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The *Saudi Journal of Health Systems Research* is a peer-reviewed, Open Access online journal dedicated to healthcare management. It is the official publication of the Kingdom of Saudi Arabia ´s Ministry of Health and the Ministry's voice to the global scientific community. The journal fosters an environment of research excellence to elevate scientific research in the Kingdom of Saudi Arabia. This journal welcomes papers that cover research, trends, and techniques covering the following topics:
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Unsung Heroes: An Overview of the Informal Caregivers in the Gulf Cooperation Council – A Scoping Review and Thematic Analysis

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Keywords
Informal caregivers · Disability · Elderly · Gulf cooperation council · Support systems and interventions

Abstract

Introduction: Informal caregivers (ICs), usually family or friends providing unpaid care, offer emotional and psychological support and personalized care and help navigate healthcare systems, improving health outcomes. They reduce healthcare costs by decreasing the need for professional care services, which is essential in today's healthcare systems strained by aging populations and chronic diseases. Even though the challenges faced by ICs are well known, there is surprisingly little research on this topic within the Gulf Cooperation Council (GCC) region, a region where caregiving is deeply rooted in Islamic cultural practices. This study aimed to map the current state of research on ICs in the GCC. The objectives include identifying key themes in the literature, highlighting gaps, and providing insights that can inform the development of targeted interventions and policies amidst ongoing socioeconomic changes and demographic shifts, specifically the increase in elderly populations, and healthcare reforms. ***Methods:*** This study employed a scoping review and thematic analysis following the PRISMA-ScR guidelines. A comprehensive search of PubMed, ScienceDirect, and ProQuest Psychology databases identified articles 25 published between January 2010 and November 2023. ***Results:*** Out of 2,055 articles, only 44 were included, with the majority conducted in Saudi Arabia. They identified four key challenges faced by ICs: high levels of stress and anxiety, limited access to formal support systems, reliance on informal coping mechanisms, and significant socioeconomic impacts. The health services available were underutilized, with a notable gap in support for caregivers. ***Conclusion:*** The study underscores the critical challenges faced by ICs in the GCC, particularly in terms of mental health and access to support systems. These findings advocate for the development of targeted interventions and policies to better support this underserved population.

Introduction

Caregivers are an integral cornerstone to healthcare and societal well-being at multiple levels, serving as the backbone of support for individuals with health needs across the world. Caregiving can be categorized into two primary types based on the caregiver's relationship to the care recipient and whether they receive compensation:

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formal caregivers (or professional caregivers) and informal caregivers (ICs). The first category refers to the provision of care by a paid healthcare practitioner or a care professional either within or outside of the care facility. On the other hand, ICs tend to be individuals who share familial ties, and friendships, or reside near the recipient of care offering unpaid care [1]. Informal caregiving can be classified in several ways, reflecting the depth and nature of the care provided. One common classification is based on the level of care, where an IC can be identified as either a primary or secondary caregiver. A "primary IC" is the person who assumes the main responsibility for managing and delivering care, often handling the most intensive tasks. This primary caregiver typically receives support from other family members or friends, who serve as "secondary IC" [2, 3]. Another approach categorizes ICs based on their relationship to the care recipient, such as spouses, parents, and child caregivers [4]. Others classify it based on the duration and frequency of care like long-term versus short-term, while others base it on the living arrangement: live-in ICs or non-residential ICs [5]. An IC can fit into multiple categories simultaneously. For example, one might be a primary, live-in, informal child caregiver who provides long-term care. This layered classification allows for a more comprehensive understanding of the diverse caregiving situations and the specific challenges and needs associated with each [6].

ICs provide essential emotional and psychological support, facilitating personalized care, and assisting in navigating the complexities of healthcare systems, thus affecting health outcomes for care recipients [7, 8]. Beyond the confines of individual care, their role extends to maintaining familial bonding, fostering community cohesion, and teaching values of responsibility and empathy, thereby strengthening the social structure of the community [9].

ICs offer unpaid care to family members or friends at different life stages and for various health conditions, setting them apart from professional caregiving, and formal caregivers, roles that are typically compensated [10]. Economically, the IC role can significantly decrease healthcare costs by reducing the demand for professional healthcare services [9], this care is critical, especially in contexts where healthcare systems face challenges due to aging populations and the rising prevalence of chronic diseases [11]. However, the burden is shifted to ICs, who face financial strain due to direct care-related costs and lost income from reduced work hours or job loss. This, in turn, affects their long-term financial stability and retirement security [12, 13].

Caregiving roles can also have significant psychosocial and economic impacts on the ICs themselves. ICs often face profound psychosocial and economic impacts that can significantly affect their well-being. The emotional toll of caregiving, characterized by stress, anxiety, and depression, is compounded by social isolation due to the intensive nature of caregiving duties, leading to a decrease in social engagement and a sense of loneliness [14, 15]. In many cases, ICs struggle with their sense of self and experience conflicts between caregiving and other life responsibilities, potentially impacting their physical and mental health [16].

Globally, research has highlighted the burden experienced by ICs, emphasizing the challenges, experiences, and the need for interventions to alleviate their stress and improve their well-being [17, 18]. However, research on these unsung heroes within the Gulf Cooperation Council (GCC) region remains unclear and not highlighted despite the concept of caregiving and informal caregiving being deeply embedded within Islamic culture [13, 19]. This type of care upholds the practice of caring for the elderly, sick, and disabled within the family unit, aligning with Islamic teachings that stress the importance of caring for one's parents and relatives as a moral duty and form of worship [16]. Recognizing the multifaceted importance of ICs is essential not only for the development of targeted support and integration into healthcare policies but also for ensuring the sustainability of healthcare systems and fostering a more stable family unit and resilient society [10].

To address this gap, the use of a scoping review methodology was deemed appropriate for this investigation, given the fragmented nature of the existing evidence base concerning ICs in the GCC countries [20]. This is well needed especially given the rapid socioeconomic changes, increase in the elderly population, change in family dynamics from extended to nuclear, and healthcare reforms in the GCC, understanding the current landscape of informal caregiving is crucial for developing targeted interventions and policies to support ICs effectively. To help achieve this, this research aimed to map out the current state of research on these ICs in the GCC countries, including understanding their relationships with care recipients, the conditions of these recipients, tools used in each study (e.g., questionnaires, scales, interview questions, etc.), and identifying common key themes of challenges and needs faced by ICs in GCC countries.

Methods

This scoping review adheres to the PRISMA extension for Scoping Reviews (PRISMA-ScR) [21]. Following the established framework for scoping reviews outlined by Arksey and O'Malley [22], the primary objective of this methodology is to map the breadth and nature of existing literature on a given topic, rather than to assess the quality or rigor of individual studies. In line with this approach, the team did not perform a critical assessment of the methodologies used in the studies reviewed.

Search Strategy

A comprehensive search was performed in the following databases: PubMed, ScienceDirect, and Proquest Psychology Database to identify articles published from Jan 2010 to Nov 2023, using the following terms and their equivalence (informal caregivers OR unpaid caregivers OR family caregivers OR non-professional caregivers OR lay caregivers) AND (GCC OR "Gulf Cooperation Council" OR "Saudi Arabia" OR SA OR KSA OR UAE OR "United Arab Emirates" OR Qatar OR Kuwait OR Oman OR Bahrain). The search was limited to English publications, and reference lists were screened for additional studies.

Inclusion and Exclusion Criteria

The included studies met the following criteria:

- Conducted in one of the GCC countries.
- Focused on ICs.
- Peer-reviewed article.
- Published in English.
- Published between Jan 2010 and Nov 2023.

