):14-26.		
Al-ghraiybah et al	2021	Al-ghraiybah T, Sim J, Lago L. The relationship between the nursing practice environment and five nursing-sensitive patient outcomes in acute care hospitals: A systematic review. Nursing Open. 2021 Mar 4.	Wrong intervention	Intervention is nurse practice environment and not nurse staffing
dit Dariel et al	2015	dit Dariel OP, Regnaux JP. Do Magnet®-accredited hospitals show improvements in nurse and patient outcomes compared to non-Magnet hospitals: a systematic review. JBI Evidence Synthesis. 2015 Jun 1;13(6):168-219.	Wrong intervention	Intervention is magnet accreditation and not nurse staffing
Kazanijan et al	2005	Kazanjian A, Green C, Wong J, Reid R. Effect of the hospital nursing environment on patient mortality: a systematic review. Journal of Health Services Research & Policy. 2005 Apr 1;10(2):111-7A.	Wrong intervention	Intervention is nurse practice environment and not nurse staffing
Johnston et al	2015	Johnston MJ, Arora S, King D, Bouras G, Almoudaris AM, Davis R, Darzi A. A systematic review to identify the factors that affect failure to rescue and escalation of care in surgery. Surgery. 2015 Apr 1;157(4):752-63.	Wrong intervention	Focused on factors that affect failure to rescue and not nurse staffing

Kushemererwa et al	2020	Kushemererwa D, Davis J, Moyo N, Gilbert S, Gray R. The Association between Nursing Skill Mix and Mortality for Adult Medical and Surgical Patients: Protocol for a Systematic Review. International Journal of Environmental Research and Public Health. 2020 Jan;17(22):8604.	Protocol paper	Protocol paper and not original article
Olley et al	2018	Olley R, Edwards I, Avery M, Cooper H. Systematic review of the evidence related to mandated nurse staffing ratios in acute hospitals. Australian Health Review. 2018 Apr 17;43(3):288-93.	Wrong outcome	Outcome is on general evidence and not patient care outcomes
Copanitsanou et al	2017	Copanitsanou P, Fotos N, Brokalaki H. Effects of work environment on patient and nurse outcomes. British Journal of Nursing. 2017 Feb 9;26(3):172-6.	original paper	Original paper and not a systematic review
Myers et al	2018	Myers H, Pugh JD, Twigg DE. Identifying nurse-sensitive indicators for stand-alone high acuity areas: A systematic review. Collegian. 2018 Aug 1;25(4):447-56.	Wrong study setting (non-ward setting)	Intensive care unit
Bae et al	2021	Bae SH. Relationships between comprehensive characteristics of nurse work schedules and adverse patient outcomes: A systematic	Wrong intervention	Intervention is nurses' working schedule and not nurse staffing

		literature review. Journal of Clinical Nursing. 2021 Feb 22.		
Butler et al	2011	Butler M, Collins R, Drennan J, Halligan P, O'Mathuna D, Schultz T, Sheridan A, Vilis E. Hospital nurse staffing models and patient and staff-related outcomes-an epic EPOC systematic review. JBI Evidence Implementation. 2011 Sep 1;9(3):326.	Wrong intervention	Intervention is nurse staffing models not a change in nurse staffing numbers
Bae et al	2011	BAE SH. Assessing the relationships between nurse working conditions and patient outcomes: systematic literature review. Journal of nursing management. 2011 Sep;19(6):700-13.	Wrong intervention	Intervention is nurse working conditions and not nurse staffing

Appendix 10 - Excluded primary studies within systematic reviews and reasons for exclusion.

systematic review	Title	reason for exclusion
Griffith et al	Zander, B., Dobler, L., Bäumler, M. and Busse, R., 2014. Implicit rationing of care services in German acute care hospitals – Results of the international nursing study Rn4cast. Health Care, 76(11), pp.727-734.	German
Assaye et al	Soares M, Bozza FA, Angus DC, Japiassu AM, Viana WN, Costa R, et al. Organizational characteristics, outcomes, and resource use in 78 Brazilian intensive care units: the ORCHESTRA study. Intensive Care Med 2015;41(12):2149– 60.	ICU setting
	Silva MCMd, Sousa RMCd, Padilha KG. Factors associated with death and readmission into the Intensive Care Unit. Rev Lat Am Enfermagem 2011;19:911–9.	ICU setting
	Chittawatanarat K, Sataworn D, Thongchai C. Thai Society of Critical Care Medicine Study G. Effects of ICU characters, human resources and workload to outcome indicators in Thai ICUs: the results of ICU-RESOURCE I study. J Med Assoc Thai 2014;97(Suppl 1):S22–30.	ICU setting
	Cremasco MF, Wenzel F, Zanei SSV, Whitaker IY. Pressure ulcers in the intensive care unit: the relationship between nursing workload, illness severity and pressure ulcer risk. J Clin Nurs 2013;22(15/16):2183–91.	ICU setting
	Al Tehewy M, Fahim H, Gad NI, El Gafary M, Rahman SA. Medication administration errors in a university hospital. J Patient Saf 2016;12(1):34–9.	Wrong intervention (number and type of shift)
	Daud-Gallotti RM, Costa SF, Guimara˜es T, Padilha KG, Inoue EN, Vasconcelos TN, et al. Nursing workload as a risk factor for health care associated infections in	ICU setting

	ICU: a prospective study. PLoS One 2012;7(12):e52342.	
	Celen MK, Tamam Y, Hosoglu S, Ayaz C, Geyik MF, Apak I. Multiresistant bacterial colonization due to increased nurse workload in a neurology intensive care unit. Neurosciences 2006;11(4):265–70.	ICU setting
	Aycan IO, Celen MK, Yilmaz A, Almaz MS, Dal T, Celik Y, et al. Bacterial colonization due to increased nurse workload in an intensive care unit. Rev Brasil Anestesiol 2015;65:180–5	ICU setting
	. Cremasco MF, Wenzel F, Zanei SSV, Whitaker IY. Pressure ulcers in the intensive care unit: the relationship between nursing workload, illness severity and pressure ulcer risk. J Clin Nurs 2013;22(15/16):2183–91	ICU setting
	Bjorklund de Lima L, Rejane Rabelo E. Nursing workload in the post-anesthesia care unit. Acta Paul Enferm 2013;26(2): 116–22	Wrong intervention (Nursing workload measure)
	Day SW. Evaluating the impact of the Guatemalan Nursing Program on staff, organizational, and clinical outcomes. University of Tennessee Health Science Center; 2010; p. 93	Wrong intervention (Addition of a nurse educator)
	Ilhan MN, Durukan E, Taner E, Maral I, Bumin MA. Burnout and its correlates among nursing staff: questionnaire survey. J Adv Nurs 2008;61(1):100–6	Nurse outcome (Burn out)
	Karakoc A, Yilmaz M, Alcalar N, Esen B, Kayabasi H, Sit D. Burnout syndrome among hemodialysis and peritoneal dialysis nurses. Iran J Kidney Dis 2016;10(6):395–404.	Nurse outcome (Burn out)
	Roomaney R, Steenkamp J, Kagee A. Predictors of burnout among HIV nurses in the Western Cape. Curationis 2017;40(1):1–9	Nurse outcome (Burn out)

	Kunaviktikul W, Wichaikhum O, Nantsupawat A, Nantsupawat R, Chontawan R, Klunklin A et al. Nurses' extended work hours: patient, nurse and organizational outcomes. Int Nurs Rev 2015;62(3):386–93.	Wrong intervention (Nursing workload measure)
	De Paiva LC, Gomes Cana´rio AC, Corsino de Paiva China EL, Gonc¸alves AK. Burnout syndrome in health-care professionals in a university hospital. Clinics 2017;72(5):305–9.	Nurse outcome (Burn out)
	Lu MM, Ruan H, Xing WJ, Hu Y. Nurse burnout in China: a questionnaire survey on staffing, job satisfaction, and quality of care. J Nurs Manag 2015;23(4):4	Nurse outcome (Burn out)
	Mohammadpoorasl A, Maleki A, Sahebihagh MH. Prevalence of professional burnout and its related factors among nurses in Tabriz in 2010. IJNMR 2012;17(7):524–9	Nurse outcome (Burn out)
	Naz S, Hashmi AM, Asif A. Burnout and quality of life in nurses of a tertiary care hospital in Pakistan. J Pak Med Assoc 2016;66(5):532–6	Nurse outcome (Burn out)
	. Negi Y, Bagga R. Burnout among nursing professionals in tertiary care hospitals of Delhi. J Health Manag 2015;17(2):163–77	Nurse outcome (Burn out)
	Nantsupawat A, Srisuphan W, Kunaviktikul W, Wichaikhum, Aungsuroch Y, Aiken LH. Impact of nurse work environment and staffing on hospital nurse and quality of care in Thailand. J Nurs Scholarsh 2011;43(4):426–32	Nurse outcome (Burn out)
	Nantsupawat A, Nantsupawat R, Kulnaviktikul W, McHugh MD. Relationship between nurse staffing levels and nurse outcomes in community hospitals, Thailand. Nurs Health Sci 2015;17(1):112–8	Nurse outcome (Emotional exhaustion and Needle stick injuries)

Thungjaroenkul et al	Amaravadi, R.K., Dimick, J.B., Pronovost, P.J., & Lipsett, P.A. (2000). ICU nurseto-patient ratio is associated with complications and resource use after esophagectomy. Intensive Care Medicine, 26, 1857-1862.	ICU setting
	Pronovost PJ, Jenckes MW, Dorman T, Garrett E, Breslow MJ, Rosenfeld BA, Lipsett PA, Bass E. Organizational characteristics of intensive care units related to outcomes of abdominal aortic surgery. Jama. 1999 Apr 14;281(14):1310-7.	ICU setting
	Lassnigg A, Hiesmayr M, Bauer P, Haisjackl M. Effect of centre-, patient-and procedure-related factors on intensive care resource utilisation after cardiac surgery. Intensive care medicine. 2002 Oct;28(10):1453-61.	ICU setting
	Dimick, Justin B., et al. "Effect of nurse-to-patient ratio in the intensive care unit on pulmonary complications and resource use after hepatectomy." American Journal of Critical Care 10.6 (2001): 376.	ICU setting
	Bloom JR, Alexander JA, Nuchols BA. Nurse staffing patterns and hospital efficiency in the United States. Social science & medicine. 1997 Jan 1;44(2):147-55.	Wrong outcome (cost of care)
	Lee TY, Yeh ML, Chen HH, Lien GH. The skill mix practice model for nursing: measuring outcome. Journal of advanced nursing. 2005 Aug;51(4):406-13.	Wrong outcome (cost of care)
	Hall LM, Doran D, Pink GH. Nurse staffing models, nursing hours, and patient safety outcomes. JONA: The Journal of Nursing Administration. 2004 Jan 1;34(1):41-5.	Wrong outcome (cost of care)
	Pratt RA, Burr G, Leelarthaepin B, Blizard P, Walsh S. The effects of All-RN and RN-EN staffing on the quality and cost of patient care. The Australian journal of advanced nursing: a quarterly publication of the Royal	Wrong intervention (skill mix)

