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Estimating long-term care needs in data-scarce settings: a diagnostic model with evidence from MENA

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Abstract

Background Rapid population ageing, high burdens of non-communicable diseases (NCDs), and limited formal care systems are converging in the Middle East and North Africa (MENA) region, generating an urgent need for evidence-based long-term care (LTC) planning. However, the absence of individual-level data on care dependency hampers assessment and policy design.

Methods We developed a population-based LTC Needs Index to estimate care dependency in data-scarce contexts. The Index integrates demographic ageing, prevalence of disability, and transition probabilities from five major NCDs (cardiovascular disease, diabetes, cancer, Alzheimer's disease, and Parkinson's disease) using standardized national and international data sources. Cross-country comparability was ensured through normalization and weighting procedures, and the model's robustness was tested using Bayesian, bootstrap, and deterministic sensitivity analyses.

Results The LTC Needs Index reveals substantial heterogeneity in care dependency across eight MENA countries, ranging from approximately 3% of the total population in Oman to 22.8% in Saudi Arabia. Projections for 2024–2030 show a consistent upward trend in LTC needs, primarily driven by demographic ageing. Disability emerged as the dominant factor, accounting for 67–94% of total index values, with diabetes and cardiovascular diseases contributing most strongly in Gulf states. Sensitivity analyses confirmed the index's stability under varying assumptions.

Conclusions The LTC Needs Index offers a scalable, validated diagnostic model for estimating population-level LTC needs in data-limited settings. It highlights the need for differentiated LTC strategies reflecting the varying contributions of disability and NCDs across countries. To advance equity and precision in planning, countries should invest in nationally representative survey data on ageing, disability, and care dependency to capture intra-country inequalities. The Index provides a transferable framework applicable to other data-scarce regions seeking to strengthen long-term care systems and policy preparedness for population ageing.

Keywords Long-term care needs, Ageing populations, Non-communicable diseases, Data-scarce settings, MENA region, Composite index modelling

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Introduction

Global population ageing is a central demographic trend of the twenty-first century. The number of adults aged ≥ 60 years is projected to approach two billion by 2050, with most growth in low-and middle-income countries (LMICs) [1, 2]. The global share of people aged ≥65 years will rise from 9% in 2019 to 16% by 2050, and those aged ≥80 years will represent about 4% of the world population [3]. This demographic shift is progressing faster in LMICs than in historical European or OECD transitions [3]. Concurrently, non-communicable diseases (NCDs) account for more than 70% of deaths and a major share of disability in LMICs [4, 5]. Population ageing, combined with behavioral risks such as tobacco use, inactivity, and obesity, is driving rapid increases in cardiovascular disease, diabetes, cancers, respiratory illnesses, and neurodegenerative diseases [6, 7].

Accurate estimation of long-term care (LTC) dependency is essential for effective health and social care planning [8, 9]. Data limitations and conceptual inconsistencies, however, continue to constrain projections, especially in LMICs. This constraint is pronounced in Middle East and North Africa (MENA), where population ageing is accelerating rapidly: the number of people aged 60 years and older is expected to triple by 2050 [1]. The region's demographic shift, driven by longevity gains, fertility decline, happening concurrently with rising NCD burden, illustrates a truncated epidemiological transition in which chronic conditions have supplanted infectious diseases as leading causes of morbidity, mortality, and economic pressure [10, 11]. MENA countries now report some of the world's highest prevalence of obesity and diabetes; in Saudi Arabia, for example, diabetes rates have nearly doubled in the past decade [11, 12].

Despite the accelerating need for support, formal LTC systems in MENA remain limited. Care provision continues to rely predominantly on families, especially women, reflecting entrenched gender norms and resulting in substantial unmet health and care needs [12–14]. Comprehensive LTC policies are rare, and formal service delivery is fragmented [11]. National data on ageing, disability, and care dependency are scarce, and definitions vary widely across countries, impeding comparable measurement and evidence-based planning [15].

Global literature demonstrates a strong link between NCDs, disability, and care dependency throughout the life course. NCDs now account for nearly three-quarters of deaths and are the leading drivers of disability worldwide [11, 16, 17]. Disability arises from interactions between health conditions and social or environmental contexts [18]. As chronic conditions accumulate, functional limitations in activities of daily living (ADLs) and instrumental ADLs (IADLs) increase, eventually leading to care dependency, the need for assistance with self-care or independent living [3, 19]. This continuum highlights the requirement for integrated, person-centered systems that align chronic disease management, disability inclusion, and LTC planning.

While high-income countries maintain robust ageing surveys such as HRS, ELSA, and SHARE [20], comparable data infrastructure is absent in MENA. Without reliable microdata, estimating LTC needs from ADL/IADL limitations is not feasible [21, 22]. Proxy measures based on disability prevalence or service utilisation may understate care dependency and exclude informal caregiving [23]. Variation in definitions and social stigma further contribute to under-reporting [24, 25]. Emerging HRS-style surveys in Lebanon and Egypt remain limited in scope and representativeness [26], leaving a persistent evidence gap.

To address this gap, this study develops a diagnostic, population-based LTC Needs Index to quantify care dependency in data-limited settings across MENA. The Index integrates demographic and epidemiological indicators to estimate population-level needs for LTC. Using standardized data sources, it enables cross-country comparability and supports evidence-based planning for sustainable, gender-sensitive care systems. The following sections describe the index construction, application, and validation in detail.

The LTC Needs Index is not intended to replace direct, individual-level measures of care dependency where such data are available. In settings with nationally representative ageing surveys, such as ELSA or SHARE, direct counts of individuals with ADL/IADL limitations provide the most transparent and accurate estimates of LTC need at a given point in time. However, in many low- and middle-income regions, including much of MENA, individual-level data on functional limitations are unavailable, fragmented, or non-comparable across countries. In these contexts, reliance on single indicators, such as disability prevalence or disease-specific burden alone, does not yield an estimate of the population share likely to require LTC, nor does it capture how age structure and comorbidity interact to generate care dependency.

The LTC Needs Index addresses this gap by integrating available aggregate data on disability prevalence, major NCDs, and population age structure within a single, normalised framework. By explicitly accounting for interactions between ageing, disability, and disease burden, the Index produces a policy-relevant approximation of the proportion of the population with potential LTC needs, providing information that is not directly observable from separate prevalence measures. Normalisation and consistent weighting further enable cross-country comparison and attribution of LTC needs to the underlying components, enhancing interpretability rather than obscuring it. Under clearly stated assumptions applied

uniformly across countries, the Index therefore serves as a diagnostic planning tool for data-scarce settings, while remaining complementary to, rather than a substitute for microdata-based assessments where these exist.

The eight countries included in this study (Saudi Arabia, Morocco, Tunisia, Egypt, Lebanon, Jordan, Oman, and Qatar) were selected to ensure representation across geographical subregions, income levels, and stages of demographic ageing within MENA. The sample includes North African countries (Morocco, Tunisia, Egypt), Levantine countries (Jordan, Lebanon), and Gulf states (Saudi Arabia, Oman, Qatar). It spans upper-middle-income and high-income settings and reflects varying stages of demographic and epidemiological transition, from relatively advanced ageing contexts (e.g., Morocco, Tunisia) to younger but rapidly transitioning Gulf states (e.g., Oman, Qatar). Data availability was a necessary inclusion criterion; however, country selection was also guided by the objective of capturing structural diversity in LTC needs across the region.

Methods

LTC needs index calculation

Figures 1 and 2 provide a visual overview of the conceptual logic underpinning the LTC Needs Index. Figure 1 outlines how population characteristics translate into need, demand, and cost, with demographic, economic, and cultural factors shaping the flow from individuals in need to service utilisation. Figure 2 presents the operational structure of the Index, showing how age distribution, disability prevalence, and non-communicable disease components are normalised, weighted, and combined into a single composite measure. Together, these diagrams clarify the pathways through which epidemiological and demographic inputs determine aggregate LTC needs.

The LTC Needs Index is constructed as a weighted sum of demographic and epidemiological components reflecting population-level demand for care. These include the age structure, disability prevalence, the prevalence of selected NCDs (cardiovascular disease, diabetes, cancer, Alzheimer's disease and other dementias, Parkinson's disease), and their interactions. Each component is expressed as a population-weighted function of age-specific prevalence and aggregated using a linear index formulation.