Articles were excluded if the following criteria were met:

- Included paid caregivers, such as hired nurses, domestic helpers, and personal care assistants.
- Not chronic or not health-related caregiving studies: articles were excluded if they focused on caregiving for individuals without chronic conditions or specific health needs, such as infants or school children not requiring medical care.
- Incorporated data from countries outside the GCC.
- Focused on the recipients of care: Studies were excluded if they primarily targeted the needs of the care recipients, the education of ICs, or the outcomes of such education (including awareness, training, attitudes, etc.) with the mere intention of improving care for the care recipient.
- The research aimed to validate new tools: questionnaires or scales, including tool translations or developments.
- Unable to access the publications: were not open access or could not be readily accessed through common academic platforms such as university subscriptions or requested through ResearchGate.
- Papers focused on case reports and case studies.

Study Selection

The research process was conducted by utilizing the systematic review accelerator, a tool designed to make the review more efficient. Four independent reviewers selected studies based on inclusion and exclusion criteria after removing duplicates and screening titles, abstracts, and full texts.

Data Extraction

For each article selected for inclusion in the review, a detailed data extraction process was carried out for the following: publication, focus, country, study design and methods, aim, inclusion and exclusion criteria, ICs relationships, condition of the care recipient, age of the care recipient, sample size, tools, key findings, and conclusion, as presented in Table 1.

Results

The initial search across the electronic databases, conducted independently by two researchers, retrieved 2,055 articles. After removing duplicates, this number was narrowed down to 1,927 unique articles. A rigorous screening process was employed to ensure the articles' relevance to the research topic and adherence to specific criteria. Initially, 1,521 articles were discarded during the review of titles and abstracts because they did not align with the research focus. The remaining articles underwent a detailed full-text review, leading to the exclusion of another 362 articles for not meeting the required inclusion and exclusion criteria. After this comprehensive screening process, 44 articles were ultimately deemed suitable for inclusion Figure 1. Upon analysis of the extracted data, a narrative synthesis was conducted by three researchers based on the studies' results and conclusion, from which four main themes emerged: well-being and mental health, coping mechanisms, socioeconomic status, and support systems and interventions. General characteristics of the studies were analyzed and displayed in Table 2 showing frequencies of studies per Country, Age of the care recipient, Condition of the care recipient, and Research Focus. Considering the research focus across the studies, approximately 22% concentrated on QoL while nearly 25% addressed the issues of burnout and IC burden. The importance of these measures lies not only in their impact on ICs' well-being but also in their broader implications for healthcare outcomes. Finally, word cloud analysis for the most common words across the 44 articles is shown in Figure 2. This word analysis highlights the most frequently used terms related to ICs and the articles, with "caregivers" being the most prominent, indicating that it is the central topic. Other important terms include health-related themes