	Australian Nursing Federation. 1993 Mar 1;10(3):27-39.	
	Newhouse RP, Johantgen M, Pronovist PJ, Johnson E. Perioperative nurses and patient outcomes: mortality, complications, and length of stay. The Journal of nursing administration. 2010 Oct 1;40(10 Suppl):S54-67.	Wrong intervention (skill mix)
	Needleman J, Buerhaus PI, Stewart M, Zelevinsky K, Mattke S. Nurse staffing in hospitals: is there a business case for quality?. Health Affairs. 2006 Jan;25(1):204-11.	Wrong intervention (costs)
	Barkell NP, Killinger KA, Schultz SD. The relationship between nurse staffing models and patient outcomes: a descriptive study. Outcomes Management. 2002 Jan 1;6(1):27-33.	Wrong intervention (skill mix)
	McCue M, Mark BA, Harless DW. Nurse staffing, quality, and financial performance. Journal of health care finance. 2003 Jan 1;29(4):54-76.	Wrong outcome (cost of care)
Twigg et al	Bowblis, J. R., & Ghattas, A. (2017). The impact of minimum quality standard regulations on nursing home staffing, quality, and exit decisions. Review of Industrial Organization, 50(1), 43–68. https://doi.org/10.1007/s11151-016-9528-x	nursing home
	Chan, T. C., Killeen, J. P., Vilke, G. M., Marshall, J. B., & Castillo, E. M. (2010). Effect of mandated nurse–patient ratios on patient wait time and care time in the emergency department. Academic Emergency Medicine, 17(5), 545–552. https://doi.org/10.1111/j.1553-2712.2010.00727.x	Emergency department
	Chen, M. M., & Grabowski, D. C. (2015). Intended and unintended consequences of minimum staffing standards for nursing homes. Health Economics, 24(7), 822–839. https://doi.org/10.1002/hec.3063	nursing home

	Cox, K. S., Anderson, S. C., Teasley, S. L., Sexton, K. A., & Carroll, C. A. (2005). Nurses' work environment perceptions when employed in states with and without mandatory staffing ratios and/or mandatory staffing plans. Policy, Politics, & Nursing Practice, 6(3), 191–197. https://doi.org/10.1177/1527154405279091	Nurse outcomes
	Hodgson, A., Morgan, D., & Peterson, R. (2016). Does better nurse staffing improve detection of depression and anxiety as secondary conditions in hospitalized patients with pneumonia? Nursing Economics, 34(3), 134	Mental health outcome
	Law, A. C., Stevens, J. P., Hohmann, S., & Walkey, A. J. (2018). Patient outcomes after the introduction of statewide intensive care unit nurse staffing regulations. Critical Care Medicine, 46(10), 1563.	ICU setting
	Leigh, J. P., Markis, C. A., Iosif, A.-M., & Romano, P. S. (2015). California's nurse-to-patient ratio law and occupational injury. International Archives of Occupational and Environmental Health, 88(4), 477–484.	Nurse outcome
	Park, J., & Stearns, S. C. (2009). Effects of state minimum staffing standards on nursing home staffing and quality of care. Health Services Research, 44(1), 56–78. https://doi. org/10.1111/j.1475-6773.2008.00906.x	nursing home
	Spetz J, Herrera C. Changes in nurse satisfaction in California, 2004 to 2008. Journal of Nursing Management. 2010 Jul;18(5):564-72.	nurse outcome
	Spetz, J. (2008). Nurse satisfaction and the implementation of minimum nurse staffing regulations. Policy, Politics, & Nursing Practice, 9(1), 15–21. https://doi.org/10.1177/1527154408316950	Nurse outcome

	Tellez, M. (2012). Work satisfaction among California registered nurses: A longitudinal comparative analysis. Nursing economic$, 30(2), 73–81	Nurse outcome
	Tellez, M., & Seago, J. A. (2013). California nurse staffing law and RN workforce changes. Nursing Economics, 31(1), 18	Nurse outcome
	Matsudaira, J. D. (2014). Government regulation and the quality of healthcare evidence from minimum staffing legislation for nursing homes. Journal of Human Resources, 49(1), 32–72. https://doi.org/10.1353/jhr.2014.0003	nursing home
	Weichenthal, L., & Hendey, G. W. (2011). The effect of mandatory nurse ratios on patient care in an emergency department. The Journal of Emergency Medicine, 40(1), 76–81. https://doi.org/10.1016/j.jemer med.2009.02.037	Emergency department
	Zhang, X., & Grabowski, D. C. (2004). Nursing home staffing and quality under the nursing home reform act. The Gerontologist, 44(1), 13–23. https://doi.org/10.1093/geront/44.1.13	nursing home
Shin et al	UK Neonatal Staffing Study Group. Patient volume, staffing, and workload in relation to risk-adjusted outcomes in a random stratified sample of UK neonatal intensive care units: a prospective evaluation. The Lancet. 2002 Jan 12;359(9301):99-107.	ICU setting
	Brooks-Carthon JM, Kutney-Lee A, Sloane DM, Cimiotti JP, Aiken LH. Quality of care and patient satisfaction in hospitals with high concentrations of black patients. Journal of Nursing Scholarship. 2011 Sep;43(3):301-10.	wrong intervention (practice environment)
Lang et al	Kustaborder MJ, Rigney M. Interventions for safety.	wrong intervention (nurse staffing mix)

	Bostrom J, Zimmerman J. Restructuring nursing for a competitive health care environment. Nursing economic$. 1993 Jan 1;11(1):35-41.	wrong intervention (nurse restructuring/ skill mix)
	Needleman J, Buerhaus P. Nurse staffing and patient safety: current knowledge and implications for action. International Journal for Quality in Health Care. 2003 Aug 1;15(4):275-7.	editorial
	Behner KG, Fogg LF, Fournier LC, Frankenbach JT, Robertson SB. Nursing resource management: analyzing the relationship between costs and quality in staffing decisions. Health Care Management Review. 1990 Jan 1;15(4):63-71.	wrong intervention (labour efficiency)
	Shukla RK. All-RN model of nursing care delivery: A cost-benefit evaluation. Inquiry. 1983 Jul 1:173-84.	wrong intervention
	Arndt M, Crane S. Influences on nursing care volume. Journal of the Society for Health Systems. 1998 Jan 1;5(4):38-49.	nurse outcome
	Hinshaw AS, Scofield R, Atwood JR. Staff, patient, and cost outcomes of all-registered nurse staffing. JONA: The Journal of Nursing Administration. 1981 Nov 1;11(11):30-6.	Wrong intervention (skill mix)
	Grillo-Peck AM, Risner PB. The effect of a partnership model on quality and length of stay. Nursing economic$. 1995 Nov 1;13(6):367-72.	wrong intervention (nurse partnership model)
	Ceria CD. Nursing absenteeism and its effects on the quality of patient care. The Journal of nursing administration. 1992 Dec;22(12):11-38.	wrong intervention (absenteeism)
	Bloom JR, Alexander JA, Nuchols BA. The effect of the social organization of work on the voluntary turnover rate of hospital nurses in the United States. Soc Sci Med. 1992;34:1413-1424.	nurse outcome

	Lanza ML, Kayne HL, Gulliford D, et al. Staffing of inpatient psychiatric units and assault by patients. J Am Psychiatr Nurses Assoc. 1997;3:42-4	nurse outcome
	Shortell SM, Hughes EF. The effects of regulation, competition, and ownership on mortality rates among hospital inpatients. New England Journal of Medicine. 1988 Apr 28;318(17):1100-7.	wrong intervention
	Clarke SP, Sloane DM, Aiken LH. Effects of hospital staffing and organizational climate on needlestick injuries to nurses. American journal of public health. 2002 Jul;92(7):1115-9.	nurse outcome
	GLANDON GL, COLBERT KW, Thomasma M. Nursing delivery models and RN mix: cost implications. Nursing Management. 1989 May 1;20(5):30-3.	nurse outcome
	Halloran EJ. RN staffing: more care—less cost. Nursing Management. 1983 Sep 1;14(9):18-23.	nurse outcome
	Osinski EG, Powals JG. The cost of all RN staffed primary nursing. Supervisor nurse. 1980 Jan;11(1):16-21.	nurse outcome
	Bradbury RC, Golec JH, Steen PM. Relating hospital health outcomes and resource expenditures. Inquiry. 1994 Apr 1:56-65.	Wrong intervention (nurse skill mix)
	Krakauer H, Bailey RC, Skellan KJ, Stewart JD, Hartz AJ, Kuhn EM, Rimm AA. Evaluation of the HCFA model for the analysis of mortality following hospitalization. Health services research. 1992 Aug;27(3):317.	Wrong intervention (nurse skill mix)
	Kuhn EM, Hartz A, Gottlieb MS, Rimm AA. The relationship of hospital characteristics and the results of peer review in six large states. Med Care. 1991;29:1028-1038.	nurse outcome
Kane et al 2007	Fridkin SK, Pear SM, Williamson TH, Galgiani JN, Jarvis WR. The role of understaffing in central venous catheter-associated bloodstream infection. Infection	ICU setting

	Control & Hospital Epidemiology. 1996 Mar;17(3):150-8.	
	Amaravadi RK, Dimick JB, Pronovost PJ, et al. ICU nurse-to-patient ratio is associated with complications and resource use after esopha- gectomy. Intensive Care Med. 2000;26: 18	ICU setting
	Dang D, Johantgen ME, Pronovost PJ, et al. Postoperative complica- tions: does intensive care unit staff nursing make a difference? Heart Lung. 2002;3 1:219-	ICU setting
	Dimick JB, Swoboda SM, Pronovost PJ, et al. Effect of nurse-to-patient ratio in the intensive care unit on pulmonary complications and re- source use after hepatectomy. Am J Crit Care. 2001	ICU setting
	Pronovost PJ, Dang D, Dorman T, et al. Intensive care unit nurse staffing and the risk for complications after abdominal aortic surgery. EffClin Pract. 2001 ;4: 19	ICU setting
	Pronovost PJ, Jenckes MW, Dorman T, et al. Organizational charac- teristics of intensive care units related to outcomes of abdominal aortic surgery. JAMA. 1999;281:1310-1	ICU setting
	Shortell SM, Zimmerman JE, Rousseau DM, et al. The performance of intensive care units: does good management make a difference? Med Care. 1994;32:508-525.	ICU setting
	Cimiotti JP, Haas J, Saiman L, et al. Impact of staffing on bloodstream infections in the neonatal intensive care unit. Arch Pediatr Adolesc Med. 2006;160:832-836	ICU setting
	Marcin JP, Rutan E, Rapetti PM, et al. Nurse staffing and unplanned extubation in the pediatric intensive care unit. Pediatr Crit Care Med. 2005;6:254-257.	ICU setting

	Cimiotti JP. Nurse Staffing and Healthcare-Associated Infections in the Neonatal ICU [dissertation]. Ann Arbor, MI: Columbia University; 2004: AAT 3128935.	ICU setting
	Robert J, Fridkin SK, Blumberg HM, Anderson B, White N, Ray SM, Chan J, Jarvis WR. The influence of the composition of the nursing staff on primary bloodstream infection rates in a surgical intensive care unit. Infection Control & Hospital Epidemiology. 2000 Jan;21(1):12-7.	ICU setting
Labelle et al 2019	Dang D, Johantgen ME, Pronovost PJ, Jenckes MW, Bass EB. Postoperative complications: does intensive care unit staff nursing make a difference?. Heart & Lung. 2002 May 1;31(3):219-28.	ICU setting
	Rao AD, Kumar A, McHugh M. Better nurse autonomy decreases the odds of 30-day mortality and failure to rescue. Journal of Nursing Scholarship. 2017 Jan;49(1):73-9.	wrong intervention (nurse work environment)
	Diya L, Van den Heede K, Sermeus W, Lesaffre E. The relationship between in-hospital mortality, readmission into the intensive care nursing unit and/or operating theatre and nurse staffing levels. Journal of advanced nursing. 2012 May;68(5):1073-81.	ICU setting
	Hickey PA, Gauvreau K, Jenkins K, Fawcett J, Hayman L. Statewide and national impact of California's staffing law on pediatric cardiac surgery outcomes. JONA: The Journal of Nursing Administration. 2011 May 1;41(5):218-25.	ICU setting
	Hickey P, Gauvreau K, Connor J, Sporing E, Jenkins K. The relationship of nurse staffing, skill mix, and Magnet® recognition to institutional volume and mortality for congenital heart surgery. JONA: The	ICU setting