The selection of indicators included in the LTC Needs Index was guided by a targeted review of the LTC, ageing, and disability literature, combined with empirical relevance to the epidemiological profile of the MENA region. Indicators were chosen based on three criteria: (i) a well-established association with ADL/IADL-related

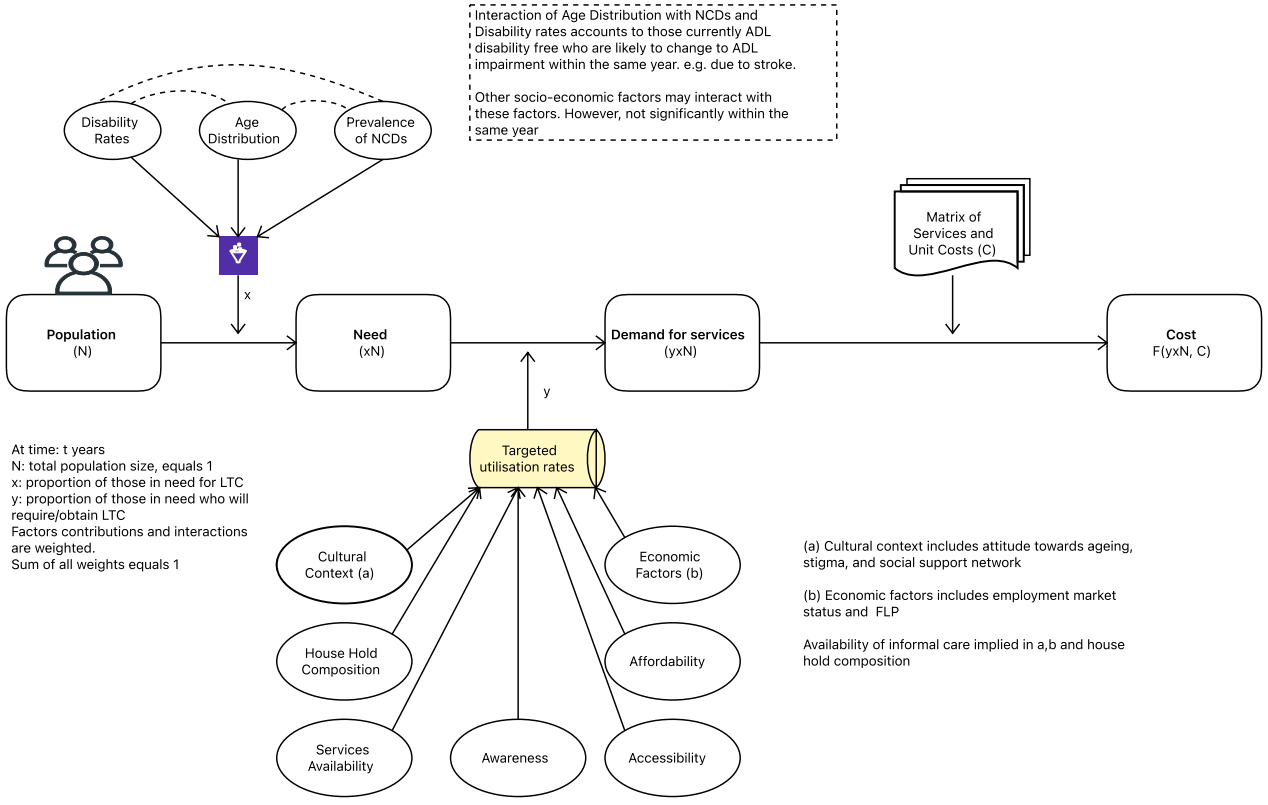


Fig. 1 LTC need, demand and cost framework. The diagram illustrates how population characteristics, disability, and non-communicable diseases translate into LTC need, demand for services, and associated costs within broader economic and cultural contexts

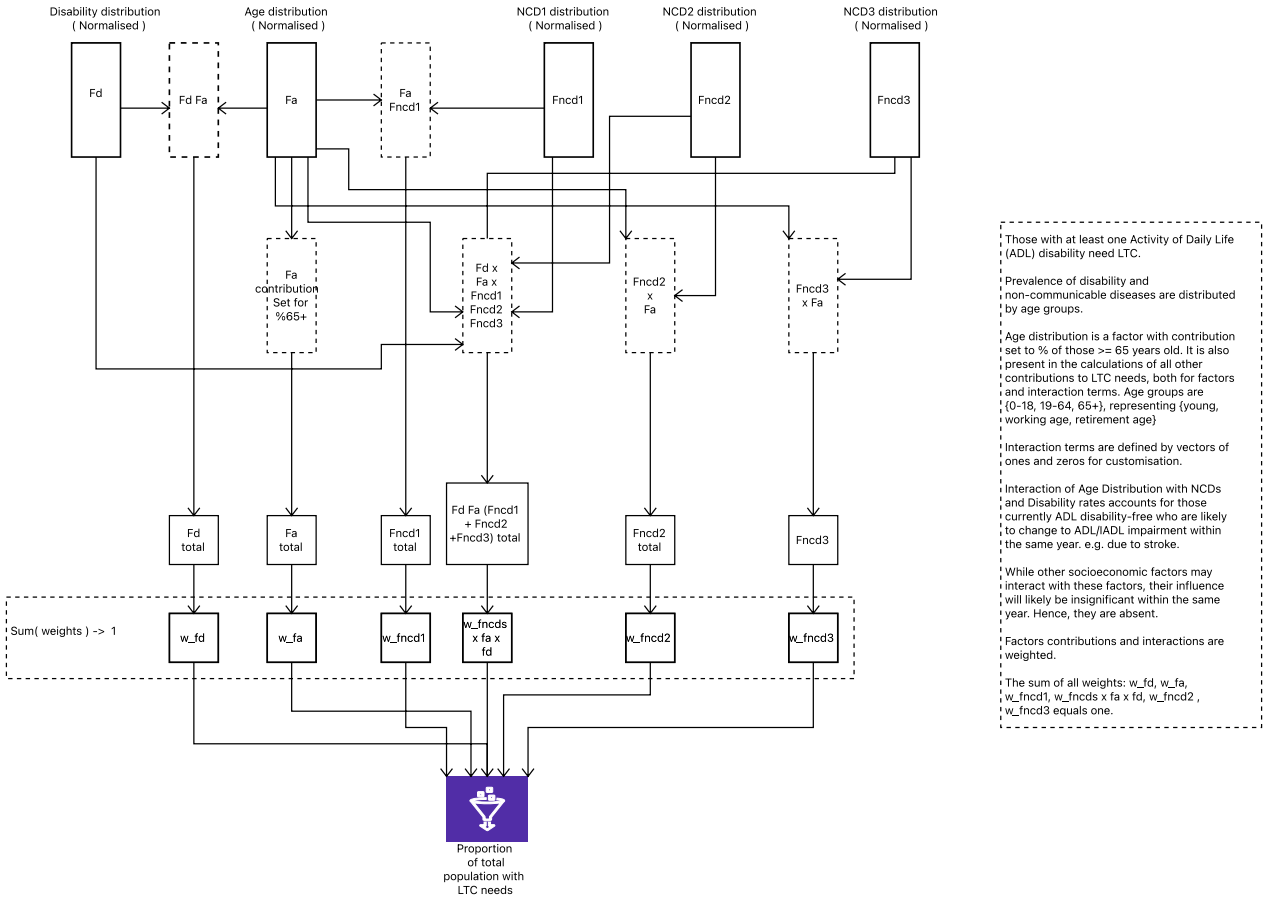


Fig. 2 LTC need calculation framework. The diagram presents the operational structure of the LTC Needs Index, showing how age distribution, disability prevalence, non-communicable disease components, and their interaction terms are normalised and combined. Only three NCDs are shown for visual clarity; the full model includes five

functional decline and care dependency; (ii) strong age gradients consistent with biological ageing processes; and (iii) sufficiently high prevalence to meaningfully contribute to population-level LTC needs.

Age structure plays a dual role in the construction of the LTC Needs Index. First, the share of the population aged 65 years and older is included as an explicit component with its own weight, capturing age-related LTC needs that are not fully explained by recorded disability or diagnosed disease, such as frailty and early functional decline. Second, age structure enters the calculation of all epidemiological components, as disability and disease prevalences are defined by age group and weighted by the corresponding population shares. In this sense, age structure acts as a structural modifier, scaling and normalising all prevalence-based components and their interaction terms. This dual role ensures that the Index reflects both latent age-related vulnerability and the demographic distribution through which epidemiological risks translate into population-level LTC need.

Recorded disability prevalence was selected as the closest available proxy for manifest functional limitation in the absence of individual-level ADL/IADL data.

The epidemiological components focus on five major non-communicable diseases: cardiovascular disease, diabetes, cancer, Alzheimer's disease and other dementias, and Parkinson's disease, because these conditions are strongly age-associated, highly prevalent in the MENA region, and consistently identified in the literature as leading clinical pathways into disability, multimorbidity, and long-term care dependency. Cardiovascular disease and diabetes were prioritised due to their exceptionally high prevalence in many MENA countries and their strong downstream association with functional impairment.

While other conditions may also lead to LTC needs, their prevalence at the population level is comparatively small, and their exclusion is therefore unlikely to materially affect aggregate estimates.

Broader social and economic determinants were not included, as they primarily influence access to or utilisation of care rather than underlying LTC need. While such

factors may shape long-term trajectories of health and care dependency, their effects are unlikely to transition an otherwise healthy individual into LTC need within a one-year period, which is the temporal unit of the Index.

Under data-scarce conditions, the selected indicators therefore represent a parsimonious, regionally relevant, and evidence-based set sufficient to approximate population-level LTC needs.

The age-related contribution is defined as:

$$F_{\text{age}} = \sum_{a \geq 65} P(a),$$
$$C_{\text{age}} = w_{\text{age}} \cdot F_{\text{age}}$$

where $P(a)$ denotes the population in age group a, and w_{age} represents the corresponding weight.

The contribution of disability is given by:

$$F_{\text{disability}} = \sum_{a} f_{\text{disability}}(a) \cdot P(a),$$
$$C_{\text{disability}} = w_{\text{disability}} \cdot F_{\text{disability}}$$

with $f_{\text{disability}}(a)$ denoting the age-specific prevalence of disability.

Each of the five NCD components, indexed by $x = 1, \ldots, 5$, contributes as:

$$F_{\text{ncd}_x} = \sum_{a} f_{\text{ncd}_x}(a) \cdot P(a),$$
$$C_{\text{ncd}_x} = w_{\text{ncd}_x} \cdot F_{\text{ncd}_x}$$

where $f_{\text{ncd}_x}(a)$ is the prevalence of the xth NCD in age group a.