Table 1. Main results of the articles reviewed

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Manee et al. [23] (2016)	Kuwait	Cross-sectional, descriptive study using a questionnaire and interviews	To compare the QoL of Arab mothers in Kuwait based on whether their children have chronic disabilities. It also sought to provide actionable recommendations for occupational therapists to enhance these mothers' QoL	Caregiver QoL	Inclusion criteria ● Mother's age is between 25 and 50 years ● Married status ● Arabic as the primary language ● Having at least one child aged 12 or younger in the family Additional criteria for case group ● Only one child in the family with a chronic disability ● Parents report that a physician has diagnosed the child with a chronic condition (e.g., autism spectrum disorder, cerebral palsy, Down syndrome, or developmental delay)	Mothers	Children with chronic disabilities	Children	The study included a case group of 71 mothers of children with chronic disabilities and a control group of 86 mothers of children without disabilities	Demographic information, the Arabic WHOQOL-BREF questionnaire, and a Support Questionnaire (SQ)	Mothers of children with disabilities in Kuwait reported significantly lower QoL scores across all four domains of the WHOQOL-BREF (physical health, psychological well-being, social relationships, and environment) compared to mothers of healthy children. These mothers received the most support from their nuclear families due to a general lack of formal support systems. The study highlights the need for occupational therapists to engage with these families, provide information on available services and community resources, and support mothers to enhance their caregiving capabilities	Well-being and mental health
Chan et al. [24] (2022)	Oman	Cross-sectional, descriptive study using a questionnaire	To explore the existence of different risk patterns of caregiver burden among primary caregivers of Omani children with leukemia	Caregiver burden	Inclusion criteria ● Individuals aged ≥18 years, of Omani nationality ● Currently acting as a caregiver for at least 1 month to an Omani child aged <15 years diagnosed with leukemia ● Caregivers without concurrent mental health issues	Parents	Children diagnosed with leukemia	Children	101	Demographic and clinical characteristics of the child with cancer and the Caregiver Burden Inventory (CBI) tool	Caregivers were divided into two clusters based on their reported burden levels: Cluster 1 ("High-Risk" Burden Group): Comprised 42 caregivers (41.6%) who were older, less educated, had more family members in the household, and spent more time caring for the child, reporting high caregiver burden scores.Cluster 2 ("Moderate-Risk" Burden Group): included 59 caregivers (58.4%) who were younger, more educated, had fewer family members in the household, and spent less time caring for their child, reporting moderate caregiver burden scores. A two-step cluster analysis revealed significant variation in caregiver burden within the study population; the study highlights the heterogeneity in caregiver burden among primary caregivers of children with leukemia in Oman, calling for targeted policy initiatives. Nursing professionals are encouraged to develop care strategies tailored to caregivers' risk burdens, including financial, psychological, and physical support	Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Ofair et al. [25] (2023)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To assess the level of knowledge and its impact on the QoL among Saudi caregivers of Parkinson's disease patients	Level of knowledge and QoL	Caregivers of patients with Parkinson's disease (PD) admitted to the Movement Disease Clinic and Neurology Department at King Saud University Medical City between April 2015 and February 2022. Specific inclusion or exclusion criteria were not defined	Adult children or spouse	Parkinson's disease (PD)	Elderly	69 caregivers	A specifically developed and validated questionnaire was used to assess the level of knowledge and attitudes of family caregivers toward PD, the effects of PD on caregivers' QoL, and its impact on the activities of daily living (ADLs) of patients from the caregivers' perspective	Longer caregiving duration was significantly associated with a decline in caregivers' QoL, leading to increased work absenteeism. The study identified a substantial need for increasing awareness and knowledge among caregivers to ensure better treatment outcomes for patients and improve the QoL for both caregivers and patients. Enhancing knowledge and awareness among PD caregivers is critical for elevating patient care standards and overall QoL	Well-being and mental health Support Systems and Interventions
Alzahrani et al. [26] (2017)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To assess the burden on caregivers of people with mental disorders and identify influencing factors	Caregiver burden	Inclusion criteria: caregivers of patients with a mental health diagnosis confirmed by the treating physician at the study site	Adult children, parents, other relatives	Mental disorders	Adults: 17–90	367	Demographic and Arabic version of the Involvement Evaluation Questionnaire (IEQ)	The majority of caregivers were male with a mean age of 36.6 years. The total mean IEQ burden score for caregivers indicated a significant burden. Younger caregivers (≤30 years) reported significant "tension," while "worrying" was higher among caregivers living with their spouse and children, especially in smaller families (<6 members). "Urging" scores were higher in caregivers living with the patient and those with close contact over the past month, particularly for caregivers of female patients and those without professional support. Caregivers of close relatives (parent, son/daughter, sibling, spouse) reported the highest-burden scores	Well-being and mental health Support Systems and Interventions
Algahtani et al. [27] (2020)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To assess the burden on caregivers of MS patients in Saudi Arabia and explore the implications for healthcare support and services	Caregiver burden	Inclusion: caregivers for patients with MS who visited the neurology clinic within the study period Exclusion: caregivers who had been caring for their patients for less than 1 year	Spouses, siblings, parents, adult children, and second-degree relatives	MS	Not defined	219	Demographic and the Arabic version of the Zarit Burden Interview (ZBI)	The majority of caregivers reported experiencing little to no burden, with a smaller proportion describing mild to moderate burden and only a minimal percentage indicating severe burden. The study reveals a generally limited burden on caregivers of MS patients in Saudi Arabia, highlighting the need for comprehensive caregiver assessment. It emphasizes the importance of specialized MS clinics that account for psychological factors and the burden of the disease, advocating for a multidisciplinary approach and the formation of support groups	Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Alsaedi et al. [28] (2022)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	The primary objective of this study was to evaluate the level of burnout experienced by caregivers of type II diabetes (T2D) patients	Caregiver burnout	Adult subjects caring for patients with T2D who agreed to take part in the study. We excluded caregivers who had been diagnosed with any psychiatric illness or had independent T2D themselves	Not mentioned	Patients with T2D	Adults	501	Sociodemographic questionnaire and a modified version of the Caregiver Stress Self-Assessment Questionnaire, developed by Dr. Steven Zari, alongside the patients' latest biochemical and clinical data		Well-being and mental health Socioeconomic status
Alshammari et al. [29] (2017)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To determine the socioeconomic, psychological, and physical consequences facing ICs; and to measure their burdens and needs	Caregiver burden	Included were ICs, aged 18 years and older, of elderly patients aged 60 years and above. Formal caregivers like nurses were excluded	Adult children, grandchildren, and others	Elderly with need for care	Elderly: 60 years and older	315	Sociodemographic, the ZBI, and a questionnaire covering the care recipient's and caregiver's details	A majority of caregivers reported low levels of education and income. Caregivers experiencing little to no stress were typically younger, male, single, and caring for younger T2D patients with a shorter disease duration. While no correlation was found between caregivers' stress levels and the HbA1c levels of T2D patients, a significant positive correlation was identified between a caregiver's stress score and their age. The study suggests the need for further research to examine additional caregiver parameters and their impact on the metabolic control of T2D patients	Well-being and mental health Support Systems and Interventions
Sulaimani et al. [30] (2023)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To assess and compare the QoL of family caregivers based on sociodemographic factors and characteristics of the child	Caregiver QoL	Family caregivers of children under 18 years of age, of both genders, with Saudi nationality, literacy, and a social media account were included. Exclusions were non-family caregivers, non-Saudi nationality, children over 18, incomplete responses, lack of a social media account, and refusal to participate	Parents, siblings, and others	Children with various disabilities	Children	95 family caregivers	Sociodemographic, child characteristics, and caregivers' QoL assessed using the RAND 36-Item Short-Form Health Survey (SF-36)	The overall mean QoL score was 57, with a range from 12 to 94. No significant differences in QoL scores were observed based on age, gender, occupational status, or income of caregivers. However, caregiver education was linked to emotional role limitations. The severity of the child's disability and having another disabled child in the family were associated with higher bodily pain scores and perceived health changes. The QoL for family caregivers of disabled children varies significantly based on education level, caregiver-child relationship, and the presence of multiple disabled children. Targeted interventions to improve emotional well-being and manage fatigue are needed, alongside societal support structures	Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Almugti et al. [31] (2022)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To assess the needs and QoL of Saudi cancer patients' caregivers	QoL and needs assessment	Included were Saudi nationals over 18 years, who were close and supportive caregivers. Excluded were caregivers of palliative care patients	Spouses, parents, adult children, and grandparents	Cancer patients	Adults aged 22–72 years	270	Demographics, The World Health Organization Quality of Life questionnaire (WHOQOL-BREF), and the Family Inventory of Needs (FIN) for family caregivers	More than half of caregivers reported good QoL in psychological, social relationships, and environmental domains, while nearly two-thirds reported lower scores in the physical health domain. Male caregivers of older age, lower education levels, and those caring short-term (less than 12 months) reported poorer QoL. Needs assessment highlighted patient care as a priority, with caregivers' own health needs rated as least important. Addressing caregivers' demographic characteristics and specific needs is essential for providing holistic care and enhancing QoL for both patients and caregivers. Further studies are needed to implement targeted care strategies	Well-being and mental health Support systems and interventions
Hafez et al. [32] (2022)	Saudi Arabia	Qualitative using individual in-depth interviews	To explore the experiences of primary caregivers caring for a child receiving end-of-life care within the Saudi Arabian healthcare system	Experiences	Inclusion criteria Saudi Arabian female primary caregivers (mother, grandmother, aunt, sister, or stepmother) caring for a child at EOL. Aged 18 years or older Caring for child(ren) diagnosed with a terminal illness or critical condition Child(ren) aged between 1 day and 14 years Able to give informed consent	Mothers, sisters	Child at end of life	Children: 1 day and 14 years of age	24	Demographic data collection and an 11-item investigator-developed interview guide consisting of open-ended questions	Primary caregivers experienced significant psychological, physical, social, and financial impacts while caring for a child at EOL, sharing experiences of heartbreak, lack of sleep, isolation, and financial challenges. The study underscores the importance of addressing these issues through nursing education, practice, policy, and research, offering valuable insights for future studies on end-of-life care both within Saudi Arabia and globally	Well-being and Mental Health Support systems and interventions
Badawoud et al., 2023 [33]	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To measure the level of burden among ICs of Alzheimer's disease (AD) patients and to identify caregiver characteristics	Caregiver burden	Inclusion criteria ICs (regardless of nationality) provide unpaid care physically or emotionally to an older adult with AD. Aged 18 years or older, caring for an AD patient at any stage (mild, moderate, or severe) Able to communicate in Arabic to complete the primarily Arabic questionnaire	First-degree relatives, second-degree relatives, informal non-relatives	AD	Elderly	148	Sociodemographic characteristics of AD patients and their caregivers, the 12-item version of the ZBI, and adapted questions on coping techniques and medication knowledge	ICs reported a moderate to high burden. There is a significant need for services to enhance their QoL and improve their medication knowledge as over half were aware of medication side effects but generally had insufficient knowledge. The study highlights the necessity of providing adequate support services to caregivers of AD patients in Saudi Arabia and enhancing their medication knowledge	Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Sharif et al. [34] (2020)	Saudi Arabia	Qualitative using semi-structured interviews	To explore family caregivers' experiences, particularly the challenges they encounter and the coping mechanisms they utilize in caring for relatives with mental disorders	Experiences of burden and coping	Inclusion criteria: participants were self-reported family caregivers of individuals diagnosed with a mental illness by a psychiatric or mental healthcare provider, providing direct care to the individual, and able to communicate in Arabic or English	Parents, siblings, uncles, spouses	Mental disorders	Not defined	13	Open-ended interview questions were designed to elicit detailed responses about caregivers' experiences	The study sheds light on the complex burdens borne by family caregivers of individuals with mental disorders in Saudi Arabia. It highlights variations in care responsibilities and their impacts, as well as the wide range of emotional, financial, and social challenges faced by caregivers. Strategies used by caregivers to manage their burdens and the types of support they find helpful were also explored. The study underscores the necessity of multifaceted support and interventions to aid caregivers and correct misconceptions, enhancing public awareness about mental disorders. Additionally, caregivers shared advice and insights for others in similar situations	Well-being and mental health Coping mechanisms Support systems and interventions
Ghazwani et al. [35] (2021)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To explore the prevalence and types of burdens experienced by caregivers of terminally ill patients, along with associated risk factors	Burden and stress	Inclusion criteria: caregivers of terminally ill Saudi patients, engaged in caregiving for at least 1 month	Adult children and others	Terminally ill cancer patients	Not defined	78	Sociodemographic characteristics, ZB), and Caregiver Distress Scale (CDS)	Caregivers experienced varying levels of burden: mild, moderate, and severe. Shorter caregiving duration and being a mother or brother were linked to higher distress scores. The relationship with the patient significantly impacted emotional burden, social impact, and personal cost, with male caregivers reporting higher emotional distress. The study highlights the significant burden and stress faced by caregivers of terminally ill cancer patients, underscoring the need for research and interventions to support them	Well-being and mental health Support systems and interventions Socioeconomic status
Almutairi et al. [36] (2017)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To identify HRQOL among caregivers of Saudi cancer patients more than 1-year post-diagnosis	HRQOL	Inclusion criteria: caregivers aged 18 or older, able to speak/understand Arabic or English, with a relative diagnosed with cancer at least 1 year ago. Non-Saudis and those unwilling to participate were excluded	Spouses, parents, adult children, grandchildren, and others	Cancer patients	Not defined	289	Demographics and a Short-Form Health Survey SF-36 (the RAND 36-item) i	Female caregivers reported significantly lower functioning scores than male caregivers in several domains, and older caregivers had lower scores in the physical component summary. Additionally, cancer type significantly predicted health change domains for caregivers. The study highlights the need for supportive interventions for caregivers, emphasizing the importance of their well-being in cancer patient care provision	Well-being and mental health Support systems and interventions Socioeconomic status