	Journal of Nursing Administration. 2010 May 1;40(5):226-32.	
	Dimick JB, Swoboda SM, Pronovost PJ, Lipsett PA. Effect of nurse-to-patient ratio in the intensive care unit on pulmonary complications and resource use after hepatectomy. American Journal of Critical Care. 2001 Nov 1;10(6):376.	ICU setting
	Kiekkas P, Sakellaropoulos GC, Brokalaki H, Manolis E, Samios A, Skartsani C, Baltopoulos GI. Association between nursing workload and mortality of intensive care unit patients. Journal of nursing scholarship. 2008 Dec;40(4):385-90.	ICU setting
	Olds DM, Aiken LH, Cimiotti JP, Lake ET. Association of nurse work environment and safety climate on patient mortality: A cross-sectional study. International journal of nursing studies. 2017 Sep 1;74:155-61.	wrong intervention (nurse work environment)
	Kendall-Gallagher D, Aiken LH, Sloane DM, Cimiotti JP. Nurse specialty certification, inpatient mortality, and failure to rescue. Journal of Nursing Scholarship. 2011 Jun;43(2):188-94.	wrong intervention (nurse education)
	Lane-Fall MB, Ramaswamy TS, Brown SE, He X, Gutsche JT, Fleisher LA, Neuman MD. Structural, nursing, and physician characteristics and 30-day mortality for patients undergoing cardiac surgery in Pennsylvania. Critical care medicine. 2017 Sep;45(9):1472.	wrong intervention (nurse education)
	Diya L, Lesaffre E, Van den Heede K, Sermeus W, Vleugels A. Establishing the relationship between nurse staffing and hospital mortality using a clustered discrete-time logistic model. Statistics in medicine. 2010 Mar 30;29(7-8):778-85.	ICU setting
	Aiken LH, Clarke SP, Cheung RB, Sloane DM, Silber JH. Educational levels of hospital nurses and surgical	wrong intervention (nurse education)

	patient mortality. Jama. 2003 Sep 24;290(12):1617-23.	
	Aiken LH, Clarke SP, Sloane DM, International Hospital Outcomes Research Consortium. Hospital staffing, organization, and quality of care: cross-national findings. International Journal for quality in Health care. 2002 Feb 1;14(1):5-14.	wrong outcome (nurse outcomes)
	Ozdemir BA, Sinha S, Karthikesalingam A, Poloniecki JD, Pearse RM, Grocott MP, Thompson MM, Holt PJ. Mortality of emergency general surgical patients and associations with hospital structures and processes. BJA: British Journal of Anaesthesia. 2016 Jan 1;116(1):54-62.	Emergency department
	Newhouse RP, Johantgen M, Pronovost PJ, Johnson E. Perioperative nurses and patient outcomes—mortality, complications, and length of stay. AORN journal. 2005 Mar 1;81(3):508-28.	Operating room/peri-operative setting
	Aiken LH, Sloane D, Griffiths P, Rafferty AM, Bruyneel L, McHugh M, Maier CB, Moreno-Casbas T, Ball JE, Ausserhofer D, Sermeus W. Nursing skill mix in European hospitals: cross-sectional study of the association with mortality, patient ratings, and quality of care. BMJ quality & safety. 2017 Jul 1;26(7):559-68.	wrong intervention (nursing skill mix)
Wilson et al 2011	Archibald LK, Manning ML, Bell LM, Banerjee S, Jarvis WR. Patient density, nurse-to-patient ratio and nosocomial infection risk in a pediatric cardiac intensive care unit. The Pediatric infectious disease journal. 1997 Nov 1;16(11):1045-8.	ICU setting
	Cimiotti JP. Nurse staffing and healthcare-associated infections in the neonatal ICU. Columbia University; 2004	ICU setting
	Marcin JP, Rutan E, Rapetti PM, et al. Nurse staffing and unplanned extubation in the pediatric intensive care unit. Pediatr Crit Care Med. 2005;6:254-257.	ICU setting

Engineer 2015		
	Volpp KG, Rosen AK, Rosenbaum PR, Romano PS, Even-Shoshan O, Wang Y, Bellini L, Behringer T, Silber JH. Mortality among hospitalized Medicare beneficiaries in the first 2 years following ACGME resident duty hour reform. Jama. 2007 Sep 5;298(9):975-83.	wrong intervention
	Bradley EH, Herrin J, Curry L, Cherlin EJ, Wang Y, Webster TR, Drye EE, Normand SL, Krumholz HM. Variation in hospital mortality rates for patients with acute myocardial infarction. The American journal of cardiology. 2010 Oct 15;106(8):1108-12.	wrong intervention
	Weiner BJ, Alexander JA, Shortell SM, Baker LC, Becker M, Geppert JJ. Quality improvement implementation and hospital performance on quality indicators. Health services research. 2006 Apr;41(2):307-34.	wrong intervention
	Gaskin DJ, Spencer CS, Richard P, Anderson G, Powe NR, LaVeist TA. Do minority patients use lower quality hospitals?. INQUIRY: The Journal of Health Care Organization, Provision, and Financing. 2011 Aug;48(3):209-20.	wrong intervention
	Carretta HJ, Chukmaitov A, Tang A, Shin J. Examination of hospital characteristics and patient quality outcomes using four inpatient quality indicators and 30-day all-cause mortality. American Journal of Medical Quality. 2013 Jan;28(1):46-55.	wrong intervention
	Chukmaitov AS, Bazzoli GJ, Harless DW, Hurley RE, Devers KJ, Zhao M. Variations in inpatient mortality among hospitals in different system types, 1995 to 2000. Medical care. 2009 Apr 1:466-73.	wrong intervention
	Friedman B, Jiang HJ. Do Medicare Advantage enrollees tend to be admitted to hospitals with better or worse outcomes compared with fee-for-service	wrong intervention

	enrollees?. International journal of health care finance and economics. 2010 Jun;10(2):171-85.	
	Romley JA, Jena AB, Goldman DP. Hospital spending and inpatient mortality: evidence from California: an observational study. Annals of internal medicine. 2011 Feb 1;154(3):160-7.	wrong intervention
	Ross JS, Normand SL, Wang Y, Nallamothu BK, Lichtman JH, Krumholz HM. Hospital remoteness and thirty-day mortality from three serious conditions. Health Affairs. 2008 Nov;27(6):1707-17.	wrong intervention
	Ross JS, Normand SL, Wang Y, Ko DT, Chen J, Drye EE, Keenan PS, Lichtman JH, Bueno H, Schreiner GC, Krumholz HM. Hospital volume and 30-day mortality for three common medical conditions. New England Journal of Medicine. 2010 Mar 25;362(12):1110-8.	wrong intervention
	Sari N. Do competition and managed care improve quality?. Health economics. 2002 Oct;11(7):571-84.	wrong intervention
	Shahian DM, Nordberg P, Meyer GS, Blanchfield BB, Mort EA, Torchiana DF, Normand SL. Contemporary performance of US teaching and nonteaching hospitals. Academic Medicine. 2012 Jun 1;87(6):701-8.	wrong intervention
	Volpp KG, Rosen AK, Rosenbaum PR, Romano PS, Even-Shoshan O, Wang Y, Bellini L, Behringer T, Silber JH. Mortality among hospitalized Medicare beneficiaries in the first 2 years following ACGME resident duty hour reform. Jama. 2007 Sep 5;298(9):975-83.	wrong intervention
	Menachemi N, Chukmaitov A, Saunders C, Brooks RG. Hospital quality of care: does information technology matter? The relationship between information technology adoption and quality of care. Health care management review. 2008 Jan 1;33(1):51-9.	wrong intervention

Staplers et al	Kendall-Gallagher D, Blegen MA. Competence and certification of registered nurses and safety of patients in intensive care units. American Journal of Critical Care. 2009 Mar;18(2):106-13	ICU setting
	Hall LM, Doran D, Pink GH. Nurse staffing models, nursing hours, and patient safety outcomes. JONA: The Journal of Nursing Administration. 2004 Jan 1;34(1):41-5.	wrong intervention (skill mix)
	Bae SH, Mark B, Fried B. Impact of nursing unit turnover on patient outcomes in hospitals. Journal of Nursing Scholarship. 2010 Mar;42(1):40-9.	wrong intervention (turnover rates)
	Bae SH, Mark B, Fried B. Use of temporary nurses and nurse and patient safety outcomes in acute care hospital units. Health care management review. 2010 Oct 1;35(4):333-44.	wrong intervention (skill mix)
	Chang YK, Hughes LC, Mark B. Fitting in or standing out: Nursing workgroup diversity and unit-level outcomes. Nursing Research. 2006 Nov 1;55(6):373-80.	wrong intervention
	Krapohl G, Manojlovich M, Redman R, Zhang L. Nursing specialty certification and nursing-sensitive patient outcomes in the intensive care unit. American Journal of Critical Care. 2010 Nov;19(6):490-8.	wrong intervention
	Mallidou AA, Cummings GG, Estabrooks CA, Giovannetti PB. Nurse specialty subcultures and patient outcomes in acute care hospitals: A multiple-group structural equation modeling. International journal of nursing studies. 2011 Jan 1;48(1):81-93.	wrong intervention
	Manojlovich M, Antonakos CL, Ronis DL. Intensive care units, communication between nurses and physicians, and patients' outcomes. American Journal of Critical Care. 2009 Jan;18(1):21-30.	wrong intervention
	Manojlovich M, Sidani S, Covell CL, Antonakos CL. Nurse dose: linking staffing variables to adverse	wrong intervention

	patient outcomes. Nursing research. 2011 Jul 1;60(4):214-20.	
	Purdy N, SPENCE LASCHINGER HK, Finegan J, Kerr M, Olivera F. Effects of work environments on nurse and patient outcomes. Journal of nursing management. 2010 Nov;18(8):901-13.	wrong intervention
	Stone PW, Mooney-Kane C, Larson EL, Horan T, Glance LG, Zwanziger J, Dick AW. Nurse working conditions and patient safety outcomes. Medical care. 2007 Jun 1:571-8.	ICU setting
	Wolf D, Lehman L, Quinlin R, Rosenzweig M, Friede S, Zullo T, Hoffman L. Can nurses impact patient outcomes using a patient-centered care model?. JONA: The Journal of Nursing Administration. 2008 Dec 1;38(12):532-40.	ICU setting
Lankashear et al	Aiken LH, Smith HL, Lake ET. Lower Medicare mortality among a set of hospitals known for good nursing care. Medical care. 1994 Aug 1:771-87.	wrong intervention (magnet versus non-magnet)
	Jarman B, Gault S, Alves B, Hider A, Dolan S, Cook A, Hurwitz B, Iezzoni LI. Explaining differences in English hospital death rates using routinely collected data. Bmj. 1999 Jun 5;318(7197):1515-20.	wrong intervention (Used other clinical staffing (doctors))
	Hall LM, Doran D, Pink GH. Nurse staffing models, nursing hours, and patient safety outcomes. JONA: The Journal of Nursing Administration. 2004 Jan 1;34(1):41-5.	skill mix
Mitchell et al	Andersen BM, Rasch M, Hochlin K, Tollefsen T, Sandvik L. Hospital-acquired infections before and after healthcare reorganization in a tertiary university hospital in Norway. Journal of public health. 2009 Mar 1;31(1):98-104.	wrong intervention (nursing workload)
	Geubbels EL, Wille JC, Nagelkerke NJ, Vandenbroucke-Grauls CM, Grobbee DE, de Boer AS. Hospital-related determinants for surgical-site infection following hip	Wrong intervention