To account for comorbidities, interaction terms between disability and each NCD are included.These interaction terms capture the elevated likelihood that individuals living with both a chronic condition and an existing disability experience greater functional impairment and are therefore more likely to require LTC than would be implied by either condition alone. By weighting the joint prevalence of disability and specific NCDs, the model approximates the compounded effect of comorbidity on ADL/IADL-related care dependency at the population level:

$$F_{\text{interaction},x} = \sum_{a} f_{\text{disability}}(a) \cdot f_{\text{ncd}_x}(a) \cdot P(a),$$
$$C_{\text{interaction},x} = w_{\text{interaction},x} \cdot F_{\text{interaction},x}$$

The total LTC Needs Index is then defined as:

$$\text{LTC}_{\text{index}} = C_{\text{age}} + C_{\text{disability}} + \sum_{x=1}^{5} C_{\text{ncd}_x} + \sum_{x=1}^{5} C_{\text{interaction},x}$$

To ensure comparability across populations and to avoid double counting, the component weights are constrained to form a convex combination, such that:

$$w_{\text{age}} + w_{\text{disability}} + \sum_{x=1}^{5} w_{\text{ncd}_x} + \sum_{x=1}^{5} w_{\text{interaction},x} = 1$$

This normalisation serves three purposes: (i) it places the index on a consistent scale across settings; (ii) it prevents inflation of the index due to overlapping or correlated components; and (iii) it allows the weights to be interpreted as transition-like probabilities that reflect the relative contribution of each pathway to overall care dependency.

Baseline weights were established based on literature [8, 17, 21, 22, 27–32] and expert judgment, reflecting typical transition probabilities from NCD or disability to care dependency. Along with region-specific context consideration. These weights act as starting values, and the uncertainty surrounding them is examined through the sensitivity analyses outlined below.

Baseline weights were derived through a structured synthesis of evidence on the relative association between age, disability, major non-communicable diseases, and ADL/IADL-related care dependency reported in the LTC literature. Rather than representing directly estimated hazards from a single dataset, the weights serve as theoretically informed starting parameters reflecting plausible relative transition magnitudes at the population level. They were calibrated to ensure internal consistency and constrained to sum to one (convex combination), thereby preserving interpretability and avoiding inflation due to correlated components. The robustness of results to alternative weight specifications is demonstrated through the Bayesian, bootstrap, and deterministic sensitivity analyses presented below.

For forward projections, the age-structure component varies annually using U.S. Census Bureau estimates, while prevalence of NCDs (used the most recent Global Burden of Disease (GBD) 2021 estimates, released online by the Institute for Health Metrics and Evaluation (IHME) in 2024) and disability (international survey sources) are fixed at their 2024 baseline levels across the six-year horizon. This simplifying assumption reflects both the limited availability of year-on-year prevalence forecasts and

the relatively short projection window considered here (2024–2030). It ensures that observed changes in the LTC Needs Index are driven primarily by demographic ageing, while the epidemiological burden is held constant.

A series of sensitivity analyses were performed for Tunisia to assess the robustness of the index under uncertainty in weight specification. These included Bayesian, empirical bootstrap, and probabilistic perturbation approaches, as described below.

To summaries, the LTC Needs Index draws on demographic, disability, and disease prevalence data from multiple national and international sources with heterogeneous age coverage and reference years. To ensure cross-country comparability, all inputs were harmonised to a common age structure and baseline year using a standardised processing approach. This included aligning prevalence estimates to available age groups, applying conservative age-gradient assumptions where age-disaggregated data were unavailable, and treating baseline prevalence values as time-invariant over the short projection horizon. A detailed description of data sources, age-group coverage, and harmonisation assumptions is provided in Appendix A.

Bayesian sensitivity analysis of weight parameters

To account for uncertainty in the weight specification, a Bayesian sensitivity analysis was performed. The component weights $\boldsymbol{w} = (w_1, w_2, \ldots, w_8)$, corresponding to age, disability, five NCDs, and an interaction term, were modelled as random variables drawn from a Dirichlet distribution:

$$\boldsymbol{w} \sim \text{Dirichlet}(\boldsymbol{\alpha})$$

where $\boldsymbol{\alpha} \in \mathbb{R}^8_{>0}$ is a vector of strictly positive concentration parameters. Rather than fixing $\boldsymbol{\alpha}$, each element was defined hierarchically using baseline weights π_i, a global scale parameter s, and component-wise perturbations λ_i:

$$\alpha_i = \pi_i \cdot \lambda_i \cdot s, \qquad \lambda_i \sim \mathcal{N}^+(1, \sigma^2)$$

where π_i denotes the original baseline weight and $\mathcal{N}^+$ is a truncated normal distribution restricted to positive values. We used $\sigma = 0.5$ and $s = 10$ to reflect moderate prior uncertainty.

Posterior inference was performed via Hamiltonian Monte Carlo in `Stan`. From the resulting posterior distribution of $\boldsymbol{w}$, posterior means and 95% credible intervals were computed to assess the sensitivity of each weight. Results are summarized in Fig. 5a. Posterior inference was performed using Hamiltonian Monte Carlo implemented in Stan (v2.36) [33], accessed through the command line interface.

Bootstrap-based sensitivity analysis

A complementary non-parametric bootstrap analysis was conducted to empirically estimate the variability of the component weights under data-driven uncertainty. Using factor-specific contributions $\mathrm{v} = (v_1, \ldots, v_8)$ derived for Tunisia, 1,000 bootstrap samples were generated by resampling v with replacement.

For each bootstrap replicate, a two-step normalization was applied. First, raw proportions $\tilde{w}_i^*$ were computed as:

$$\tilde{w}_i^* = \frac{v_i^*}{\sum_j v_j^*}$$

These were then adjusted to align with the original structure:

$$w_i^* = \frac{\tilde{w}_i^* \cdot w_i}{\sum_j \tilde{w}_j^* \cdot w_j}$$

where w_i are the originally assumed weights. This scaling preserved relative importance while allowing empirical variation. Mean and 95% percentile-based confidence intervals were computed for each w_i^*. Results are shown in Fig. 5b.

Bootstrap analysis with probabilistic weight perturbation

To assess the variability of the LTC Needs Index itself, we conducted a bootstrap simulation in which the original weights $\boldsymbol{w}$ were treated as transition-like probabilities and perturbed stochastically. The interpretation of the component weights as transition-like probabilities is intended at an aggregate, population level rather than as individual-specific hazard estimates. For example, a disability weight of 0.48 indicates that, within the one-year time unit of the model and conditional on the index structure, approximately 48% of individuals with recorded disability are assumed to transition into LTC need. Analogously, weights assigned to disease-specific components reflect the likelihood that individuals living with those conditions experience functional decline sufficient to require LTC over the same period. The constraint that all weights sum to one ensures internal consistency across pathways and avoids inflation of estimated LTC need when multiple risk factors coexist. At each iteration:

$$w_i^* = \frac{|w_i + \varepsilon_i|}{\sum_{j=1}^8 |w_j + \varepsilon_j|}, \qquad \varepsilon_i \sim \mathcal{N}(0, \sigma^2)$$

with $\sigma = 0.01$, ensuring positivity and normalization. The LTC Index was then recalculated as:

$$\text{LTC}^*_{\text{index}} = \sum_{i=1}^{8} f_i \cdot w_i^*$$

where f_i denotes fixed factor-specific contributions. The empirical distribution of $\mathrm{LTC}^*_{\mathrm{index}}$ was used to construct a 95% confidence interval for the index. Results are included in Fig. 5c.

Deterministic sensitivity analysis via weight perturbation

Finally, a deterministic one-at-a-time (OAT) sensitivity analysis was performed to assess the marginal effect of individual weight changes. For each component i, the weight w_i was perturbed by a multiplicative factor $(1+\delta)$, with $\delta \in \{-0.5, -0.4, \ldots, 0.5\}$, and the perturbed weight vector renormalized:

$$\sum_{i=1}^{8} w_i^{\mathrm{perturbed}} = 1$$

The index was then recomputed as:

$$\mathrm{LTC}^*_{\mathrm{index}} = \sum_{i=1}^{8} f_i \cdot w_i^{\mathrm{perturbed}}$$

The resulting values were visualized in a heatmap, highlighting the LTC Index's sensitivity to each component's weight. This supports interpretation of the weights as transition-like probabilities and identifies highly influential components. The results appear in Fig. 5d.

Visualisation, bootstrap- and perturbation-based sensitivity analyses, as well as data management, were conducted in R (v4.4.2) [34] and Python [35].

Use of recorded disability as a proxy for functional limitations

In principle, disability prevalence could be represented within a continuous age-structured framework such as the McKendrick–von Foerster model [36, 37], which tracks population density at each age through age-specific birth and death rates. Although the model does not explicitly include disability, it can be extended to incorporate additional transitions such as disability onset and progression. In this study, however, we do not project disability prevalence forward in time. Instead, we take the 2024 age-specific prevalence distribution as fixed and apply it to the changing population age structure (using US Census Bureau projections). In this way, changes in the aggregate level of disability and its implications for LTC needs arise solely from demographic shifts.

A central measurement difficulty is that reported disability does not necessarily correspond to limitations in ADLs or IADLs [9]. While European surveys such as SHARE [38] allow direct estimation of ADL and IADL limitations, such data are largely unavailable in the MENA region. Consequently, we use recorded disability as the best available proxy indicator for ADL/IADL-related dependency. Within the LTC Needs Index, this measure is incorporated as a weighted component rather than being treated as a direct equivalent of ADL or IADL prevalence. It is important to note, however, that both recorded disability measures and ADL/IADL-based surveys, even in contexts like the EU, may contain inaccuracies due to issues such as under-reporting, over-reporting, and cultural perceptions. The logical pathways illustrating how individuals are classified as having ADL/IADL-related disability within the model are shown in Appendix B, Fig. 6, which provides a schematic rather than a numerical representation of these classification steps.

There is no consensus on how disability will evolve in ageing societies. Three main hypotheses have been proposed: (i) the expansion of morbidity scenario [39], in which rising life expectancy extends years lived in poor health; (ii) the compression of morbidity hypothesis [40], where prevention and improved health delay disability into a shorter period at life's end; and (iii) Manton's dynamic equilibrium [41], where prevalence of chronic conditions rises but severity declines. In light of data constraints and the six-year projection horizon, we adopt the expansion of morbidity as a benchmark assumption, recognising it as a conservative framing while holding age-specific disability prevalence constant over time.