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Al-Kandari et al. [37] (2017)	Kuwait	Cross-sectional, descriptive study using a questionnaire	To profile and describe coping strategies of families of children with autism spectrum disorder (ASD), focusing on mothers	Social support and coping strategies	Inclusion criteria: the study focused on mothers of children with ASD who were enrolled in 21 special needs schools registered with the Public Authority of the Disabled in Kuwait	Mothers	ASD	Children	198	Demographics, and the Brief-COPE, a self-administered questionnaire designed to assess various coping strategies	A significant number of mothers reported difficulties in performing social duties and self-care, indicating a decrease in their ability to enjoy life, with this decline more pronounced among non-Kuwaiti mothers and those with higher education levels. Receiving support from family and support groups significantly correlated with an improvement in mothers' ability to enjoy life. The most commonly reported coping strategies among these mothers were "Religion," "Acceptance," and "Positive Reframing." The study sheds light on the considerable challenges faced by mothers of children with ASD in Kuwait, underscoring the vital role of social support in enhancing mothers' well-being and their ability to cope with caregiving demands. The findings call for further research and the development of targeted support services to meet the unique needs of mothers in Arab countries	Well-being and mental health Coping mechanisms Support systems and interventions
Alshammari et al. [38] (2023)	Saudi Arabia	Mixed-methods, sequential, explanatory	To measure the burden experienced by ICs of hemodialysis patients, examine predictors of caregiver burden, and explore caregivers' experiences	Caregiver Burden	Inclusion criteria Caregivers aged over 18 years Patients receiving hemodialysis (HD) for more than 3 months Caregivers must be unpaid, able to communicate, and literate in English or Arabic Caregivers identified by patients as providing practical help and support	Spouses, siblings, parents, adult children, grandchildren	Patients receiving hemodialysis	Not defined	Quantitative phase: 61; qualitative phase: 14	Quantitative phase: demographic data collection and the Arabic version of the ZBI Qualitative Phase: Open-ended questions to explore caregivers' experiences	Caregivers generally did not experience severe burdens, although factors such as being older, female, and having comorbidities were associated with increased burden. Social support, cultural acceptance, and religious influences emerged as significant factors that might reduce caregiver burden. The study found caregiver burden to be lower compared to similar populations in other studies, highlighting the importance of understanding and mitigating factors influencing caregiver burden among ICs of hemodialysis patients and those with chronic illnesses globally	Well-being and mental health Coping mechanisms Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
AlShatti et al. [39] (2021)	Kuwait	Qualitative using semi-structured interviews	To understand how caregivers of individuals with DS perceive the impact of caregiving on their lives and to document their experiences in seeking support services	Caregivers' perceptions and experiences	Inclusion criteria: legal guardians of persons with DS, including parents, siblings, or close relatives, excluding housemaids. The study focused on mothers as the primary caregivers, recognized for their deep insights into the lives and needs of individuals with DS	Mothers/sisters	People with Down syndrome	Children and adults 3–39 years	21	Open-ended questions to facilitate detailed discussions on caregivers' experiences and perceptions	Caregivers experienced initial challenges in accepting the DS diagnosis, prompting a search for information and support. They encountered difficulties managing the health conditions associated with DS, significantly impacting their lives and necessitating substantial efforts to manage the associated burdens. Accessing quality education and social activities for individuals with DS proved to be a major challenge. Caregivers expressed a need for improved services, facilities, and benefits to better support families of individuals with DS and alleviate the socioeconomic and psychological pressures they face. The study highlights the profound effects of caregiving for individuals with DS on caregivers in Kuwait, underscoring the challenges they encounter in acceptance, healthcare management, education, and social integration. It calls for enhanced support mechanisms and services to aid these families in navigating the complexities of caregiving for persons with DS	Well-being and mental health Coping mechanisms Support systems and interventions Socioeconomic status
Kheir et al. [40] (2012)	Qatar	Cross-sectional exploratory study	To explore the specific concerns and considerations of caregivers of children with autism in Qatar, particularly in relation to their children's future, the specialized services received, and their QoL	Concerns and considerations	Inclusion Criteria for Autism Group (AG) Caregivers of children aged 3–17 years diagnosed with autism using established tools like CARS, ADI, ADOS-G, or DSM-IV criteria Exclusion criteria included chronic medical conditions potentially interfering with the study, recent initiation of behavior therapy (<2 months), or recent significant changes in family life (e.g., marriage, divorce, death) Control Group (Non-Autism Group, NAG) Caregivers of typically developing children aged 3–17 years visit a family clinic for routine check-ups Exclusion criteria included the presence of a household child with autism or other neurodevelopmental/psychotic disorders and recent significant family changes	Parents	Children with autism	Children: 3–17 years	100 total (56 in the Autism Group)	Demographic and child's life-related information, Questions on maternal concerns and considerations regarding their child's future and received services, and QoL assessed using SF-36 v2		Well-being and mental health Coping mechanisms