	arthroplasty. Infection Control & Hospital Epidemiology. 2005 May;26(5):435-41.	
	Roche M, Duffield C, Aisbett C, Diers D, Stasa H. Nursing work directions in Australia: Does evidence drive the policy?. Collegian. 2012 Dec 1;19(4):231-8.	wrong intervention (skill mix)
	Kelly D, Kutney-Lee A, Lake ET, Aiken LH. The critical care work environment and nurse-reported health care–associated infections. American Journal of Critical Care. 2013 Nov;22(6):482-8.	ICU setting
	Dimick JB, Swoboda SM, Pronovost PJ, Lipsett PA. Effect of nurse-to-patient ratio in the intensive care unit on pulmonary complications and resource use after hepatectomy. American Journal of Critical Care. 2001 Nov 1;10(6):376.	ICU setting
	Berney B, Needleman J. Impact of nursing overtime on nurse-sensitive patient outcomes in New York hospitals, 1995-2000. Policy, Politics, & Nursing Practice. 2006 May;7(2):87-100.	wrong intervention (nurses overtime)
	Alonso-Echanove J, Edwards JR, Richards MJ, Brennan P, Venezia RA, Keen J, Ashline V, Kirkland K, Chou E, Hupert M, Veeder AV. Effect of nurse staffing and antimicrobial-impregnated central venous catheters on the risk for bloodstream infections in intensive care units. Infection Control & Hospital Epidemiology. 2003 Dec;24(12):916-25.	ICU setting
	Cimiotti JP, Haas J, Saiman L, Larson EL. Impact of staffing on bloodstream infections in the neonatal intensive care unit. Archives of pediatrics & adolescent medicine. 2006 Aug 1;160(8):832-6.	ICU setting
	Pronovost PJ, Dang D, Dorman T, Lipsett PA, Garrett E, Jenckes M, Bass EB. Intensive care unit nurse staffing and the risk for complications after abdominal aortic	ICU setting

	surgery. Effective clinical practice: ECP. 2001 Sep 1;4(5):199-206.	
	Robert J, Fridkin SK, Blumberg HM, Anderson B, White N, Ray SM, Chan J, Jarvis WR. The influence of the composition of the nursing staff on primary bloodstream infection rates in a surgical intensive care unit. Infection Control & Hospital Epidemiology. 2000 Jan;21(1):12-7.	ICU setting
	UK Neonatal Staffing Study Group. Patient volume, staffing, and workload in relation to risk-adjusted outcomes in a random stratified sample of UK neonatal intensive care units: a prospective evaluation. The Lancet. 2002 Jan 12;359(9301):99-107.	ICU setting
	Hugonnet S, Uçkay I, Pittet D. Staffing level: a determinant of late-onset ventilator-associated pneumonia. Critical Care. 2007 Aug;11(4):1-7.	ICU setting
	Bae SH, Brewer CS, Kelly M, Spencer A. Use of temporary nursing staff and nosocomial infections in intensive care units. Journal of clinical nursing. 2015 Apr;24(7-8):980-90.	ICU setting
	Kendall-Gallagher D, Blegen MA. Competence and certification of registered nurses and safety of patients in intensive care units. American Journal of Critical Care. 2009 Mar;18(2):106-13.	ICU setting
	Stone PW, Mooney-Kane C, Larson EL, Horan T, Glance LG, Zwanziger J, Dick AW. Nurse working conditions and patient safety outcomes. Medical care. 2007 Jun 1:571-8.	ICU setting
	Schwab F, Meyer E, Geffers C, Gastmeier P. Understaffing, overcrowding, inappropriate nurse: ventilated patient ratio and nosocomial infections:	ICU setting

	which parameter is the best reflection of deficits?. Journal of Hospital Infection. 2012 Feb 1;80(2):133-9.	
	Amaravadi RK, Dimick JB, Pronovost PJ, Lipsett PA. ICU nurse-to-patient ratio is associated with complications and resource use after esophagectomy. Intensive care medicine. 2000 Dec;26(12):1857-62.	ICU setting
	Dancer SJ, Coyne M, Speekenbrink A, Samavedam S, Kennedy J, Wallace PG. MRSA acquisition in an intensive care unit. American journal of infection control. 2006 Feb 1;34(1):10-7.	ICU setting
	Grundmann H, Hori S, Winter B, Tami A, Austin DJ. Risk factors for the transmission of methicillin-resistant Staphylococcus aureus in an adult intensive care unit: fitting a model to the data. The Journal of infectious diseases. 2002 Feb 15;185(4):481-8.	ICU setting
	Kong F, Cook D, Paterson DL, Whitby M, Clements AC. Do staffing and workload levels influence the risk of new acquisitions of meticillin-resistant Staphylococcus aureus in a well-resourced intensive care unit?. Journal of Hospital Infection. 2012 Apr 1;80(4):331-9.	ICU setting
	Hugonnet S, Villaveces A, Pittet D. Nurse staffing level and nosocomial infections: empirical evaluation of the case-crossover and case-time-control designs. American journal of epidemiology. 2007 Jun 1;165(11):1321-7.	ICU setting
	Rogowski JA, Staiger D, Patrick T, Horbar J, Kenny M, Lake ET. Nurse staffing and NICU infection rates. JAMA pediatrics. 2013 May 1;167(5):444-50.	ICU setting
	Parikh A, Huang SA, Murthy P, Dombrovskiy V, Nolledo M, Lefton R, Scardella AT. Quality improvement and cost savings after implementation of the Leapfrog intensive care unit physician staffing standard at a	ICU setting

	community teaching hospital. Critical care medicine. 2012 Oct 1;40(10):2754-9.	
	Hugonnet S, Chevrolet JC, Pittet D. The effect of workload on infection risk in critically ill patients. Critical care medicine. 2007 Jan 1;35(1):76-81.	ICU setting
	Maillet JM, Guérot E, Novara A, Le Guen J, Lahjibi-Paulet H, Kac G, Diehl JL, Fagon JY. Comparison of intensive-care-unit-acquired infections and their outcomes among patients over and under 80 years of age. Journal of Hospital Infection. 2014 Jul 1;87(3):152-8.	ICU setting
	Daud-Gallotti RM, Costa SF, Guimarães T, Padilha KG, Inoue EN, Vasconcelos TN, da Silva Cunha Rodrigues F, Barbosa EV, Figueiredo WB, Levin AS. Nursing workload as a risk factor for healthcare associated infections in ICU: a prospective study. PloS one. 2012 Dec 27;7(12):e52342.	ICU setting
	The U. Relationship between probable nosocomial bacteraemia and organisational and structural factors in UK neonatal intensive care units. Quality & safety in health care. 2005 Aug;14(4):264.	ICU setting
	Halwani M, Solaymani-Dodaran M, Grundmann H, Coupland C, Slack RJ. Cross-transmission of nosocomial pathogens in an adult intensive care unit: incidence and risk factors. Journal of Hospital Infection. 2006 May 1;63(1):39-46.	ICU setting
	Dorsey G, Borneo HT, Sun SJ, Wells J, Steele L, Howland K, Perdreau-Remington F, Bangsberg DR. A heterogeneous outbreak of Enterobacter cloacae and Serratia marcescens infections in a surgical intensive care unit. Infection Control & Hospital Epidemiology. 2000 Jul;21(7):465-9.	ICU setting

	Fraher MH, Collins CJ, Bourke J, Phelan D, Lynch M. Cost-effectiveness of employing a total parenteral nutrition surveillance nurse for the prevention of catheter-related bloodstream infections. Journal of Hospital Infection. 2009 Oct 1;73(2):129-34.	wrong intervention (Addition of a specialist nurse)
	Barkell NP, Killinger KA, Schultz SD. The relationship between nurse staffing models and patient outcomes: a descriptive study. Outcomes Management. 2002 Jan 1;6(1):27-33.	wrong intervention (skill mix)
	Hall LM, Doran D, Pink GH. Nurse staffing models, nursing hours, and patient safety outcomes. JONA: The Journal of Nursing Administration. 2004 Jan 1;34(1):41-5.	wrong intervention (skill mix)
	Yang PH, Hung CH, Chen YM, Hu CY, Shieh SL. The impact of different nursing skill mix models on patient outcomes in a respiratory care center. Worldviews on Evidence-Based Nursing. 2012 Nov;9(4):227-33.	wrong intervention (skill mix)
	Virtanen M, Kurvinen T, Terho K, Oksanen T, Peltonen R, Vahtera J, Routamaa M, Elovainio M, Kivimäki M. Work hours, work stress, and collaboration among ward staff in relation to risk of hospital-associated infection among patients. Medical care. 2009 Mar 1:310-8.	wrong intervention (overtime)
	Dimick JB, Pronovost PJ, Heitmiller RF, Lipsett PA. Intensive care unit physician staffing is associated with decreased length of stay, hospital cost, and complications after esophageal resection. Critical care medicine. 2001 Apr 1;29(4):753-8.	wrong intervention (Physician staffing)

Appendix 11 – search strategy and strings for Systematic review

Table - Systematic review search strategy for Medline and Embase

1. exp DEVELOPING COUNTRIES/
2. "developing countr* ".ab,kw,ti.
3. "developing world* ".ab,kw,ti.
4. "LMIC*".ab,kw,ti.
5. "low* income* ".ab,kw,ti.
6. "middle income".ab,kw,ti.
7. "resource poor".ab,kw,ti.
8. "resource limited".ab,kw,ti.
9. exp AFRICA/
10. (Africa or Algeria* or Angola* or Benin or Botswana* or Burkina or Burundi* or "Cabo Verde" or "Cape Verde" or Cameroon* or "Central African Republic" or Chad or Comoros or Congo* or "Cote d'Ivoire" or Djibouti or Egypt* or Guinea* or Eritrea* or Eswatini or Swaziland or Ethiopia* or Gabon or Gambia* or Ghana* or Kenya* or Lesotho or Liberia* or Libya* or Madagascar or Malawi* or Mali or Mauritania* or Mauritius or Morocc* or Mozambique or Namibia* or Niger or Nigeria* or Rwanda* or "Sao Tome and Principe" or Senegal* or Seychelles or "Sierra Leone" or Somalia or Sudan* or Tanzania* or Togo or Tunisia* or Uganda* or Zambia* or Zimbabwe* or Southafrica* or Maghreb* or Sahara* or SubSahara*).ab,in,kw,ti.
11. exp ASIA/
12. exp FAR EAST/
13. 13 exp ASIA, CENTRAL/
14. exp ASIA, SOUTH/
15. exp ASIA, SOUTHEASTERN/
16. exp ASIA, WESTERN/
17. exp MIDDLE EAST/
18. exp TRANSCAUCASIA/
19. (Afghan* or Armenia* or Azerbaijan* or Bangladesh* or Bhutan* or Cambodia* or China or Chinese or "North Korea*" or "People* Republic of Korea" or Georgia* or India or Indian or Indonesia* or Iran* or Iraq* or Jordan* or Kazakhstan* or Kyrgyz* or Laos or Lao or Leban* or