Data sources on disability prevalence

Disability prevalence estimates in the MENA region are drawn from a range of national and regional sources, each with varying coverage and definitions. Constructing the values for each country often required combining information from multiple reports, and in some cases distributing a single headline figure across the age structure. In the summary below we highlight the main reference sources used, recognising that the underlying estimates frequently reflect a synthesis of several datasets.

For Egypt, UN-ESCWA regional estimates suggest a prevalence of around 31% among older adults, while complementary evidence from Metwally (2021, 2023) provides age-specific detail across the broader population [10, 23, 42]. In Jordan, data are available from the 2015 Population and Housing Census (published in 2021) and are supplemented by Humanity & Inclusion's analysis of disability and social protection [43, 44]. Saudi Arabia relies on the national Disability Survey conducted by the General Authority for Statistics in 2017 [25], while in Lebanon the main reference is the ILO's 2023 briefing report on living with disabilities [45]. Evidence for Morocco comes from the High Commission for Planning's presentation at the 15th Washington Group meeting (2015) [46], and for Oman from regional compilations published by UN-ESCWA [23]. In Qatar, the most recent available source is the 2010 Population and Housing

Census [24]. In Tunisia, reported prevalence ranges from 2.15% to 16.3%, with variation likely reflecting stigma and underreporting as well as differences in classification practices, such as reliance on segregated education systems [47].

Overall, the figures reported for many of these countries are considerably lower than those found in other contexts. For example, in Wales, 22.3% of females and 19.8% of males were recorded as disabled in the 2021 Census [48].

Results

LTC needs estimates and projections across countries in the MENA region

For brevity, countries are referred to using their ISO 3166-1 alpha-3 codes throughout this article: SAU (Saudi Arabia), MAR (Morocco), TUN (Tunisia), EGY (Egypt), LBN (Lebanon), JOR (Jordan), OMN (Oman), and QAT (Qatar).

Table 1 presents LTC needs projections reflecting year-on-year changes in population age structure, while NCD and disability prevalence are shown at their 2024 baseline values. Thus, variation across 2024–2030 primarily captures demographic ageing.

Across all eight countries, the LTC Needs Index reveals a clear upward trajectory between 2024 and 2030, reflecting population ageing as the main driver of projected care demand. Countries at more advanced stages of demographic transition, such as Morocco, already exhibit substantially higher index values, while Gulf states such as Oman and Qatar remain lower but are increasing rapidly in relative terms. The observed increasing trends of LTC needs due to the demographic shift alone are broadly consistent with regional demographic estimates from the United Nations [49] and with the expected expansion of morbidity described by [40] and more recent evidence are showing similar patterns of NCD-related disability growth in upper-middle-income countries [4, 13].

Table 1 highlights the steady increase in LTC need across all countries, with Saudi Arabia showing the steepest projected rise, followed by Morocco and Tunisia. The relatively flat projections for Oman and Qatar reflect their younger age structures and more recent epidemiologic transitions. The projected annual increments, averaging roughly 0.002–0.004 index points, suggest a cumulative rise of approximately 10–15 per cent over the six-year period. Such changes, though gradual, translate into hundreds of thousands of additional individuals with potential care needs by 2030. Comparable population-based projections reported for Latin America and East Asia confirm similar proportional increases in LTC

Table 1 Projected index values for total proportions of LTC Need (2024–2030), sorted by 2030 value

Country (ISO)	Metric	2024	2025	2026	2027	2028	2029	2030
SAU	Lower	0.227	0.228	0.229	0.230	0.230	0.231	0.232
	Value	0.228	0.229	0.230	0.231	0.232	0.232	0.233
	Upper	0.233	0.234	0.236	0.237	0.238	0.238	0.239
MAR	Lower	0.186	0.188	0.189	0.190	0.191	0.192	0.194
	Value	0.188	0.189	0.190	0.192	0.193	0.194	0.195
	Upper	0.194	0.196	0.197	0.198	0.200	0.201	0.202
TUN	Lower	0.099	0.101	0.102	0.103	0.105	0.106	0.107
	Value	0.101	0.102	0.103	0.105	0.106	0.108	0.109
	Upper	0.108	0.109	0.111	0.112	0.114	0.115	0.116
EGY	Lower	0.083	0.084	0.084	0.085	0.086	0.087	0.088
	Value	0.084	0.084	0.085	0.086	0.087	0.088	0.089
	Upper	0.088	0.089	0.090	0.091	0.092	0.093	0.094
LBN	Lower	0.072	0.074	0.075	0.076	0.078	0.079	0.081
	Value	0.074	0.075	0.077	0.078	0.080	0.081	0.083
	Upper	0.081	0.083	0.085	0.086	0.088	0.089	0.091
JOR	Lower	0.068	0.069	0.070	0.071	0.072	0.073	0.074
	Value	0.069	0.070	0.071	0.072	0.073	0.074	0.075
	Upper	0.073	0.074	0.076	0.077	0.078	0.079	0.081
OMN	Lower	0.027	0.027	0.028	0.028	0.029	0.029	0.030
	Value	0.028	0.028	0.028	0.029	0.030	0.030	0.031
	Upper	0.031	0.031	0.032	0.032	0.033	0.034	0.035
QAT	Lower	0.012	0.012	0.013	0.013	0.013	0.014	0.014
	Value	0.013	0.014	0.014	0.014	0.015	0.015	0.015
	Upper	0.017	0.017	0.017	0.018	0.018	0.019	0.019

NCD prevalence projections are based on the Global Burden of Disease Study 2024 [50]. Age structure projections are sourced from the U.S. Census Bureau [51]. All values are rounded to three decimal places

Table 2 Index-factor attribution for the year 2024

Factor	MAR	EGY	SAU	TUN	JOR	LBN	OMN	QAT
Age	2.23	3.34	0.96	5.16	3.06	6.42	7.29	5.60
Diab	3.85	3.91	2.29	5.84	7.30	9.44	11.49	38.68
CVD	2.60	4.63	1.57	5.47	4.49	8.84	12.20	19.24
Cancer	0.11	0.28	0.13	0.44	0.44	1.17	0.45	2.29
Alz/Dem	0.16	0.18	0.06	0.41	0.25	0.78	0.43	0.46
Park	0.02	0.04	0.01	0.05	0.03	0.08	0.09	0.13
Disab	88.89	86.40	93.89	80.90	82.95	70.33	67.08	33.02
Disab × NCDs	2.13	1.21	1.10	1.73	1.50	2.95	0.98	0.58

Diab = Diabetes; CVD = Cardiovascular diseases; Cancer = Total cancers; Alz/Dem = Alzheimer's disease and other dementias; Park = Parkinson's disease; Disab = Disability; Disab × NCDs = Interaction of disability with non-communicable diseases

Fig. 3 Heatmap of index-factor attribution across countries in 2024. Darker colors indicate greater attribution

demand associated with rapid ageing and NCD expansion [4].

Factors attribution

To better understand the composition of the LTC Needs Index, Table 2 decomposes the 2024 baseline into contributions from demographic, epidemiological, and interaction components. This helps clarify which factors dominate the overall variation across countries.

The attribution analysis demonstrates that disability overwhelmingly drives LTC needs in all MENA countries, accounting for 67–94 percent of total index values, see Table 2. Diabetes and cardiovascular diseases contribute the next-largest shares, particularly in Gulf states, while cancers and neurodegenerative conditions (Alzheimer's and Parkinson's) remain smaller components. Figure 3's heatmap underscores this gradient, with darker cells indicating countries where chronic diseases amplify the disability effect. This aligns with global evidence that functional limitations, rather than age per se, explain most care dependency [19] and with analyses linking multimorbidity to rising disability-adjusted life-years in older populations [6] (Fig. 4).

To test the robustness of these factor weightings and to evaluate uncertainty propagation, a suite of sensitivity analyses was performed. These included Bayesian estimation, non-parametric bootstrap resampling, probabilistic perturbation, and deterministic one-at-a-time perturbation. Such complementary approaches are consistent with recommended practice in diagnostic-index validation [52] and enable assessment of both structural and parameter uncertainty within the LTC Needs Index. Table 3 summarises the Bayesian posterior estimates of the factor weights and their 95% credible intervals, providing the numerical basis for the visual analyses shown in Fig. 5d. The results indicate that disability and its interaction with NCDs have the largest posterior means and widest credible intervals, confirming their dominant