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Alfakhri et al. [41] (2018)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To evaluate the prevalence of depressive symptoms among caregivers of dementia patients and to analyze how these symptoms correlate with the severity of the patient's dementia, alongside demographic and economic factors	Depression	Inclusion Criteria Caregivers of patients with a confirmed diagnosis of dementia Participants were recruited from King Abdulaziz Medical City, the Saudi AD Association, and various online platforms, including both primary and secondary caregivers providing care and assistance Caregivers under 18 years of age were excluded	Adult children, and others (not specified)	Elderly with dementia	Elderly	222	The Patient Health Questionnaire (PHQ-9) for assessing depression among caregivers, and the Blessed Dementia Scale (BLS-D) for measuring the severity of dementia in patients	No significant difference was found in general health-related QoL between caregivers of children with autism and those of typically developing children. However, mental health scores were consistently lower among caregivers in the autism group, indicating greater mental health challenges. The study highlighted the crucial impact of caring for a child with autism on caregivers' mental health, emphasizing the importance of timely specialized rehabilitation services. Additionally, religious faith played a significant role in helping caregivers come to terms with having a child with autism	Well-being and mental health Support Systems and Interventions
Almansour et al. [42] (2013)	Saudi Arabia	Retrospective cohort	To evaluate the presence of depression and anxiety in parents/caregivers of ASD children and to explore related factors	Depression and anxiety	Inclusion criteria Case Group: Parents/caregivers of at least one child diagnosed with ASD, confirmed by specialists using DSM-IV criteria. Participants were recruited through the Saudi Charitable Society of Autism Families and the Autism Clinic at the Pediatric outpatient clinic in King Fahad National Guard Hospital, King Abdulaziz Medical City (KAMC), Riyadh Control group: parents/caregivers of a normally developed child, recruited from the Well Child Clinic at King Abdulaziz Medical City, Riyadh	Adult children, and others (not specified)	ASD Children	Children	50 cases (total 100 cases and control)	A self-reported questionnaire including 14 questions on demographic data, psychiatric history of parents, and the Arabic version of the Hospital Anxiety and Depression (HAD) Scale	Parents/caregivers of children with ASD exhibited significantly higher levels of depression and anxiety compared to those of normally developed children. The unique demands and challenges of caring for a child with ASD were identified as contributing factors to these increased mental health issues. The study underscores the significant burden and stress borne by parents/caregivers of ASD children, highlighting the need for adequate support and resources to mitigate this burden. Further research and targeted interventions are essential to address the mental health needs of this population effectively	Well-being and mental health Support systems and interventions
Alenazi et al. [43] (2020)	Saudi Arabia	Mixed method: qualitative and quantitative cross-sectional using a questionnaire and interviews	To examine the severity of autism's effect on caregivers' QoL and to identify associated caregiver and child characteristics	Caregiver QoL	Inclusion criteria Parents of children diagnosed with autism spectrum disorder (ASD) Exclusions included parents of children diagnosed with ASD less than 1 year ago, parents of children with comorbidities, the presence of other siblings with disabilities, those with chronic diseases, and non-Saudi parents, due to the potential high impact of these conditions on QoL	Parents	Children with autism	Children	84	Sociodemographic and child characteristic questionnaire (e.g., age, sex, marital status of caregiver; child's gender, age, birth order, severity of autism) Arabic version of Short-Form-36 for assessing QoL		Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Lamba et al. [44] (2022)	UAE	Qualitative using semi-structured interviews	To investigate the specific challenges faced by expatriate mothers of children with ASD in the UAE and to understand the support systems that aid in coping with these challenges	Exploring challenges and support structures	Inclusion criteria Mothers with at least one child diagnosed with ASD. Immigrants in the UAE. Basic communicative English skills	Mothers	Children with autism	Children	17	Open-ended questions were designed to elicit detailed responses about the challenges faced and support received by mothers	Most caregivers reported impaired QoL, particularly in the domains of energy/fatigue and role limitations due to emotional problems. Significant factors associated with poor QOL included female gender, unemployment, and low income. Firstborn children with autism and those with a longer duration of the disease were more likely to correlate with poorer parental QOL. The findings highlight the critical need for social and emotional support to help caregivers cope with the challenges associated with their child's disability	Well-being and mental health Support systems and interventions Socioeconomic Status
Lamba et al. [45] (2022)	UAE	Qualitative using semi-structured interviews	To explore support structures and challenges experienced by expat mothers of children with ASD in the UAE	Exploring the experience	Inclusion criteria Mothers with at least one child diagnosed with ASD. Expatriates in the UAE. Basic communicative English skills	Mothers	Children with autism	Children	17	Open-ended questions designed to elicit detailed accounts of mothers' experiences, challenges, and the support received	Expat mothers expressed dissatisfaction with medical professionals, highlighting stress during the diagnosis process, misdiagnosis, or delayed diagnosis concerns. Challenges in finding suitable schools and therapeutic interventions were prevalent, with a lack of inclusive staff exacerbating systemic difficulties, leading to increased financial and emotional strain. About half of the mothers reported wanting more emotional and instrumental support from their husbands, despite appreciating the financial support. Feelings of alienation from the broader community and negative interactions with family members led to a sense of invisibility among these mothers. Support groups emerged as crucial for providing a sense of community, empathy, and information exchange, especially regarding school admissions and therapeutic support. The pandemic significantly disrupted routines for children with ASD, resulting in increased behavioral issues. This study provides valuable insights into the multifaceted experiences of expatriate mothers of children with ASD in the UAE, highlighting the importance of enhancing support systems and interventions to address their unique challenges, particularly in light of the pandemic's impact	Well-being and mental health Support systems and interventions Coping mechanisms