	Malay* or Maldives or Mongolia* or Myanmar or Burm* or Nepal* or Pakistan* or Philippines or "Sri Lanka*" or Syria* or Tajik* or Thailand or Thai or Turkey or Turkish or Turkmen* or Uzbek* or Vietnam* or Gaza or "West Bank" or Palestin* or Yemen*).ab,in,kw,ti
20.	exp LATIN AMERICA/
21.	exp SOUTH AMERICA/
22.	exp CENTRAL AMERICA/
23.	exp CARIBBEAN REGION/
24.	MEXICO/
25.	(Argentin* or Belize or Bolivia* or Brazil* or Colombia* or Cuba* or Chile* or "Costa Rica*" or Dominica* or Ecuador* or Salvador* or Grenada* or Guatemala* or Guyana* or Haiti* or Hondura* or Jamaica* or Mexico or Mexican* or Nicaragua* or Paraguay* or Peru or Peruvian* or "St* Lucia*" or "St* Vincent" or Suriname or Uruguay* or Venezuela*).ab,in,kw,ti.
26.	exp PACIFIC ISLANDS/
27.	exp POLYNESIA/
28.	exp MELANESIA/
29.	exp MICRONESIA/
30.	(Samoa* or Fiji* or Kiribati* or "Marshall Island*" or Micronesia* or Nauru* or "Papua New" or Polynesia* or "Solomon Island*" or "Timor Leste" or Tonga* or Tuvalu* or Vanuatu*).ab,in,kw,ti.
31.	exp RUSSIA/
32.	ALBANIA/ or "BOSNIA AND HERZEGOVINA"/ or BELARUS/ or BULGARIA/ or KOSOVO/ or MOLDOVA/ or MONTENEGRO/ or "REPUBLIC OF NORTH MACEDONIA"/ or ROMANIA/ or SERBIA/ or UKRAINE/
33.	(Russia* or Albania* or Bosnia* or Belarus* or Bulgaria* or Kosovo or Kosova* or Moldova* or Montenegr* or "North Macedonia*" or Romania* or Serbia* or Ukrain*).ab,in,kw,ti.
34.	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33
35.	JAPAN/ or SINGAPORE/ or TAIWAN/ or REPUBLIC OF KOREA/ or BAHRAIN/ or ISRAEL/ or KUWAIT/ or QATAR/ or SAUDI ARABIA/ or UNITED ARAB EMIRATES/

36.	AUSTRALIA/ or SOUTH AUSTRALIA/ or WESTERN AUSTRALIA/ or NEW ZEALAND/ or HAWAII/ or NEW CALEDONIA/
37.	35 or 36
38.	38 34 not 37
39.	39 (nurse* or nursing).ti.
40.	38 and 39
41.	41 (missed or missing).ti.
42.	(lack or lacking).ti.
43.	(shortage or absence).ti.
44.	(unmet or incomplete).ti.
45.	"delay*".ti.
46.	(staffing or error* or fail* or omission* or rationing or unfulfil*).ti.
47.	41 or 42 or 43 or 44 or 45 or 46
48.	40 and 47
49.	limit 48 to yr="2011 -Current"
50.	limit 49 to conference abstracts
51.	49 not 50

Table - Systematic review search strategy for CINAHL

#	Query
S6	S3 AND S4 AND S5
S5	S1 OR S2
S4	TI (missed or missing) OR TI (lack or lacking) OR TI (staffing or error* or fail* or omission* or rationing or unfulfil*) TI (unmet or incomplete) OR TI (shortage or absence) OR TI (delay*) OR TI (medical error*) OR AB (medical error*) OR KW (medical error*) OR MH "Health Care Rationing"/
S3	TI (nurse* or nursing) OR MH "Nursing care+"/ OR MH "Nursing Staff, Hospital/" OR MH "Personnel Staffing and Scheduling+"/
S2	(MH "AFRICA+"/ OR TI (Africa or Algeria* or Angola* or Benin or Botswana* or Burkina or Burundi* or "Cabo Verde" or "Cape Verde" or Cameroon* or "Central African Republic" or Chad or Comoros or Congo* or "Cote d'Ivoire" or Djibouti or Egypt* or Guinea* or Eritrea* or Eswatini or Swaziland or Ethiopia* or Gabon or Gambia* or Ghana* or Kenya* or Lesotho or Liberia* or Libya* or Madagascar or Malawi* or Mali or Mauritania* or Mauritius or Morocc* or Mozambique or Namibia* or Niger or Nigeria* or Rwanda* or "Sao Tome and Principe" or Senegal* or Seychelles or "Sierra Leone" or Somalia or Sudan* or Tanzania* or Togo or Tunisia* or Uganda* or Zambia* or Zimbabwe* or Southafrica* or Maghreb* or Sahara* or SubSahara*) OR MH "ASIA+"/ OR MH "FAR EAST+"/ OR MH "ASIA, CENTRAL+"/ OR MH "ASIA, SOUTH+"/ OR MH "ASIA, SOUTHEASTERN+"/ OR MH "ASIA, WESTERN+"/ OR MH "MIDDLE EAST+"/ OR MH "TRANSCAUCASIA+"/ OR TI (Afghan* or Armenia* or Azerbaijan* or Bangladesh* or Bhutan* or Cambodia* or China or Chinese or "North Korea*" or "People* Republic of Korea" or Georgia* or India or Indian or Indonesia* or Iran* or Iraq* or Jordan* or Kazakhstan* or Kyrgyz* or Laos or Lao or Leban* or Malay* or Maldives or Mongolia* or Myanmar or Burm* or Nepal* or Pakistan* or Philippines or "Sri Lanka*" or Syria* or Tajik* or Thailand or Thai or Turkey or Turkish or Turkmen* or Uzbek* or Vietnam* or Gaza or "West Bank" or Palestin* or Yemen*)) OR (MH "LATIN AMERICA+"/ OR MH "SOUTH AMERICA+"/ OR MH "CENTRAL AMERICA+"/ OR MH "CARIBBEAN REGION+"/ OR MH "MEXICO"/ OR TI (Argentin* or Belize or Bolivia* or Brazil* or Colombia* or Cuba* or Chile* or "Costa Rica*" or Dominica* or Ecuador* or Salvador* or Grenada* or Guatemala* or Guyana* or Haiti* or Hondura* or Jamaica* or Mexico or Mexican* or Nicaragua* or Paraguay* or Peru or Peruvian* or "St* Lucia*" or "St* Vincent" or Suriname or Uruguay* or Venezuela*) OR MH "PACIFIC ISLANDS+"/ OR MH "POLYNESIA+"/ OR MH "MELANESIA+"/ OR MH "MICRONESIA+"/ OR TI (Samoa* or Fiji* or Kiribati* or "Marshall Island*" or Micronesia* or Nauru* or "Papua New" or Polynesia* or "Solomon Island*" or "Timor Leste" or Tonga* or Tuvalu* or Vanuatu*) OR MH "RUSSIA+"/ OR MH (ALBANIA/ or "BOSNIA AND HERZEGOVINA"/ or BELARUS/ or BULGARIA/ or KOSOVO/ or MOLDOVA/ or MONTENEGRO/ or "REPUBLIC OF NORTH MACEDONIA"/ or ROMANIA/ or SERBIA/ or UKRAINE/) OR TI (Russia* or Albania* or Bosnia* or Belarus* or Bulgaria* or Kosovo or Kosova* or Moldova* or Montenegr* or "North Macedonia*" or

	Romania* or Serbia* or Ukrain*)) OR (AB (Africa or Algeria* or Angola* or Benin or Botswana* or Burkina or Burundi* or "Cabo Verde" or "Cape Verde" or Cameroon* or "Central African Republic" or Chad or Comoros or Congo* or "Cote d'Ivoire" or Djibouti or Egypt* or Guinea* or Eritrea* or Eswatini or Swaziland or Ethiopia* or Gabon or Gambia* or Ghana* or Kenya* or Lesotho or Liberia* or Libya* or Madagascar or Malawi* or Mali or Mauritania* or Mauritius or Morocc* or Mozambique or Namibia* or Niger or Nigeria* or Rwanda* or "Sao Tome and Principe" or Senegal* or Seychelles or "Sierra Leone" or Somalia or Sudan* or Tanzania* or Togo or Tunisia* or Uganda* or Zambia* or Zimbabwe* or Southafrica* or Maghreb* or Sahara* or SubSahara*) OR AB (Afghan* or Armenia* or Azerbaijan* or Bangladesh* or Bhutan* or Cambodia* or China or Chinese or "North Korea*" or "People* Republic of Korea" or Georgia* or India or Indian or Indonesia* or Iran* or Iraq* or Jordan* or Kazakhstan* or Kyrgyz* or Laos or Lao or Leban* or Malay* or Maldives or Mongolia* or Myanmar or Burm* or Nepal* or Pakistan* or Philippines or "Sri Lanka*" or Syria* or Tajik* or Thailand or Thai or Turkey or Turkish or Turkmen* or Uzbek* or Vietnam* or Gaza or "West Bank" or Palestin* or Yemen*) OR AB (Argentin* or Belize or Bolivia* or Brazil* or Colombia* or Cuba* or Chile* or "Costa Rica*" or Dominica* or Ecuador* or Salvador* or Grenada* or Guatemala* or Guyana* or Haiti* or Hondura* or Jamaica* or Mexico or Mexican* or Nicaragua* or Paraguay* or Peru or Peruvian* or "St* Lucia*" or "St* Vincent" or Suriname or Uruguay* or Venezuela*) OR AB (Samoa* or Fiji* or Kiribati* or "Marshall Island*" or Micronesia* or Nauru* or "Papua New" or Polynesia* or "Solomon Island*" or "Timor Leste" or Tonga* or Tuvalu* or Vanuatu*) OR AB (Russia* or Albania* or Bosnia* or Belarus* or Bulgaria* or Kosovo or Kosova* or Moldova* or Montenegr* or "North Macedonia*" or Romania* or Serbia* or Ukrain*) OR KW (Africa or Algeria* or Angola* or Benin or Botswana* or Burkina or Burundi* or "Cabo Verde" or "Cape Verde" or Cameroon* or "Central African Republic" or Chad or Comoros or Congo* or "Cote d'Ivoire" or Djibouti or Egypt* or Guinea* or Eritrea* or Eswatini or Swaziland or Ethiopia* or Gabon or Gambia* or Ghana* or Kenya* or Lesotho or Liberia* or Libya* or Madagascar or Malawi* or Mali or Mauritania* or Mauritius or Morocc* or Mozambique or Namibia* or Niger or Nigeria* or Rwanda* or "Sao Tome and Principe" or Senegal* or Seychelles or "Sierra Leone" or Somalia or Sudan* or Tanzania* or Togo or Tunisia* or Uganda* or Zambia* or Zimbabwe* or Southafrica* or Maghreb* or Sahara* or SubSahara*) OR KW (Afghan* or Armenia* or Azerbaijan* or Bangladesh* or Bhutan* or Cambodia* or China or Chinese or "North Korea*" or "People* Republic of Korea" or Georgia* or India or Indian or Indonesia* or Iran* or Iraq* or Jordan* or Kazakhstan* or Kyrgyz* or Laos or Lao or Leban* or Malay* or Maldives or Mongolia* or Myanmar or Burm* or Nepal* or Pakistan* or Philippines or "Sri Lanka*" or Syria* or Tajik* or Thailand or Thai or Turkey or Turkish or Turkmen* or Uzbek* or Vietnam* or Gaza or "West Bank" or Palestin* or Yemen*) OR KW (Argentin* or Belize or Bolivia* or Brazil* or Colombia* or Cuba* or Chile* or "Costa Rica*" or Dominica* or Ecuador* or Salvador* or Grenada* or Guatemala* or Guyana* or Haiti* or Hondura* or Jamaica* or Mexico or Mexican* or Nicaragua* or Paraguay* or Peru or Peruvian* or "St* Lucia*" or "St* Vincent" or Suriname or Uruguay* or Venezuela*) OR KW (Samoa* or Fiji* or Kiribati* or "Marshall Island*" or Micronesia* or Nauru* or "Papua New" or Polynesia* or "Solomon Island*" or