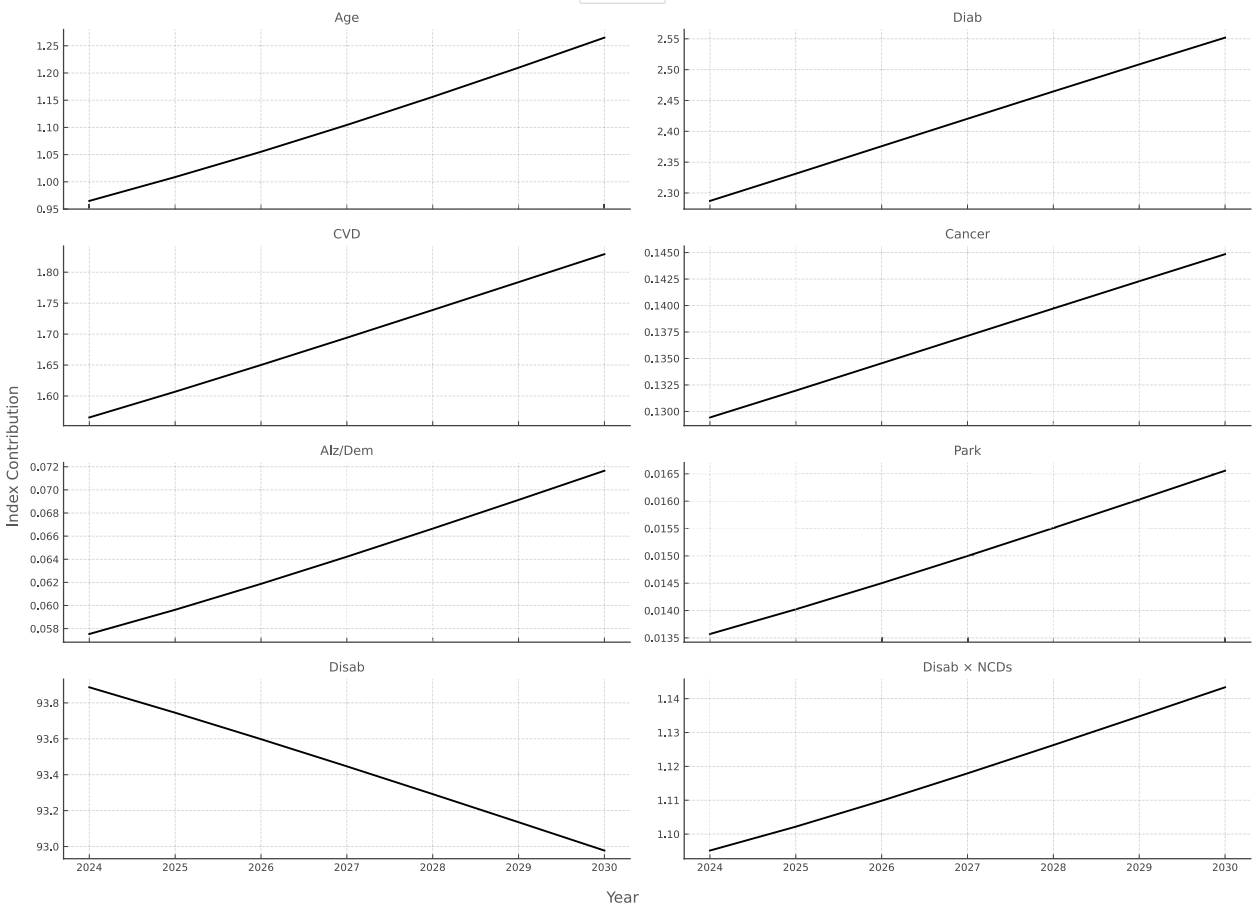


Fig. 4 Projected contribution of individual factors to LTC need index in Saudi Arabia (2024–2030). Factor abbreviations as defined in Table 2

Table 3 Bayesian sensitivity analysis of factor weights

Factor	Mean weight	Lower CI	Upper CI
Age	0.05	3.19×10^{-10}	0.24
Diab	0.05	2.89×10^{-7}	0.26
CVD	0.05	2.04×10^{-9}	0.26
Cancer	0.05	2.08×10^{-8}	0.27
Alz/Dem	0.05	7.30×10^{-7}	0.27
Park	0.05	1.84×10^{-6}	0.27
Disab	0.48	0.08	0.83
Disab × NCDs	0.20	0.00	0.56

influence on overall LTC needs, whereas age and single-disease components contribute comparatively little once disability is accounted for.

Figure 5 shows that despite parameter perturbations, the LTC Needs Index remains stable within narrow confidence bounds. The consistency across Bayesian and bootstrap frameworks demonstrates internal validity, while deterministic perturbations help identify components with the greatest marginal influence, chiefly disability and its interactions with NCDs. Similar index-stability findings have been reported when composite health-burden indicators are validated using hierarchical Bayesian methods [4].

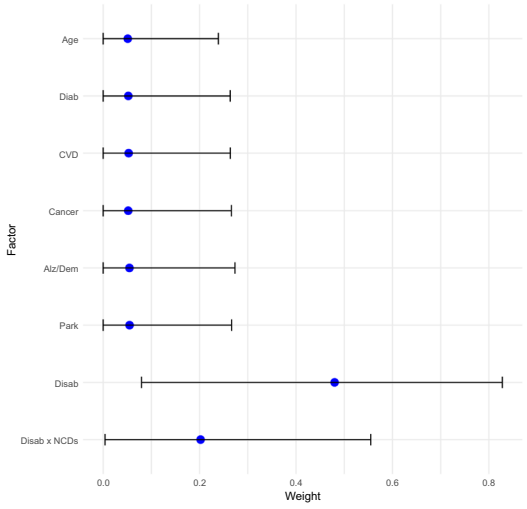
We explored the broader implications of these results in the Discussion. Appendix C, Figs. 7, 8, provide supplementary cross-country and demographic projections.

Discussion

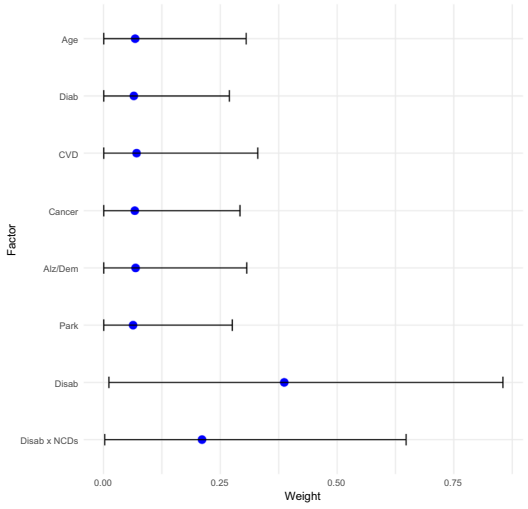
Sensitivity analysis results

The results of the four sensitivity analyses, summarised visually in Fig. 5 reveal a consistent and interpretable structure in the distribution of component weights and their impact on the LTC Needs Index. Each panel in the figure corresponds to one of the methods described in the Methods section: (a) Bayesian sensitivity analysis, (b) bootstrap-based resampling of weights, (c) probabilistic perturbation of the index, and (d) deterministic one-at-a-time perturbation of weights.

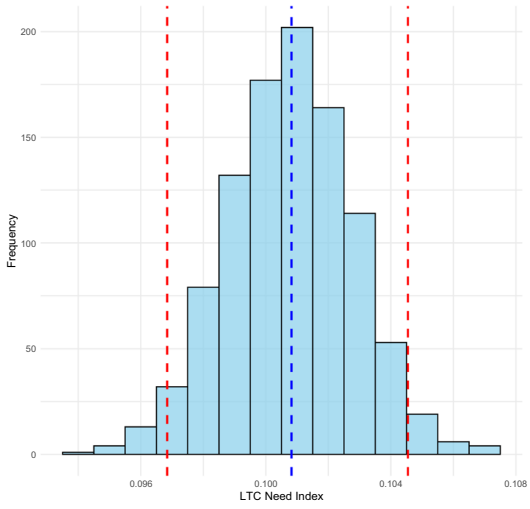
Across both the Bayesian (panel a) and bootstrap-based (panel b) analyses, components with relatively small average weights, namely *Age*, *Diab*, *CVD*, *Cancer*, *Alz/Dem*, and *Park*, exhibit right-skewed distributions. This pattern suggests that these factors are often assigned low influence, though occasional samples attribute them



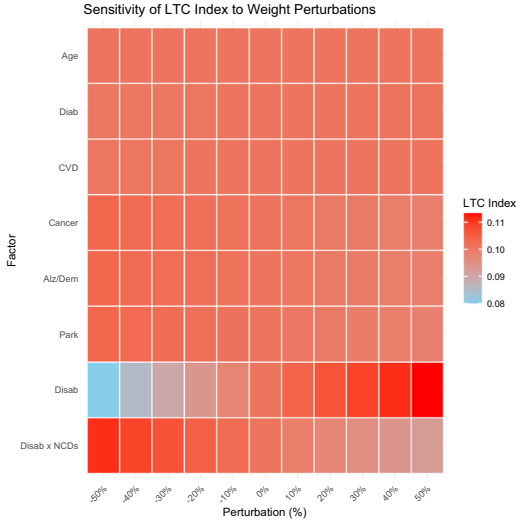
(a) Bayesian sensitivity analysis of weights



(b) Bootstrap sensitivity analysis of weights



(c) LTC index from bootstrap analysis with probabilistic weight perturbation



(d) LTC index sensitivity to deterministic weight perturbation

Fig. 5 Sensitivity analysis results for LTC index in Tunisia. Each panel corresponds to the methods described in the Methods section: (**a**) Bayesian, (**b**) bootstrap resampling of weights, (**c**) probabilistic perturbation of the index, and (**d**) deterministic one-at-a-time perturbation

greater importance, resulting in long upper tails. In contrast, the *Disability* and *Disability* × *NCDs* components consistently receive higher average weights with more symmetric, though relatively wide distributions. These two components appear to drive the index most strongly, albeit with residual uncertainty in their exact contributions.

The LTC index's robustness to random variation in weights is further demonstrated in the probabilistic perturbation analysis (panel c), where weights were perturbed around their original values using small random noise. The resulting distribution of the LTC index was tightly clustered, with a median of approximately `0.1007` and a 95% bootstrap confidence interval from `0.0953` to `0.1061`. Despite allowing for uncertainty in all eight components, the aggregate index showed limited volatility, highlighting the model's structural resilience

Finally, the deterministic perturbation analysis (panel d) explored how systematic changes in individual weights affect the index value. Perturbing each weight by ±50% while holding others constant revealed that the index is most sensitive to changes in the *Disability* component.

This component produced the largest variation in the LTC index across the tested range, while changes to low-weighted components had minimal impact. These findings reinforce the interpretation of the *Disability* pathway as a key driver of LTC needs in the Tunisian context.