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
AL-Sawafi et al. [46] (2021)	Oman	Qualitative using semi-structured interviews	To understand the lived experiences, challenges, and needs of Omani relatives of hospitalized schizophrenia patients, focusing on those who have been involved in caregiving at home	Experience and needs of relatives	Inclusion criteria Adult family members of hospitalized patients with schizophrenia who have been living with and taking care of the patient at home for at least 1 month Participants were required to stay with the patient throughout their hospital admission as attendants, as per unit requirements Exclusion Criteria: Family members not residing with the patient and any paid caretakers	Parents, siblings, partners	Schizophrenia	Adults	20	Open-ended and yes/no questions designed to capture the comprehensive experiences of caregivers	Four main themes emerged: burden, stigma, violence, and family needs. Siblings particularly highlighted positive aspects of their caregiving experiences. The study introduced the concept of "stigma resistance," suggesting its potential to inform the development of programs aimed at reducing stigma. The study sheds light on the significant challenges and needs of relatives living with individuals diagnosed with schizophrenia in Oman. It emphasizes the importance of mental health professionals understanding these experiences to tailor interventions that can alleviate caregiver burden and leverage positive caregiving experiences. The findings advocate for the establishment of stigma reduction programs, informed by the concept of stigma resistance, to support caregivers effectively	Well-being and mental health Support systems and interventions Coping mechanisms
Aljuaid et al. [47] (2022)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To measure the QoL among caregivers of dependents diagnosed and treated for major chronic diseases during the COVID-19 pandemic, and to understand the variation in QoL across different disease conditions	QoL	Inclusion criteria Caregivers of dependents diagnosed and treated for cardiovascular disease, diabetes, cancer, kidney disease, AD, lower respiratory infections, and other chronic diseases during COVID-19	Spouses, parents, relatives, friends, and others	Patients diagnosed with chronic diseases, including cardiovascular disease, diabetes, cancer, and others, during COVID-19	Adults	1,081	Demographics and the WHOQOL-BREF questionnaire	Caregivers of cancer patients reported the highest mean QoL, followed by those caring for patients with diabetes, cardiovascular diseases, and other diseases. Significant differences in QoL were observed among caregivers of the four disease groups, with the overall QoL levels of participants found to be low. The study underscores the need for incorporating QoL assessments for caregivers of chronically ill patients into the healthcare system and recommends regular psychological and physical health check-ups for caregivers. It highlights the importance of further research to explore factors influencing health outcomes and positive developments that can enhance the well-being of caregivers and patients at personal, organizational, and national levels	Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Alquwez and Alshahrani [48] (2021)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To explore the influence of spiritual coping and social support on the mental health and QOL of the caregivers of patients with stroke in Saudi Arabia	Mental Health and QoL	Inclusion criteria Caregivers provide care to a family member who is a stroke survivor Not receiving financial compensation for the provided care At least 18 years old and members of the immediate family of the patients Exclusion criteria included formal caregivers (e.g., hired private nurses) and distant family members	Adult children, siblings	Patients with stroke	Adults	123	Demographics questionnaire, the 20-item "Spiritual Coping Strategies Scale." Multidimensional Scale of Perceived Social Support, Hospital Anxiety and Depression Scale, and WHOQOL-BREF for assessing caregivers' QoL	Respondents predominantly experienced mild to moderate levels of depression and mild to severe anxiety, emphasizing the emotional toll of caregiving. Caregivers rated their psychological health highest, indicating the importance of emotional well-being in their QoL perception, while physical health was rated lowest due to the adverse effects of caregiving's physical demands. Spiritual coping strategies, particularly religious coping, were frequently utilized, aligning with the cultural context of Saudi Arabia. The study underscores the critical role of spiritual coping strategies and social support in managing mental health and enhancing the QoL of caregivers of stroke survivors in Saudi Arabia. It suggests the need for healthcare providers to facilitate the use of these coping mechanisms, monitor the quality of social support, and guide caregivers through the challenges of their caregiving roles to improve their mental well-being and QoL	Well-being and mental health Support systems and interventions Coping mechanisms
Kouther et al. [49] (2022)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To determine the different factors affecting the mental health of caregivers of children with cerebral palsy	Mental health	Inclusion criteria Caregivers of children diagnosed with cerebral palsy, older than 6 months The main caregiver, is defined as the person spending the most time caring for the child Exclusion criteria included caregivers previously diagnosed with psychiatric disorders	Parents	Children with cerebral palsy	Children	40	Demographics, and Depression Anxiety Stress Scale-21 (DASS-21) to assess mental health levels	A notable proportion of caregivers reported experiencing moderate to extremely severe levels of depression, anxiety, and stress. The mental health of caregivers was significantly linked with factors such as the child's visual impairment, frequency of hospital admissions, and emergency department visits. Increased Pediatric Intensive Care Unit (PICU) admissions in the past year were also significantly related to higher anxiety scores among caregivers. The study highlights the significant mental health challenges faced by caregivers of children with cerebral palsy, particularly concerning the child's need for acute medical care and hospital admissions. It underscores the necessity for healthcare professionals to adopt a family-centered approach in planning medical and social support early and proactively for children with cerebral palsy and their families, aiming to alleviate the mental health burden on caregivers	Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Almehmadi and Alrashed [50] (2023)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To investigate the experience of caregivers in informal settings within the Saudi society through identifying the caregivers' s needs along with their expectations of the formal system	Expressed needs and expectations	Inclusion criteria Saudi caregivers care for at least one individual with a dependency due to disability, aging, or both Providing care in an informal setting without receiving payments directly related to caregiving activities Able to read Arabic and residing in Saudi Arabia for at least 1 year before data collection	Spouse, parents/in-laws, grandparents/in-laws, adult children, sibling/in-law, others	Dependencies resulting from disability, aging, or both. The article does not provide further details on the specific conditions or illnesses	All: 0–61+	271	A validated questionnaire containing demographics, information about the care recipient and caregiver, and a five-level Likert scale for assessing needs and expectations	Caregivers identified a range of needs including equipment for care recipients, personal free time to socialize, alternative care settings, and adequate income. Expectations for formal support were higher among caregivers of individuals with disabilities than those caring for elderly dependents, with the highest expectation being improved facilitation of care recipients' mobility within their communities. The study reveals significant expectations of formal support among ICs in Saudi society, alongside various unmet needs. It underscores the vital role of primary caregivers and the necessity of considering the needs of both care recipients and caregivers in healthcare service planning. The findings advocate for policy and intervention development informed by the priorities and expectations of ICs. Further research is encouraged to deepen understanding of these issues and guide future healthcare policies and practices	Well-being and mental health Support systems and interventions
Madani et al. [51] (2018)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To assess the QoL of caregivers of children with sickle cell disease (SCD) and to determine the risk factors associated with poor QoL	QoL	Inclusion criteria Caregivers aged 16 years or over of pediatric patients (aged up to 16 years) diagnosed with SCD more than 1 year ago and registered for treatment at the hospital	Parents/siblings	Children with sickle cell disease	Children less than 16	164	Questionnaire collecting demographic and socioeconomic data, caregiving characteristics, psychological or financial support received, daily free time management, and satisfaction levels, and the TNO-AZL Questionnaire for Adult's Health-Related Quality of Life (TAAQOL questionnaire)	The most affected QoL dimensions among caregivers were emotions, sleep quality, and sexual life, while professional achievement, cognitive skills, and social contact were relatively less impacted. Negative emotions were more pronounced in mothers and were influenced by satisfaction with social relationships. Positive emotions correlated with caregiver satisfaction regarding health, job achievement, living conditions, and the condition of the child with SCD. A strong link was observed between sleep quality and cognitive skills. Caregivers of children with SCD face significant economic and emotional burdens that detrimentally affect various aspects of their QoL. These challenges are significantly shaped by the caregivers' social and professional success levels. The study underscores the importance of healthcare providers and authorities focusing on the QoL of caregivers and families of children with SCD to provide support and help them cope with the psychological and financial impacts of the disease	Well-being and mental health Support systems and interventions Socioeconomic status

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Alqahtani et al. [52] (2018)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To identify the prevalence and risk factors for depression among caregivers of AD patients	Depression	Inclusion criteria Caregivers of AD patients from Aseer Central Hospital	Adult children or spouses	Patients diagnosed with AD	Elderly	110	Demographics questionnaire, and the Hamilton Rating Scale for Depression to assess symptoms of depression among caregivers	Most caregivers exhibited symptoms of depression, ranging from mild to moderate. Depression prevalence was significantly higher among caregivers of patients who experienced repeated falls, and depression scores positively correlated with the duration of daily care. The high prevalence of depression among caregivers of AD patients suggests that psychiatric care for caregivers and measures to prevent falls are necessary	Well-being and mental health Support systems and interventions
Al-Balushi et al. [53] (2019)	Oman	Cross-sectional, descriptive study using a questionnaire	To assess the prevalence and predictors of caregiver burden among caregivers of children with ADHD	Caregiver burden	Inclusion criteria Caregivers of drug-naive children with ADHD. Exclusion criteria: those with severe medical illnesses or illiteracy	Direct parent or guardian	Children and adolescents diagnosed with ADHD, drug-naive, and without other comorbidities or an IQ below 80	Children	117	Sociodemographic, clinical data, and ZBI for measuring caregiver burden		Well-being and mental health Support systems and interventions Socioeconomic status
Saimaldaher and Wazqar [54] (2020)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To investigate the relationships between caregiving stress, mental health, and physical health among family caregivers of adult patients with cancer in Saudi Arabia	Stress, mental and physical health	Inclusion Criteria 18 years or older fluent in English or Arabic Excluding criteria: caregivers with histories of neurological disorders or serious mental illnesses, as well as those caring for pediatric cancer patients		Cancer patients	Adults	160	Demographics and Modified Caregiver Strain Index (MCSI) to assess caregiving stress, and DUKE Health Profile to evaluate mental and physical health status	A significant caregiver burden was found among those caring for children with ADHD in Oman, with approximately 34% of caregivers experiencing moderate to severe burden. Contributing factors included lower income levels and the specific type of ADHD diagnosis (predominantly the mixed type), emphasizing the influence of economic and clinical factors on the caregiver's experience. The study highlights the need for targeted support and interventions to alleviate the burden on caregivers, suggesting a broader approach to managing ADHD that includes addressing the socioeconomic challenges faced by families	Well-being and mental health Support systems and interventions
Khusaifan and Keshky [55] (2017)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To explore the role of social support as a mediator in the relationship between depression and life satisfaction among caregivers of AD patients in Saudi Arabia	Social support, life satisfaction, depression	Inclusion criteria Primary family caregivers of AD patients Exclusions included pregnant caregivers, those with a history of depression, individuals taking antidepressant or psychotropic drugs, and those in recent mourning (less than 6 months)	Children, grandchildren, or spouses	AD	Older adults	122	Multidimensional Scale of Perceived Social Support (MSPSS) to measure informal social support Satisfaction With Life Scale (SWLS) to assess life satisfaction Beck Depression Inventory 2nd Edition (BDI-II) to measure the severity of depression	Social support was identified as a partial mediator in the relationship between depression and life satisfaction. Higher levels of social support were associated with increased life satisfaction and reduced depression levels among caregivers. The study highlights the critical importance of developing and strengthening social support networks to enhance the mental health and overall well-being of caregivers of AD patients in Saudi Arabia. It suggests that interventions aimed at increasing social support could be beneficial in improving caregivers' QoL	Well-being and mental health Support systems and interventions Coping mechanisms