	"Timor Leste" or Tonga* or Tuvalu* or Vanuatu*) OR KW (Russia* or Albania* or Bosnia* or Belarus* or Bulgaria* or Kosovo or Kosova* or Moldova* or Montenegr* or "North Macedonia*" or Romania* or Serbia* or Ukrain*)) NOT (MH ("JAPAN/ or SINGAPORE/ or TAIWAN/ or REPUBLIC OF KOREA/ or BAHRAIN/ or ISRAEL/ or KUWAIT/ or QATAR/ or SAUDI ARABIA/ or UNITED ARAB EMIRATES/ or AUSTRALIA/ or SOUTH AUSTRALIA/ or WESTERN AUSTRALIA/ or NEW ZEALAND/ or HAWAII/ or NEW CALEDONIA/))
S1	(MH "DEVELOPING COUNTRIES+"/ OR TI ("developing countr* ") OR TI ("developing world* ") OR TI ("LMIC*") OR TI ("low* income* ") OR TI ("middle income") OR TI ("resource poor") OR TI ("resource limited") OR TI ("resource constrained")) OR (AB ("developing countr* ") OR AB ("developing world* ") OR AB ("LMIC*") OR AB ("low* income* ") OR AB ("middle income") OR AB ("resource poor") OR AB ("resource limited") OR AB ("resource constrained")) OR (KW ("developing countr* ") OR KW ("developing world* ") OR KW ("LMIC*") OR KW ("low* income* ") OR KW ("middle income") OR KW ("resource poor") OR KW ("resource limited") OR KW ("resource constrained"))

Appendix 12 - List of papers excluded from systematic reviews and reasons for their exclusion

S/ N	Citation	Reason for exclusion
1	Cho SH, Kim YS, Yeon KN, You SJ, Lee ID. Effects of increasing nurse staffing on missed nursing care. International nursing review. 2015 Jun;62(2):267-74.	High-income setting (South Korea)
2	Lake ET, French R, O'Rourke K, Sanders J, Srinivas SK. Linking the work environment to missed nursing care in labour and delivery. Journal of nursing management. 2020 Nov;28(8):1901-8.	High-income setting (US)
3	Khajooee R, Bagherian B, Dehghan M, AZIZZADEH FM. Missed nursing care and its related factors from the points of view of nurses affiliated to Kerman University of Medical Sciences in 2017.	Arabic (non-English)
4	Yaghoubi M, Torki ME, Salesi M, Ehsani-Chimeh E, Bahadori M. the relationship between teamwork and missed nursing care: Case study in a military hospital in Tehran. Journal of Military Medicine. 2019;21(1):63-72.	Arabic (non-English)
5	Blizzard HL. The relationship between the perceptions of implicit rationing of nursing care and emotionally intelligent leadership style among direct-care nurses (Doctoral dissertation).	High-income setting (US)
6	Tou YH, Liu MF, Chen SR, Lee PH, Kuo LM, Lin PC. Investigating missed care by nursing aides in Taiwanese long-term care facilities. Journal of nursing management. 2020 Nov;28(8):1918-28.	Focused on nursing homes and not acute care settings
7	Siqueira LD, Caliri MH, Kalisch B, Dantas RA. Cultural adaptation and internal consistency analysis of the MISSCARE Survey for use in Brazil1. Revista latino-americana de enfermagem. 2013 Mar;21:610-7.	Portuguese (non-English)
8	Dutra CK, Guirardello ED. Nurse work environment and its impact on reasons for missed care, safety climate, and job satisfaction: A cross-sectional study. Journal of Advanced Nursing. 2021 May;77(5):2398-406.	Focus is on nurse work environment
9	Zhi LI, Chen H, Deai YU. Status quo of nursing lack in level three first-class hospitals of Zhongshan city. Chinese Journal of Practical Nursing. 2013 Jan 1;29(23):51-3.	Chinese (non-english)
10	You L, Zheng J, Liu K, Liu J, Wang Y, Lin X, Zheng L, Pei D. The prevalence and change of rationing of nursing care in level 2 and level 3 hospitals across Guangdong province. Chinese Journal of Practical Nursing. 2016:1166-9.	Chinese (non-english)

11	Kalánková D, Suhonen R, Stolt M, Kurucová R, Katajisto J, Žiaková K, Gurková E. Psychometric testing of perceived implicit rationing of nursing care (PIRNCA). Journal of advanced nursing. 2020 Jun;76(6):1469-82.	HIC setting (Slovak republic)

Appendix 13 -Data abstraction tool subheadings for systematic review

Primary data abstraction tool

First author (Year)	Citation	Study objective	Country	Study design	Study setting	Time frame	Study population	Conflict of interest	Source of funding

Extraction of factors associated with missed nursing care

Factor	Study A	Study B	Study C	Study D
A	Effect estimate			
B		Effect estimate		
C				

Extraction of missed nursing care

Named missed nursing care tool	Study A	Study B	Study C	Study D
Task 1	Proportion of tasks missed			
Task 2		Proportion of tasks missed		
Task 3				
Task 4				

Appendix 14– Actual task frequencies and proportions

Table - Relative frequency of missed nursing tasks and ranking of studies employing the original MISSACRE tool

Nurse tasks	Arslan et al (2021)	**Arslan Rank**	Nahasaram et al	Nahasaram Rank	Al-Faouri et al	**Al-Faouri Rank**	Hammad et al	**Hammad rank**	Chegini et al	**Chegini rank**	Saqer et al	**Saqer rank**	Kalisch et al	**Kalisch rank**
Assess effectiveness of medication	1.14	**16**	1.83	**10**	1.99	**12**	2.3	**12**	1.8	**21**	2.8	**12**	1.24	**12**
Turning patient every 2 h	1.61	**6**	2.36	**4**	2.6	**5**	2.44	**9**	2.9	**7**	3.1	**5**	1.52	**5**
Mouth care	1.22	**12**	2.31	**5**	2.86	**4**	2.64	**4**	2.9	**7**	3.2	**2**	1.46	**6**
PRN medication requests acted on within 15 min	1.2	**14**	1.78	**15**	1.82	**17**	2.06	**15**	2.8	**13**	2.6	**16**	1.18	**15**
IV/central line site care and assessments according to hospital policy	1.06	**24**	1.66	**20**	1.63	**22**	1.7	**24**	2.9	**7**	2.4	**21**	1.12	**21**
Medications administered within 30	1.15	**15**	1.8	**13**	1.96	**14**	1.96	**19**	2.9	**7**	2.8	**12**	1.13	**20**

min before or after scheduled time														
Patient bathing/skin care	1.46	**7**	1.74	**17**	2.25	**11**	2.65	**3**	2.1	**17**	2.9	**8**	1.09	**22**
Monitoring intake/output	1.12	**18**	1.82	**12**	1.67	**18**	1.9	**20**	2.1	**17**	2.5	**18**	1.3	**10**
Vital signs assessed as ordered	1.08	**23**	1.45	**22**	1.52	**23**	1.74	**23**	1.7	**23**	2.4	**21**	1.06	**24**
Hand washing	1.12	**18**	1.53	**21**	1.98	**13**	1.99	**18**	2.2	**16**	2.7	**14**	1.4	**7**
Patient assessments performed each shift	1.09	**22**	1.78	**15**	1.67	**18**	2.26	**14**	3	**4**	2.5	**18**	1.16	**17**
Wound care	1.11	**20**	1.42	**23**	1.87	**16**	2.01	**16**	1.9	**19**	2.5	**18**	1.18	**15**
Bedside glucose monitoring as ordered	1.13	**17**	1.34	**24**	1.47	**24**	1.88	**21**	1.8	**21**	2.3	**24**	1.07	**23**
Focused reassessments according to patient condition	1.63	**5**	1.79	**14**	1.67	**18**	2.47	**8**	2.9	**7**	2.6	**16**	1.14	**19**
Patient teaching about procedures, tests, and	1.29	**11**	2.44	**2**	2.29	**10**	2.59	**5**	3	**4**	3	**7**	1.58	**4**

other diagnostic studies														
Emotional support to patient and/or family	1.45	**8**	2.19	**6**	2.36	**7**	2.41	**11**	3.2	**2**	2.9	**8**	1.63	**3**
Teach patient about plans for their care after discharge and when to call after discharge	1.93	**3**	1.91	**9**	2.31	**9**	2.5	**7**	3.3	**1**	3.1	**5**	1.23	**13**
Attending family conferences/ interdisciplinary conferences	2.26	**2**	2.46	**1**	3.19	**2**	2.84	**1**	3.1	**3**	3.2	**2**	1.85	**1**
Feeding patient when the food is still warm	1.45	**8**	2.1	**7**	2.98	**3**	2.58	**6**	1.9	**19**	3.2	**2**	1.3	**10**
Ambulation 3 times per day or as ordered	2.35	**1**	2.38	**3**	3.26	**1**	2.72	**2**	2.8	**13**	3.3	**1**	1.82	**2**
Assist with toileting needs within 5 min of request	1.37	**10**	1.94	**8**	2.59	**6**	2.44	**9**	2.9	**7**	2.9	**8**	1.32	**8**

Response to call light is initiated within 5 min	1.81	**4**	1.74	**17**	1.91	**15**	2	**17**	3	**4**	2.7	**14**	1.19	**14**
Setting up meals for patients who can feed themselves	1.22	**12**	1.83	**10**	2.33	**8**	2.29	**13**	1.7	**23**	2.9	**8**	1.16	**17**
Full documentation of all necessary data	1.11	**20**	1.73	**19**	1.66	**21**	1.76	**22**	2.8	**13**	2.4	**21**	1.31	**9**

Emboldened – individual study rank ordering

Table- Relative frequency of missed nursing tasks and ranking of studies employing the MISSACRE Brazil tool