Taken together, these results validate the use of the LTC Needs Index as a stable and interpretable summary measure. While individual weights may vary under different assumptions or sampling procedures, the index itself remains robust–highlighting its suitability for policy planning, needs-based benchmarking, and cross-country comparisons.

The Index should be viewed not as a substitute for comprehensive ageing surveys, but as an interim diagnostic tool that can both inform planning and highlight the need for improved data infrastructure.

External validation against published data

We validated the overall value of the LTC index for the older age group by comparing it against published results and found broadly consistent outcomes. The index is constructed from cause-specific prevalence estimates of major non-communicable diseases (including dementia, cardiovascular disease, diabetes, cancers, and Parkinson's disease) using the age groups available in the source data. For the older population, this corresponds to the 55+ category, which we adopt as a proxy for the 65+ population given the absence of finer age disaggregation.

Applying the LTC need index calculations as defined in the methods section, the estimated values for England (2024 data) are 24% for those aged 55+ (without adding the age component) and 24.44% when including the age component. These values are considered valid for comparison with the 65+ population, as they fall within the expected range. They represent the share of adults 55+ in England estimated to be in need of support with at least one ADL or IADL.

According to [53], based on ELSA 2018 data, approximately 24% of individuals aged 65+ in England receive some form of long-term care (either residential or home-based), a figure often interpreted as a proxy for ADL-related needs. More recent evidence from the Health Survey for England (2021, Part 2) shows similar results: 24% of men and 28% of women aged 65+ needed help with at least one ADL in the past month, while 21% of men and 29% of women needed help with at least one IADL. The likelihood of needing help with daily activities rises steeply with age, with just over half (52%) of those aged 80 and over reporting limitations. Among all adults aged 65+, around 22% reported unmet needs for ADL support and 15% for IADL support [54]. Comparative evidence from Poland also highlights the importance of including IADLs: around 20% of those aged 65+ reported at least one ADL limitation, but over 40% reported at least one IADL limitation [55].

The baseline inputs used in this validation exercise are consistent with the published evidence cited above. Specifically, age-specific prevalence of major non-communicable diseases was taken from Global Burden of Disease estimates for England, while functional limitation was benchmarked against nationally representative survey evidence indicating that approximately one quarter of adults aged 65 years and older report at least one ADL or IADL limitation. The resulting index value of around 24% therefore falls squarely within the range implied by these underlying prevalence measures, providing reassurance that the index reproduces empirically observed levels of care dependency when applied in a data-rich setting.

Methodological innovation and applicability

A principal strength of this study resides in its methodological innovation. The region is characterised by sparse data, especially concerning ageing and LTC needs, with older individuals (50+, the group with the most LTC needs) mostly excluded from national household surveys [56]. By developing the LTC Needs Index as a weighted composite of demographic and epidemiological indicators, the model effectively addresses the substantial challenge posed by the lack of micro-level data through an innovative approach that integrates internationally standardised sources with expert knowledge derived from previous primary research to establish the transition probabilities from the onset of certain diseases to the experience of LTC needs. Importantly, sensitivity analyses conducted as part of this study demonstrated the robustness of the factor weights and methodological consistency, thereby enhancing confidence in the index as a diagnostic tool. It is particularly well-suited for replication in other regions encountering similar data constraints, such as Sub-Saharan Africa, South Asia, and parts of Latin America, where policymakers require a foundational tool to benchmark LTC needs and facilitate system design.

Regional heterogeneity in estimated LTC needs

The findings expose significant differences in the estimated current and projected LTC needs across different countries, as well as in the attribution of these needs to underlying demographic and epidemiological determinants. These insights carry substantial implications for system planning, health and social care policy formulation, and the sustainability of informal caregiving, which continues to constitute the predominant mode of provision within the region [49].

The LTC Needs Index shows that by 2030, the share of the population with LTC needs will be highest in Saudi Arabia (0.233) and in Morocco (0.195), with Tunisia

(0.109) also facing substantial growth (Table 1). By contrast, Oman (0.031) and Qatar (0.015) remain at earlier stages of demographic ageing and show the lowest projected LTC needs. Countries such as Egypt (0.089), Lebanon (0.083), and Jordan (0.075) fall in the middle of the distribution. These projections reflect broader patterns of demographic and epidemiological transitions across the region. Morocco and Tunisia, for instance, are experiencing rapid population ageing with relatively limited health and social care infrastructure [57, 58]. Gulf states, though still demographically younger, face steep rises in chronic disease prevalence that will quickly increase their LTC needs if left unaddressed [59].

Attribution patterns: disability and disease burden

In nearly all countries examined, disability emerges as the predominant factor driving LTC needs. As of 2024, disability constitutes 93.89% of LTC attribution in Saudi Arabia, 88.89% in Morocco, and exceeds 80% in Egypt, Tunisia, and Jordan. Even in nations where disability accounts for a lesser proportion, such as Lebanon (70.33%) and Oman (67.08%), it still represents the majority of LTC attribution. Disabilities contribute to functional decline, which is the primary determinant of care dependency, rather than age alone [60, 61].

For Saudi Arabia, where the LTC index is projected to reach 0.233 by 2030, with considerable disability attribution, the implication is that policies must prioritise disability prevention, rehabilitation, and inclusive social support systems. This finding aligns with recent national research [62] and is reflected in current efforts under Vision 2030, which is framed within a disability rights framework to improve accessibility. However, such a Vision is still in the planning and implementation phase, with formal LTC services remaining scarce, and much of the burden falling on families, particularly women [63].

In Qatar, the attribution structure differs notably where diabetes accounts for 38.68% of LTC needs, compared to only 33.02% from disability (Table 2). Cardiovascular disease is also a major contributor at 19.24%. This contrasts sharply with the disability-dominated profiles seen elsewhere. The high diabetes burden reflects Qatar's epidemiological reality as the country has one of the highest diabetes prevalence rates globally, with nearly one in six adults affected [64]. Projections indicate that without intervention, nearly one-third of national health spending could be allocated to diabetes care by 2050 [65].

From a practice perspective, this means that LTC systems in Qatar and similar Gulf states must integrate diabetes management and complication prevention as core LTC strategies. Scaling up primary prevention, obesity reduction programs, and early detection tools such as the PRISQ diabetes risk score [66] can help reduce downstream LTC demand. For individuals already living with diabetes, ensuring access to multidisciplinary care, including endocrinology, nutrition, and rehabilitation, is critical to delaying functional decline and LTC dependency.

The contrast between Saudi Arabia's disability-driven LTC profile and Qatar's diabetes-driven profile illustrates the heterogeneity of ageing and health transitions across the MENA region. While disability prevention and inclusive LTC infrastructure will be universally important, Gulf states must also prioritise aggressive NCD management to mitigate future LTC demand. Conversely, North African states like Morocco and Tunisia, where projected LTC needs are already high (0.195 and 0.109 by 2030, respectively), face immediate challenges in scaling care provision despite limited resources.

This heterogeneity underscores the danger of adopting uniform LTC models across MENA. Instead, regional cooperation could focus on knowledge transfer, for example, Gulf states sharing experiences in financing and infrastructure development, while North African countries contribute lessons in community-based and informal caregiving systems.

Global comparison: where MENA stands

When considered on a global scale, the MENA region remains at an earlier stage of population ageing in comparison to Europe, North America, East Asia, and even certain countries in Latin America, where detailed longitudinal surveys are available. The current evidence regarding LTC needs from various parts of the world predominantly depends on nationally representative household surveys focusing on older adults, such as the English Longitudinal Study of Ageing (ELSA), the Survey of Health, Ageing and Retirement in Europe (SHARE), and the U.S. Health and Retirement Study (HRS) [38, 67, 68].

As the LTC Needs Index developed in this study estimates care needs across the entire population rather than solely focusing on functional limitations among older adults, a direct comparison is not feasible. Nonetheless, an examination of international literature concerning ADL/IADL prevalence provides a provisional reference point. In India, for instance, analyses of WHO SAGE data suggest that up to 55.7% of older adults report at least one difficulty in ADLs [69, 70]. In Vietnam, 44.6% of the elderly report ADL limitations, and 35.2% report IADL limitations [71]. A global prevalence of one or more IADLs in Europe was found to be 23.8% [72]. In East Asia, data from the Korean Longitudinal Study of Ageing show prevalence rates of 6.14% for ADLs and 15.49% for IADLs among those aged 65+ [73].

These figures underscore both the high global prevalence of functional limitations and the central role of disability in driving LTC needs. They also highlight

that while the disability-driven LTC profile observed in MENA is broadly consistent with international patterns, it is unfolding at a much earlier stage of demographic ageing, and in the absence of structured monitoring systems that underpin LTC policy in Europe, North America, and East Asia.

Compared to countries which are at a later stage of their demographic transitions, MENA remains in a formative stage of LTC system development. In Europe, formal LTC systems are increasingly universalised, especially in Nordic countries where state provision and professionalisation are standard [74, 75]. In East Asia, countries such as Japan and South Korea have adopted hybrid LTC insurance models that blend familial and institutional care [76–79]. By contrast, MENA's systems are fragmented, underfinanced, and reliant on informal, family-based structures, often unsupported by legislation or funding [49]. This places MENA closer to regions like Latin America, where social protection systems are similarly uneven [80]. A consistent theme in the region is the dominance of informal caregiving, particularly by women [12, 58]. The World Health Organization notes that in most MENA countries, 80–95% of LTC is delivered by unpaid female family members, often without formal support or recognition [56]. This "silent system" of care is culturally embedded but increasingly unsustainable in the face of demographic and social change, including rising female labour force participation, urbanisation, and smaller household sizes.