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Kheir et al. [56] (2012)	Qatar	Cross-sectional, descriptive study using a questionnaire	To assess and compare the QoL of caregivers of children with autism with caregivers of typically growing children in Qatar	Caregiver QoL	Inclusion criteria Caregivers of children aged 3–17 years diagnosed with autism Exclusion criteria for the autism group included recent initiation of behavior therapy, changes in family dynamics, or the presence of chronic medical conditions For the non-autism group, exclusion criteria included having a child with autism or other neurodevelopmental disorders in the household	Parents	Children with autism	Children aged 3–17	98 participants (56 caregivers of children with autism and 42 caregivers of typically developing children)	Demographics and the SF-36 v2 Health Survey, a widely used and validated tool for assessing health-related QoL across various populations, including translated versions	There were no significant differences in most QoL domains between caregivers of children with autism and caregivers of typically developing children. However, caregivers of children with autism reported poorer personal health and a more pessimistic outlook regarding their health prospects. The study underscores the nuanced impact of caregiving for a child with autism on caregivers' health perceptions in Qatar, indicating a pressing need for enhanced support services tailored to the unique challenges faced by families of children with autism. These services should aim to improve both the caregivers' QoL and their outlook on health	Well-being and mental health Support systems and interventions
Al-Dhawyani et al. [57] (2022)	Oman	Cross-sectional, descriptive study using a questionnaire	To identify factors contributing to perceived unmet needs among primary caregivers of Omani children with leukemia	Unmet needs	Inclusion criteria Adult Omani primary caregivers of children aged 14 years or younger diagnosed with any type of leukemia Caregivers of children admitted to NOC wards or attending the day care unit for chemotherapy treatment	Parents	Children diagnosed with leukemia	Children aged 14 years or younger	101	Sociodemographic questionnaire and an Arabic version of the Needs Assessment of Family Caregivers-Cancer (NAFC-C) scale	There were significant correlations between total NAFC-C scores and factors such as the child's age, caregiver's age, employment status, and family income. Unmet needs varied significantly across different caregiving domains, influenced by sociodemographic variables. The study underscores the significant impact of sociodemographic factors on the unmet needs of primary caregivers of children with leukemia in Oman. It emphasizes the need for healthcare professionals to consider these factors when providing care and support, suggesting that tailored information and support services are crucial for alleviating caregiver distress and enhancing their ability to cope with caregiving challenges. The findings highlight the complexity of caregiving in the context of pediatric leukemia and the importance of addressing caregivers' needs through comprehensive support mechanisms	Well-being and mental health Support systems and interventions Socioeconomic status