Nurse tasks	Lima et al	**Lima ranking**	Haftu et al	**Haftu ranking**	Lima Silva et al	**Lima Silva ranking**	Moura et al	**Moura rank**	Dutra et al (2019)	**Dutra rank**	Silva et al	**Silva rank**
Assess effectiveness of medications	32.9	**10**	8.67	**9**	31	**7**	14.6	**20**	8.62	**10**	85.5	**22**
Turning patient every 2 h	43.6	**5**	24.14	**4**	31	**7**	39.6	**7**	24.14	**4**	48.4	**3**
Mouth care	34.6	**9**	5.17	**15**	14	**19**	37.5	**8**	5.17	**15**	42	**1**
PRN medication requests acted on within 15 min	21.8	**15**	3.45	**22**	38	**4**	34.4	**9**	3.45	**19**	77.4	**18**
IV/central line site care and assessments according to hospital policy	19	**18**	1.72	**19**	17	**17**	9.4	**23**	1.72	**20**	88.8	**23**
Medications administered within 30 min before or	22.8	**14**	12.07	**8**	31	**7**	22.9	**16**	12.07	**8**	74.1	**14**

after scheduled time												
Patient bathing/skin care	6.4	**25**	1.72	**19**	3	**25**	9.4	**23**	1.72	**20**	74.2	**15**
Monitoring intake/output	28.2	**12**	8.62	**10**	3	**25**	25	**15**	8.62	**10**	64.5	**7**
Vital signs assessed as ordered	13.9	**21**	0	**22**	3	**25**	5.2	**26**	0	**22**	98.4	**28**
Hand washing	6.3	**26**	0	**22**	14	**19**	4.2	**27**	0	**22**	88.8	**23**
Patient assessments performed each shift	19	**18**	6.9	**12**	24	**12**	10.4	**22**	6.9	**12**	90.3	**26**
Wound care	1.3	**28**	0	**22**	7	**24**	21.9	**17**	0	**22**	70.9	**10**
Bedside glucose monitoring as ordered	3.8	**27**	0	**22**	0	**28**	1	**28**	0	**22**	95.2	**27**
Focused reassessments according to patient condition	20.3	**17**	5.17	**15**	21	**14**	20.8	**18**	5.17	**15**	88.8	**23**

Patient teaching about procedures, tests, and other diagnostic studies	25.3	**13**	5.17	**15**	24	**12**	13.5	**21**	5.17	**15**	79	**19**
Emotional support to patient and/or family	35.9	**8**	25.86	**3**	34	**6**	26	**14**	25.86	**3**	82.3	**20**
Teach patient about plans for their care after discharge and when to call after discharge	46.8	**4**	15.52	**6**	66	**2**	29.2	**11**	15.52	**6**	75.8	**16**
Attending family conferences/ interdisciplinary conferences	67.5	**2**	44.83	**1**	50	**3**	55.2	**1**	44.83	**1**	53.2	**6**
Ambulation 3 times per day or as ordered	66.2	**3**	31.03	**2**	93	**1**	53.1	**2**	31.03	**2**	66.7	**9**
Assist with toileting	20.8	**16**	8.62	**10**	31	**7**	33.3	**10**	8.67	**9**	50	**4**

needs within 5 min of request												
Response to call light is initiated within 5 min	37.8	**7**	5.17	**15**	28	**11**	42.7	**4**	5.17	**15**	70.9	**10**
Setting up meals for patients who can feed themselves	28.8	**11**	13.8	**7**	17	**17**	52.1	**3**	13.8	**7**	70.9	**10**
Full documentati on of all necessary data	40.5	**6**	6.89	**14**	21	**14**	19.8	**19**	6.89	**14**	82.3	**20**
Sit up the patient out of bed	74	**1**	18.96	**5**	38	**4**	41.7	**5**	18.69	**5**	64.6	**8**
Use of preventive measures for patient at risk of falling	15.4	**20**	0	**22**	10	**21**	27.1	**13**	0	**22**	75.8	**16**
Airway aspiration	12.7	**23**	0	**22**	10	**21**	41.7	**5**	0	**22**	43.6	**2**
Feeding the patient or administering	12.8	**22**	6.9	**12**	10	**21**	9.4	**23**	6.9	**12**	50	**4**

the diet by probe tube at the proper time												
Hydrating the patient by providing oral fluids or by administering the probe tube	11.8	**24**	0	**22**	21	**14**	28.1	**12**	0	**22**	72.6	**13**

Emboldened – individual study rank ordering

Appendix 15 – Model fit statistics for multi-level models examining nurse staffing and care delivery

Table – Selecting the best-unadjusted model for nurse staffing and nurse-delivered care.

Model	Model specification	Likelihood ratio test*	AIC	BIC
Model 1	Linear model	Not applicable	-992.36	-983.57
Model 2	Two-level (shift and baby) random intercept model	<0.001[a]	-1132.74	-1115.17
Model 3	Two-level random slope model	1.00[b]	-1130.74	-1108.78
Model 4	Random intercept model with hospital adjusted for as a fixed covariate	0.0004[b]	-1104.21	-1055.90
Model 5	**Three-level (Hospital, shift and baby) random intercept model**	**0.0006[b]**	**-1139.89**	**-1117.93**
Model 6	Three-level random slope model	0.51[c]	-1138.99	-1112.64

*Likelihood ratio test is based on Maximum Likelihood estimation, while the AIC and BIC were based on restricted maximum likelihood estimations

a- Model 2 was compared with Model 1 for likelihood ratio tests.

b- Models 3, 4 and 5 were compared to Model 2 for likelihood ratio tests.

c- Model 6 was compared to Model 5 for likelihood ratio tests.

Table – Model fit statistics for selecting the best model for nurse staffing and nurse-delivered care.

Model building	Model	Model specification	Likelihood ratio test*	AIC	BIC
Base model	Model 1	Three-level random intercept model (unadjusted)	Not applicable	-1139.89	-1117.93
First covariate selection	**Model 2**	**Model 1 adjusted for patient severity**	**<0.001[a]**	**-1143.26**	**-1112.51**
	Model 3	Model 1 adjusted for shift type	0.79 [a]	-1115.69	-1080.56
	Model 4	Model 1 adjusted for the number of nursing students (as a continuous variable)	0.57 [a]	-1126.31	-1099.96
	Model 5	Model 1 adjusted for the number of nursing students (as a categorical variable)	0.11 [a]	-1105.03	-1052.33
Second covariate[b] selection	Model 6	Model 1 adjusted for patient severity and number of nursing students (as a continuous variable	0.34[c]	-1130.18	-1095.04
	Model 7	Model 1 adjusted for patient severity and shift type.	0.39[c]	-1119.96	-1076.05

*Likelihood ratio test is based on Maximum Likelihood estimation, all other model estimations were based on restricted maximum likelihood estimations

a- Models 2 to 5 were compared to Model 1 for likelihood ratio tests.

b- The second covariate selection involved independently adding covariates to the best model (Model 2) from the first covariate selection and examining the resulting model fit statistics.

c- Models 6 and 7 were compared to Model 2 for likelihood ratio tests.

Table – Selecting the best-unadjusted model for nurse staffing and overall nursing care provided.

Model	Model specification	Likelihood ratio test*	AIC	BIC
Model 1	Linear model	Not applicable	-386.60	-377.82
Model 2	Two-level random intercept model	<0.001[a]	-768.99	-751.42
Model 3	Two-level random slope model	1.00[b]	-766.99	-745.03
Model 4	Random intercept model with hospital adjusted for as a fixed covariate	<0.001[b]	-808.77	-760.46
Model 5	**Three-level random intercept model**	**<0.001[b]**	**-829.32**	**-807.36**
Model 6	Three-level random slope model	1.00[c]	-829.32	-807.36

*Likelihood ratio test is based on Maximum Likelihood estimation, while the AIC and BIC were based on restricted maximum likelihood estimations

a- Model 2 was compared with Model 1 for likelihood ratio tests.

b- Models 3, 4 and 5 were compared to Model 2 for likelihood ratio tests.

c- Model 6 was compared to Model 5 for likelihood ratio tests.

Table – Model fit statistics for selecting the best model for nurse staffing and overall nursing care provided.

Model building	Model	Model specification	Likelihood ratio test*	AIC	BIC
Base model	Model 1	Three-level random intercept model (unadjusted)	Not applicable	-829.32	-807.36
First covariate selection	Model 2	Model 1 adjusted for patient severity	0.87[a]	-813.76	-783.02
	Model 3	Model 1 adjusted for shift type	0.008[a]	-818.09	-782.95
	Model 4	**Model 1 adjusted for the number of nursing students (as a continuous variable)**	**<0.001[a]**	**-841.01**	**-814.66**
	Model 5	Model 1 adjusted for the number of nursing students (as a categorical variable)	0.002 [a]	-810.66	-757.96
Second covariate[b] selection	Model 6	Model 1 adjusted for the number of nursing students (as a continuous variable) and patient severity	0.37[c]	-826.87	-791.73
	Model 7	Model 1 adjusted for the number of nursing students (as a continuous variable) and shift type.	0.61[c]	-821.25	-781.72

*Likelihood ratio test is based on Maximum Likelihood estimation, all other model estimations were based on restricted maximum likelihood estimations

a- Models 2 to 5 were compared to Model 1 for likelihood ratio tests.

b- The second covariate selection involved independently adding covariates to the best model (Model 4) from the first covariate selection and examining the resulting model fit statistics.

c- Models 6 and 7 were compared to Model 2 for likelihood ratio tests.

Table – Selecting the best-unadjusted model for combined nursing (nurses and nurse student) hours and amount of nursing care provided.

Model	Model specification	Likelihood ratio test*	AIC	BIC
Model 1	Linear model	Not applicable	-579.80	-571.02
Model 2	Two-level random intercept model	<0.001[a]	-829.70	-812.13
Model 3	Two-level random slope model	1.00[b]	-827.70	-805.74
Model 4	Random intercept model with hospital adjusted for as a fixed covariate	<0.001[b]	-817.60	-769.28
Model 5	**Three-level random intercept model**	**0.0002**[b]	**-843.51**	**-821.56**
Model 6	Three-level random slope model	1.00[c]	-841.51	-815.16

*Likelihood ratio test is based on Maximum Likelihood estimation, while the AIC and BIC were based on restricted maximum likelihood estimations

a- Model 2 was compared with Model 1 for likelihood ratio tests.

b- Models 3, 4 and 5 were compared to Model 2 for likelihood ratio tests.

c- Model 6 was compared to Model 5 for likelihood ratio tests.

Table – Model fit statistics for selecting the best model for nurse staffing and overall nursing care provided.

Model building	Model	Model specification	Likelihood ratio test*	AIC	BIC
Base model	Model 1	Three-level random intercept model (unadjusted)	Not applicable	-843.51	-821.56
First covariate selection	Model 2	Model 1 adjusted for patient severity	0.50[a]	-828.19	-793.05
	Model 3	Model 1 adjusted for shift type	0.06[a]	-818.09	-782.95

*Likelihood ratio test is based on Maximum Likelihood estimation, all other model estimations were based on restricted maximum likelihood estimations

a- Models 2 to 3 were compared to Model 1 for likelihood ratio tests.