Policy and practice implications

This study presents a comparative diagnostic model of LTC needs across eight nations within the MENA region. It emphasises both the extent of LTC needs and the variability of factors influencing care dependency. These escalating LTC needs contrast with the existing support and LTC systems in the region, exposing substantial gaps in unmet health and care needs among the general population with specific disease burdens [81–83], particularly among older individuals [49, 56]. The evidence underscores a growing disparity between population ageing and the preparedness of health systems across numerous MENA countries. Current data highlight the importance of forecasting LTC needs not only based on age demographics but also considering functional status, comorbidities, and the availability of family caregivers, all of which are incorporated within the LTC Needs Index.

The unique epidemiological profile in MENA, with a dual burden of disability and rapidly rising NCDs, necessiates tailored LTC system responses rather than replication of external models. Previous studies from Europe indicate that not all needs will directly result in formal LTC needs; it is the combination of needs, complexities, and availability of informal care that are likely to contribute to higher needs for formal LTC services [84, 85]. Furthermore, emerging technologies and advances in artificial intelligence (AI) are increasingly valuable levers to enhance self-care and enable individuals to manage basic care needs and long-distance care provision [86, 87].

A central implication of this study is the need to integrate NCD management into LTC planning, particularly in Gulf countries such as Qatar. The attribution analysis revealed that in Qatar, diabetes accounts for 38.68% of projected LTC needs and cardiovascular disease for 19.24%, exceeding the share attributed to disability. This epidemiological profile underscores that LTC needs in several countries including Qatar is strongly shaped by NCDs and their long-term complications, such as functional decline, amputations, and cognitive impairment associated with poorly controlled diabetes [64, 65]. Consequently, LTC strategies cannot be treated as separate from national NCD action plans. Early interventions, including lifestyle modification, obesity reduction, and systematic screening programs, can generate significant returns by delaying or preventing disability and dependency in later life [88, 89]. Embedding chronic disease management within LTC planning is therefore essential to reduce future care needs and ensure sustainability.

The study underscores the urgent necessity to invest in data systems and forecasting capacity for LTC. Current projections, including those generated by this LTC Needs Index, rely heavily on aggregate prevalence estimates of disability and chronic disease. While valuable for regional comparisons, such data inevitably obscure intra-country disparities, such as urban–rural divides, socioeconomic inequalities, or gendered differences in care access. A recent WHO report notes that only Egypt and Lebanon have initiated systematic data collection on functional status, care arrangements, or unmet LTC needs among older adults [56]. To promote evidence-based planning, MENA countries must prioritise the development of comprehensive national LTC datasets, ideally longitudinal, capturing individual trajectories of disability, chronic disease, and care utilisation. Such data would facilitate more precise demand forecasting, enable cost estimation, and strengthen the foundation for policy formulation. Without these investments, policymakers risk engaging in reactive planning rather than strategic, proactive approaches to the rapidly evolving demographic and epidemiological challenges.

Replicability

The LTC Needs Index is structurally transferable to other data-scarce settings. Replication requires only three inputs that are commonly available through international databases: age-structured population data, age-specific disability prevalence (or proxy measures), and age-specific

prevalence of major non-communicable diseases. The convex weighting framework and sensitivity-testing approach allow transparent adaptation to alternative epidemiological profiles, including settings in Sub-Saharan Africa and South Asia undergoing rapid NCD transitions.

Informal care

The Index estimates underlying care dependency irrespective of whether care is provided formally or informally. In contexts where family-based care predominates, combining Index estimates with qualitative or household-level data on caregiving capacity would enable more comprehensive assessment of unmet need and caregiver burden. Such integration is particularly relevant in settings where women provide the majority of unpaid care.

Limitations

Several limitations must be recognised. First, the model estimates potential need rather than actual demand, which may be influenced by cultural preferences, social norms, and service availability. Second, reliance on aggregate prevalence data can mask intra-country inequalities, such as urban–rural disparities or socioeconomic gradients in care need. While uncertainty in disease prevalence is captured through GBD uncertainty intervals, formal probabilistic uncertainty for disability prevalence could not be implemented due to heterogeneous data sources and the frequent absence of age-specific variance estimates; imposing such distributions would require strong assumptions not supported by available data. Finally, although sensitivity analyses confirm the robustness of the index, longitudinal validation with real-world LTC utilisation data remains an important future step.

Conclusion

A key contribution of this study is the development and application of a new, validated tool for LTC needs at the population level in MENA. In this region, nationally representative, micro-level household data on care dependency is nearly entirely absent. Other countries, at a more advanced stage of their demographic transition, often rely on detailed longitudinal surveys of older adults, such as SHARE in Europe or HRS in the United States. For MENA countries, actionable evidence on LTC needs remains unavailable. The LTC Needs Index introduced here fills this evidence gap by using demographic and epidemiological indicators, weighted by expert-informed transition probabilities, to provide timely estimates of the scale and composition of LTC needs at national and regional levels. This method enables policymakers to move beyond speculation and begin planning targeted interventions, resource allocation, and system development while awaiting more detailed data. Importantly, the Index's capacity to attribute LTC needs to specific factors, such as disability or diabetes, adds further value by guiding decision-makers to the conditions and populations most in need of support, thereby allowing for more efficient and equitable prioritisation in health and social care planning. The utility of this innovative approach extends beyond the MENA region and can be applied to many other countries.

The LTC Needs Index unveils both commonalities and differences in the factors influencing care dependency throughout the MENA region. Although disability remains the predominant determinant in most countries, reaching as high as 94% in Saudi Arabia, other contexts, such as Qatar, illustrate how non-communicable diseases, notably diabetes (39%), can fundamentally alter care demand patterns. These findings emphasise the importance of implementing differentiated, context-sensitive strategies: expanding disability-inclusive support systems in the region, integrating non-communicable disease management into long-term care planning, and establishing structured support mechanisms for informal caregivers.

Beyond emphasising urgent LTC needs, the findings also highlight the broader challenge of system preparedness. Demographic and epidemiological shifts are happening faster than policy responses in many MENA countries, creating a widening gap between care demands and available services. Without decisive action, the burden will persist on unpaid female family members, negatively affecting health equity, gender equality, and labour force participation. Proactively investing in inclusive LTC systems can turn this challenge into an opportunity, strengthening social protection, creating care-sector jobs, and advancing rights-based approaches to disability and ageing.

Future directions must therefore focus on three priorities. First, strengthening national data infrastructures, including longitudinal surveys and registries of functional health, to enable more precise forecasting and policy evaluation. Second, embedding LTC within broader health and economic planning frameworks, ensuring integration with NCD control, disability rights, and social protection strategies. Third, fostering cross-regional dialogue and learning, particularly with regions such as East Asia and Latin America, where innovative LTC financing and delivery models have already been implemented.

Overall, the demographic and health transitions taking place in MENA mark a turning point. By investing in inclusive systems for people with disabilities, preventing non-communicable diseases, and supporting the hidden workforce of informal caregivers, MENA can strive to build sustainable, fair long-term care systems before the pressures of ageing become overwhelming.

Appendix A Data sources and harmonisation

Detailed descriptions of country-specific disability data sources are provided in the section "Data sources on disability prevalence." Given heterogeneity in age coverage,

reference years, and reporting formats across datasets, additional harmonisation steps were required to ensure cross-country comparability.

Population age structure was obtained from the U.S. Census Bureau population projections and aligned to the age groupings available across epidemiological and disability sources (0–14, 15–39, 40–44, 45–49, 50–54, 55+, and 65+). Disease prevalence estimates for cardiovascular disease, diabetes, cancer, Alzheimer's disease and other dementias, and Parkinson's disease were sourced from the Global Burden of Disease (GBD) study, which provides internally harmonised age-specific estimates using a consistent methodology across countries.

Disability prevalence estimates varied in their age disaggregation. Where age-specific values were unavailable, reported prevalence was allocated across age groups using conservative age-gradient assumptions informed by international evidence on the monotonic increase of disability with age. All prevalence estimates were aligned to a 2024 baseline and treated as time-invariant over the projection horizon (2024–2030), reflecting the short time frame and the absence of reliable annual forecasts. All harmonisation assumptions were applied uniformly across countries.

Appendix B Counting ADL disabilities

Figure 6 provides a conceptual schematic illustrating possible pathways into long-term care (LTC) need. "May need LTC" refers to individuals at elevated risk of transitioning into care dependency due to age, chronic disease, or emerging functional limitations, while "Need LTC" denotes those already experiencing ADL/IADL-related