Appendix 16 – Sample stata code

```
//multilevel model building
//importance of context, single level model adjusts for context - standard errors too small

//linear regression
regress NCI_score_round s_NHPPS_round
estat ic

//random intercept model
mixed NCI_score_round s_NHPPS_round || shift_id: ,  reml nolog
estat ic

//Random slope model
mixed NCI_score_round s_NHPPS_round|| shift_id:s_NHPPS_round , reml nolog //random slope model - Realtionship between NCI and staffing can vary acorss shifts. In a way it is similar to fitting an interaction term in a model but in theis case it is on the random part of the model. The effect of staffing on amount of care should vary across shifts
estat ic

//3 level random intercept
mixed NCI_score_round s_NHPPS_round || hospitalcode: || shift_id: , reml nolog
estat ic ///better model

//2-level random intercept model with hospital as a fixed effect covariate
mixed NCI_score_round s_NHPPS_round i.hospitalcode|| shift_id: , stddev reml nolog
estat ic

//3 level random slope
mixed NCI_score_round s_NHPPS_round || hospitalcode:s_NHPPS_round || shift_id: , reml nolog
estat ic

////3 level random intercept
///with shift
mixed NCI_score_round s_NHPPS_round i.n_shifttype || hospitalcode: || shift_id: , reml nolog
estat ic
```

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```

//pate
mixed NCI_score_round s_NHPPS_round i.n_patientcarecategory || hospitalcode: || shift_id:, reml nolog
estat ic

mixed NCI_score_round s_NHPPS_round numberofnursingstudentsontheshif || hospitalcode: || shift_id:, reml nolog
estat ic
////best model fit
```

```
mixed NCI_score_round s_NHPPS_round numberofnursingstudentsontheshif || hospitalcode: numberofnursingstudentsontheshif || shift_id:, reml nolog
estat ic


///side to create a nurse student category
drop nurse_stu_cat
gen nurse_stu_cat=.
sum numberofnursingstudentsontheshif, detail
order nurse_stu_cat, after (numberofnursingstudentsontheshif)
replace nurse_stu_cat=0 if numberofnursingstudentsontheshif ==0
replace nurse_stu_cat=1 if numberofnursingstudentsontheshif ==1 & numberofnursingstudentsontheshif <=5
replace nurse_stu_cat=2 if numberofnursingstudentsontheshif >5 & numberofnursingstudentsontheshif <11
replace nurse_stu_cat=3 if numberofnursingstudentsontheshif >=11 & numberofnursingstudentsontheshif <16
replace nurse_stu_cat=4 if numberofnursingstudentsontheshif >=16 & numberofnursingstudentsontheshif <21
replace nurse_stu_cat=5 if numberofnursingstudentsontheshif >=21 & numberofnursingstudentsontheshif <26
replace nurse_stu_cat=6 if numberofnursingstudentsontheshif >=26 & numberofnursingstudentsontheshif <31
replace nurse_stu_cat=7 if numberofnursingstudentsontheshif >=31 & numberofnursingstudentsontheshif <36
replace nurse_stu_cat=8 if numberofnursingstudentsontheshif >=36
label define vfp 0"0" 1"1-5" 2"6-10" 3 "11-15" 4 "16-20" 5"21-25" 6"26-30" 7"31-35" 8">=36"
label values nurse_stu_cat vfp
browse numberofnursingstudentsontheshif nurse_stu_cat
edit
vioplot NCI_score_round, over (nurs_stu_cat) legend( ring(0) pos(2) cols(1)) xtitle("Number of nursing students") ytitle ("Nursing care index") obs scheme(s2color) ///Figure
tab nurs_stu_cat

///start here
//nNCI_score

///AIC and BIC test statistics for the best base model
//linear regression
regress nNCI_score_round s_NHPPS_round //y - mean value of dependent variable, Bo - intercept -expected value of y when NHPSS_round equal to 0 so when there an no nurses and care is provided for by only students, moithers etc. B1 - expected or predicted change in Y for each change in NHPPS_round
estat ic


//random intercept model
mixed nNCI_score_round s_NHPPS_round || shift_id: , reml nolog //random intercept model - assumption here is there is an intercept that changes based on the cluster level residual.
// slope is the same (becuse I havent put any random effect variables)
//so coefficient is the average change in NCI for each unit increase in NHPPS across any shift (not intuitive)
estat ic
```

Appendix 17- Emergency, traige and treatment plus (ETAT+) training for added nurses

Day 1: 25TH APRIL				
Registration			8.00am	All
Introduction to the course	Lecture	Plenary	8.30am	
Introduction to NEST	Lecture	Plenary	9.00am	
Introduction to Comprehensive Newborn protocol and standards of care	Lecture	Plenary	10.00am	Pediatrician
Tea			**10.00am**	
Family centered care and pain management	Lecture + discussion	Plenary	10.50am	Pediatrician
Newborn transition and adaptation	Lecture/discussion	Plenary	11.50am	Pediatrician
Lunch			**1.30pm**	
Newborn clinical signs and symptoms	Lecture/video/discussion	Plenary	2.30pm-4.00	Pediatrician
Use of Radiant warmer and suction machine	Lecture/discussion	plenary	4.00pm	nurse
End			**5.00pm**	
Day 2: 26th April, 2022				
Recap/pending issues	Lecture	Plenary	8.00am	Paediatrician
Pulse oximetry, oxygen therapy and monitoring	Lecture + demonstration	Plenary	8.30am-10.30am	Pediatrician/nurse
Tea			10.30am	
Newborn Resuscitation (NR)	Lecture+ demonstration	Plenary	11.00am-1.00pm	Pediatrician
Lunch			1.00pm	
Practical sessions- NR,use of radiant warmers and suction machine Practical sessions – oxygen therapy	Practical	Groups	2.00pm-5.00pm	
End			05.00pm	
Day 3: 27th April, 2022				

Recap/pending issues	Lecture	Plenary	8.00am	Nurse
Feeds and fluids management including breast milk expression and use	Interactive lecture/demonstations /exercises	Plenary	8.30am - 10.30am	Pediatrician/nurse
Tea			**10.30am**	
Breastfeeding techniques	Lecture	Plenary	11.00am-12.00pm	Nurse
Neonatal hypoglycemia	Lecture	Plenary	12.00am-1.00pm	Pediatrician
Lunch			**1.00pm**	
Practical sessions- NG/OG insertions, expression, cup feeding, drills, hypoglycemia discussion, heel prick, buccal glucose	practical	Groups	2.00pm-5.00pm	
End			05.00pm	
Day 4: 28th APRIL, 2022				
Recap/Pending issues	Lecture	Plenary	8.00am	Nurse
RDS and use of CPAP	Lecture	Plenary	9.00am	Pediatrician/nurse
Tea			10.00am	
Neonatal Jaundice	Lecture	Plenary	10.30am	Pediatrician/nurse
Lunch			01.00pm	
Practical sessions- CPAP, Phototherapy	Practical	Groups	02.00pm - 5.00pm	All
End			5.00pm	
Day 5: 29TH APRIL, 2022				
Recap/pending issues			8.00-8.15am	
Neonatal Seizures			8.15-9.15am	
Mixed scenarios			9.15am-10.30am	

Tea	10.30am - 11.30am	
Practical assessments	11.30- 2.00pm	
Practical assessments post-test/Evaluation	2.00pm	
Certification and closing remarks	2.15pm	
Lunch	3.00pm	

Appendix 18 – Model fit statistics for the best multilevel models comparing nurse-delivered care between the pre-intervention and post-intervention periods.

Table – Selecting the best-unadjusted model for the intervention and nurse-delivered care.

Model	Model specification	Likelihood ratio test*	AIC	BIC
Model 1	Linear model	NA	-720.67	-711.92
Model 2	Two-level random intercept model	<0.001	-1079.02	-1061.50
Model 3	Two-level random slope model	0.006	-1084.43	-1062.53
Model 4	Random intercept model with hospital adjusted for as a fixed covariate	0.30	-1066.37	1044.47
Model 5	**Three-level random intercept model**	**0.0001**	**-1094.09**	**-1072.19**
Model 6	Three-level random slope model	0.06	-1097.23	-1070.95

*Likelihood ratio test is based on Maximum Likelihood estimation, while the AIC and BIC were based on restricted maximum likelihood estimations

a- Model 2 was compared with Model 1 for likelihood ratio tests.

b- Models 3, 4 and 5 were compared to Model 2 for likelihood ratio tests.

c- Model 6 was compared to Model 5 for likelihood ratio tests.

Table – Model fit statistics for selecting the best model for intervention and nurse delivered care.

Model building	Model	Model specification	Likelihood ratio test*	AIC	BIC
Base model	**Model 1**	**Three-level random intercept model (unadjusted)**	**<0.001**	**-1094.09**	**-1072.19**
First covariate selection	Model 2	Model 1 adjusted for patient severity	0.0001	-1097.18	-1066.51
	Model 3	Model 1 adjusted for shift type	0.08	-1076.32	-1041.27
	Model 4	Model 1 adjusted for the number of nursing students (as a continuous variable)	0.02	-1086.51	-1060.23
	Model 5	Model 1 adjusted for the number of nursing students (as a categorical variable)	NA	-659.24	-616.81
Second covariate selection	Model 6	Model 2 adjusted for shift type	0.06	-1081.17	-1037.37
	Model 7	**Model 2 adjusted for the number of nursing students (as a continuous variable)**	**0.008**	**-1091.25**	**-1056.21**
Third covariate selection	Model 8	Model 7 adjusted for shift type	0.72	-1069.99	-1021.81

*Likelihood ratio test is based on Maximum Likelihood estimation, all other model estimations were based on restricted maximum likelihood estimations

a- Models 2 to 5 were compared to Model 1 for likelihood ratio tests.

Appendix 19 – model fit statistics for the best multilevel models comparing amount of nursing care between the pre-intervention and post-intervention periods.

Table – Selecting the best-unadjusted model for intervention and amount of nursing care.

Model	Model specification	Likelihood ratio test*	AIC	BIC
Model 1	Linear model	NA	-485.52	-476.76
Model 2	Two-level random intercept model	<0.001	-900.19	-882.67
Model 3	Two-level random slope model	0.57	-898.51	-876.60
Model 4	Random intercept model with hospital adjusted for as a fixed covariate	0.002	-896.64	-874.74
Model 5	Three-level random intercept model	<0.001	-971.99	-950.09
Model 6	**Three-level random slope model**	**0.002**	**-981.44**	**-955.15**

*Likelihood ratio test is based on Maximum Likelihood estimation, while the AIC and BIC were based on restricted maximum likelihood estimations

a- Model 2 was compared with Model 1 for likelihood ratio tests.

b- Models 3, 4 and 5 were compared to Model 2 for likelihood ratio tests.

c- Model 6 was compared to Model 5 for likelihood ratio tests.

Table – Model fit statistics for selecting the best model for intervention and amount of nursing care.

Model building	Model	Model specification	Likelihood ratio test*	AIC	BIC
Base model	**Model 1**	**Three-level random slope model**	<0.001	-972.38	-946.10
First covariate selection	**Model 2**	**Model 1 adjusted for patient severity**	**0.0005**	**-980.03**	**-944.99**
	Model 3	Model 1 adjusted for shift type	0.34	-961.44	-922.02
	Model 4	Model 1 adjusted for the number of nursing students (as a continuous variable)	0.048	-972.20	-941.54
Second covariate selection	Model 6	Model 2 adjusted for shift type	0.08	-963.17	-914.99
	Model 7	**Model 2 adjusted for nursing students (as a continuous variable)**	**0.01**	**-972.81**	**-933.39**
Third covariate selection	Model 8	Model 7 adjusted for shift type	0.20	-954.74	-902.18

*Likelihood ratio test is based on Maximum Likelihood estimation, all other model estimations were based on restricted maximum likelihood estimations

a- Models 2 to 5 were compared to Model 1 for likelihood ratio tests.