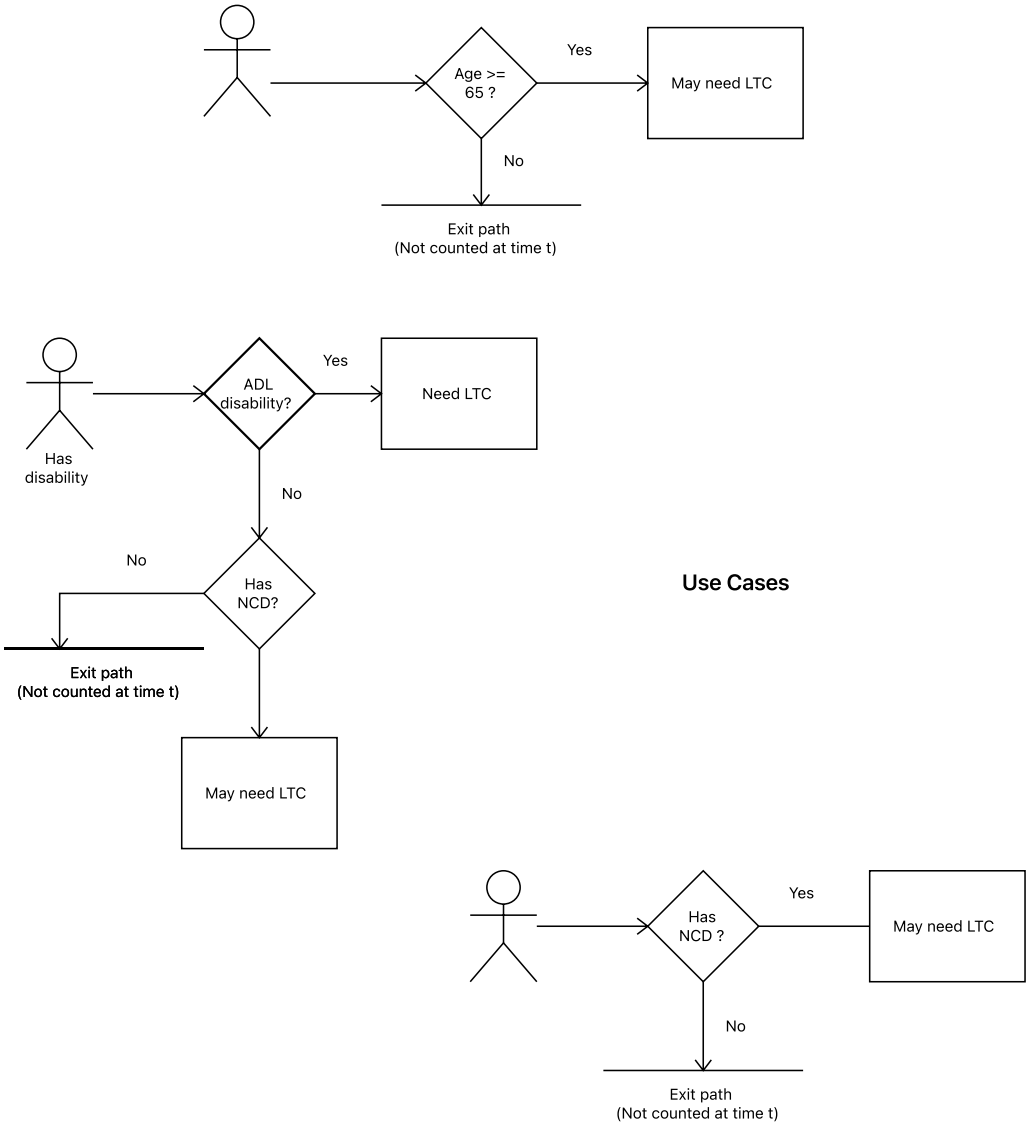


Fig. 6 Conceptual schematic illustrating possible pathways into long-term care (LTC) need. The categories "May need LTC" and "Need LTC" are illustrative distinctions intended to show progression towards care dependency and are not operational states used in the index calculation

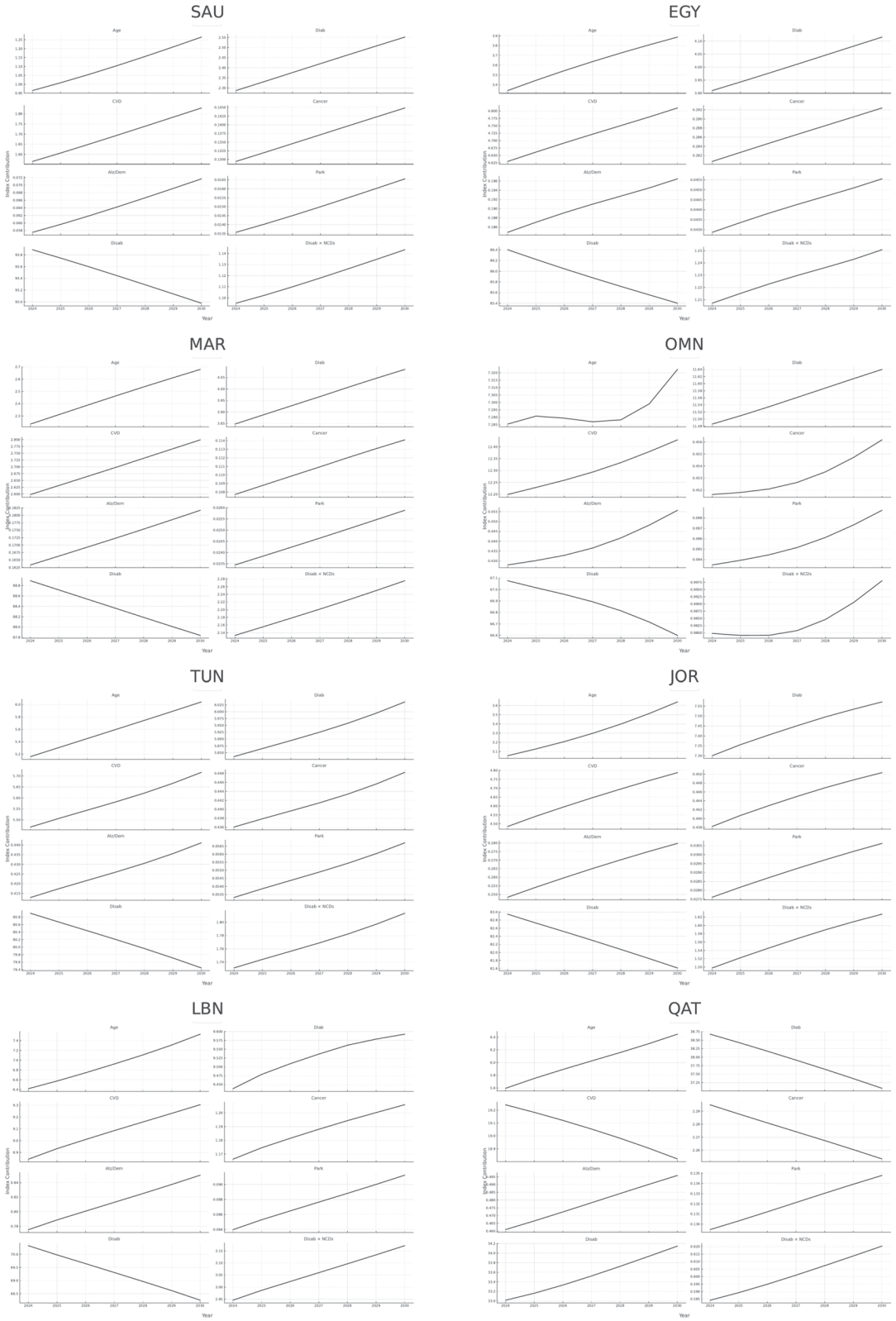


Fig. 7 Projected contribution of individual factors to LTC need index for eight countries (2024–2030), shown using abbreviated factor labels. Each panel displays a single country. Factor abbreviations are defined in Table 2

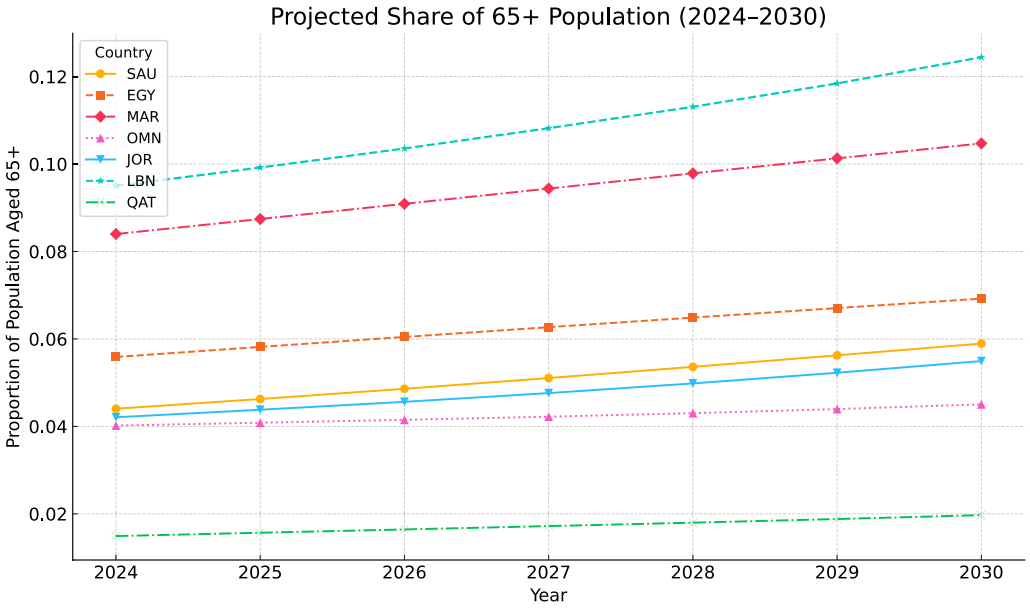


Fig. 8 Projected proportion of the population aged 65 and older from 2024 to 2030 across eight countries. Each line represents a country using distinct markers and line styles for clarity

dependency; only the latter is counted in the index at time t. Age ≥ 65 in the diagram represents an increased risk pathway rather than an assumption of disability and does not imply that all individuals aged 65 years and older are classified as disabled within the model.

Appendix C Factor attributions for the eight MENA countries

This appendix reports the factor attribution results for the eight MENA countries.

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Author contributions
M.I. conceived and designed the LTC Needs Index, conducted the analyses, and led the overall writing of the manuscript. S.H. contributed to the conceptual framing, authored most of the Discussion section, and critically reviewed and edited the Introduction. P.K. initiated the collaboration, advised on the inclusion of NCD indicators, and drafted the initial version of the Introduction. All authors reviewed and approved the final manuscript.

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Data availability
All data used in this study are publicly available.

Code availability
Available upon reasonable request.

Materials availability
Not applicable.

Declarations

Ethics approval and consent to participate
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Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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