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Al-Farsi et al. [58] (2016)	Oman	Cross-sectional, descriptive study using a questionnaire-case-control	To examine stress, anxiety, and depression among parents of children with and without diagnosed ASD, exploring the variation in these psychological indices among different caregiver groups	Depression, anxiety, and stress	Inclusion criteria Parents of children diagnosed with ASD or without ASD, confirmed by CARS-2 and DSM-IV-TR criteria, and parents of children with other intellectual disabilities or typically developing children Excluded were families if the child had developmental disorders not categorized under the study groups	Parents	Autism Spectrum Disorder	Children	220 parents of children with ASD (107 fathers and 113 mothers). Control groups included parents of children with other intellectual disabilities and parents of typically developing children, totaling 234	Demographics questionnaire and the Depression Anxiety Stress Scales-21 (DASS-21)	Parents of children with ASD (CASD) reported higher mean scores for anxiety and depression compared to control groups. Depression and stress scores were significantly higher in CASD than in parents of children with intellectual disabilities (CID) and typically developing children (CTD). While differences in anxiety scores were not statistically significant between groups, they were elevated in CASD. The study reveals that caregivers of children with ASD in Oman experience significant psychological distress, aligning with global research. These findings highlight the critical need for supportive interventions to improve the mental health and well-being of parents caring for children with ASD.	Well-being and mental health Support systems and interventions Coping mechanisms
Bahari [59] (2021)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To examine the prevalence of psychological distress among Saudi family caregivers and identify factors associated with it	Factors associated with psychological distress	Inclusion criteria Saudi adults aged 18 years or older Able to read and understand Arabic Providing daily care for a family member diagnosed with hypertension, diabetes, and/or asthma Excluded were caregivers of patients with multiple chronic conditions	siblings, adult children, spouses, others	hypertension, diabetes, and/or asthma	Not defined	163	Demographics and Kessler Psychological Distress Scale-6 (K6) to assess the level of psychological distress	Psychological distress among family caregivers was significantly associated with factors such as employment status, education level, monthly expenses related to caregiving, time dedicated to caregiving, and the specific chronic disease of the care recipient. These findings highlight the complex interplay between caregiving responsibilities and caregivers' psychological well-being. The study underscores the high prevalence of psychological distress among family caregivers in Saudi Arabia, particularly those caring for relatives with chronic conditions like hypertension, diabetes, and asthma. It emphasizes the need for effective programs to enhance caregivers' understanding of psychological distress and improve their participation in treatment plans. Addressing caregivers' psychological distress is crucial for developing more effective caregiving strategies, benefiting both caregivers and care recipients	Well-being and Mental Health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Alshahrani and Algashmari [60] (2021)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To estimate the prevalence of depressive symptoms among caregivers and examine the impact of financial pressure and ASD severity	Depression, financial stress, autism severity	Inclusion criteria Parents of children with ASD attending the Prince Mohammed Bin Salman Autistic Center, Ministry of Defense, Taif city	Parents	ASD	Children	50	PHQ-9 questionnaire for depression, alongside sociodemographic factors	Financial stress and autism severity were identified as significant factors contributing to the development of depressive symptoms among caregivers. Autism severity exhibited a more pronounced effect on caregiver depression than financial stress, indicating the complex nature of caregiver stress and depression. The study underscores the multifaceted challenges faced by caregivers of children with ASD, highlighting the significant impact of both financial stress and autism severity on their mental health. It emphasizes the necessity for comprehensive care strategies that consider the emotional and financial difficulties encountered by caregivers. Advocating for the inclusion of mental health support for caregivers within the care plans for children with ASD, the research points to the critical need for holistic approaches that address the intertwined challenges caregivers face	Well-being and mental health Support systems and interventions Socioeconomic status
Muliira et al. [61] (2024)	Oman	Cross-sectional, descriptive study using a questionnaire	To explore the determinants of QoL among Omani family caregivers of adult patients experiencing cancer pain	Caregiver QoL	Inclusion criteria Adult patients with confirmed cancer diagnoses and their primary caregivers Caregivers aged ≥18 years, speaking English or Arabic and having been in the caregiving role for at least 1 month Hired caregivers were excluded	Adult children, spouses, others (neighbor, mother, in-law, friend, grandchild, niece)	Adults with cancer pain	Adults	165	Demographics questionnaire, Katz index, Caregiver Reaction Assessment, and Family Pain Questionnaire A modified caregiver cancer pain and symptom management self-efficacy scale, and the Caregiver Quality of Life Index–Cancer Scale–Persian Version.	Caregivers reported low QoL, significantly influenced by their health status, confidence in managing the patient's pain, and the patient's functional status and level of pain. Moderate knowledge and self-efficacy in cancer pain and symptom management were observed among caregivers, with better outcomes linked to higher self-efficacy levels. The distress caused by the patient's pain and its perceived impact on caregivers' health were significant predictors of caregivers' QoL. The greatest negative impacts were reported in areas of support and adaptation, indicating the need for better support systems for caregivers. Despite challenges, caregivers showed resilience in mental/emotional burden and financial strain domains, suggesting areas for targeted support. The study highlights the complex challenges faced by family caregivers of cancer patients in Oman, emphasizing the need for supportive care programs tailored to their unique needs. Improving caregivers' skills in managing cancer pain and symptoms, coupled with comprehensive health promotion programs, could markedly enhance their QoL. The findings call for focused health policy and program development to support caregivers as essential parts of the cancer care continuum in Oman	Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Tahir et al. [62] (2023)	Qatar	Cross-sectional, descriptive study using a questionnaire	To assess stress levels and evaluate coping strategies among caregivers during the COVID-19 pandemic's total lockdown	Stress levels and coping strategies during COVID-19	Inclusion criteria Caregivers of patients from the Mental Health and Intellectual Disability service of Hamad Medical Corporation (HMC) database, identifying adults with intellectual disability and coexisting challenging behaviors	Parents, siblings	Adults with intellectual disability and challenging behaviors, with some also diagnosed with autism spectrum disorder	Adults	100	Demographics questionnaire, Brief Coping Orientation to Problems Experienced Inventory (Brief-COPE), and the Perceived Stress Scale (PSS) to measure coping strategies and perceived stress levels among caregivers	Caregivers reported moderate to high levels of stress during the pandemic lockdown, with religion emerging as the most frequently utilized coping strategy. Emotional support, informational support, and venting were significant predictors of perceived stress levels among caregivers. The COVID-19 pandemic has notably affected the stress levels and coping mechanisms of caregivers for adults with intellectual disabilities in Qatar, underscoring the necessity for targeted support and resources. The study emphasizes the role of cultural beliefs and the availability of resources in influencing caregivers' coping strategies, particularly highlighting the importance of religion and family support in managing stress	Well-being and mental health Support systems and interventions Coping mechanisms
Alhawsawi et al. [63] (2023)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To identify the characteristics of ICs, assess the socioeconomic, psychological, and physical impacts on them, and measure their burdens and needs	Level of burden	Inclusion criteria All ICs of adult patients (>18 years old) are willing to participate Excluded were ICs of pediatric patients	not mentioned	Patients registered in the Home Health-Care Unit	Elderly	122 (92 of which are ICs)	A validated questionnaire to collect data on care recipient and caregiver characteristics, the socioeconomic, psychological, and physical impacts on caregivers, and The Zarit Burden Interview to assess caregiver burden	A majority of caregivers reported experiencing no to minimal burden, with factors such as the caregiver-recipient relationship and duration of caregiving significantly influencing the perceived burden. Caregivers expressed a need for more frequent home healthcare visits and financial support. The study indicates that most ICs face minimal burden but highlights the necessity of providing flexible medical consultations, educational workshops, and psychological support to alleviate their burdens. The research underscores the essential role of ICs within the healthcare system and the importance of implementing comprehensive support mechanisms to address their diverse challenges	Well-being and mental health Support systems and interventions

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
AlAhmari et al. [64] (2022)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	Investigate the impact of having children with DS on the different domains of the caregivers' QoL in Saudi Arabia	Caregiver QoL	Inclusion criteria Parents of children with DS aged 0–14 years, with or without medication Excluded were caregivers with a child having a dual diagnosis, other sick children needing care, or caregivers suffering from mental health conditions	Parents	Children with Down syndrome	Children	261	Demographic, and WHOQOL-BREF to assess the QoL across multiple domains	Caregivers experienced significant impacts on their QoL across all domains, with environmental domain scores being the highest and social domain scores the lowest. Educational level, number of children, and average monthly income were significantly correlated with various QoL domains, affecting caregivers' QoL differently. The study reveals that having a child with DS significantly affects caregivers' QoL in Saudi Arabia, particularly in social interactions and environmental satisfaction. It underscores the necessity for targeted interventions to support these caregivers, focusing on improving the psychological, physical, social, and environmental aspects of their lives. The findings highlight the complex nature of caregiving for children with DS and the need for comprehensive support systems to enhance caregivers' well-being	Well-being and mental health Support systems and interventions
Al-Zahrani et al. [65] (2015)	Saudi Arabia	Cross-sectional, descriptive study using a questionnaire	To determine the prevalence of depression, anxiety, and stress among caregivers of hospitalized Saudi patients and identify associated factors	Psychological impact (Depression, Anxiety, Stress)	Inclusion criteria Arabic-speaking caregivers aged 14–80, providing care for hospitalized patients Excluded were paid caregivers	Family caregivers (spouse, adult children, parents, siblings) and non-family caregivers (friends)	Conditions requiring hospitalization (not specified)	Not Defined	353	Demographics, and DASS-21 (Depression Anxiety Stress Scales-21, Arabic version) to evaluate symptoms of depression, anxiety, and stress among caregivers	There is a high prevalence of depression, anxiety, and stress among caregivers, with most of majority suffering from at least one psychiatric disorder. Increased risk of psychological symptoms is associated with lower income, higher education, immediate relation to the patient, and older age of caregivers. The study highlights the substantial psychological distress among caregivers of hospitalized patients in Saudi Arabia and underscores the need for healthcare systems to recognize and address the psychological needs of caregivers. It suggests implementing supportive measures and interventions to alleviate their burden	Well-being and mental health Support systems and interventions Socioeconomic status

Table 1 (continued)

Study	Country	Study design and methods	Aim	Focus	Inclusion and exclusion criteria	IC relationships	Condition of the care recipient	Age of the care recipient	Sample size	Tools	Key findings and conclusion	Themes
Alshekaili et al. [66] (2019)	Oman	Cross-sectional, descriptive study using a questionnaire	To explore the prevalence and correlates of depressive symptoms among parents/caregivers of children with ASD	Depression risk factors	Inclusion criteria Caregivers aged 20–65 years attending the clinic with children diagnosed with ASD. Excluded were caregivers of children with other developmental disorders, and caregivers who were medically unwell, illiterate, or did not consent	Parent/primary caregiver	Children diagnosed with ASD	Children	80	Demographics and the Patient Health Questionnaire-9 (PHQ-9) to assess depressive symptoms	A high prevalence rate of depressive symptoms among caregivers indicates a substantial emotional burden. Unemployment and being the sole caregiver were significant predictors of depressive symptoms, suggesting that financial instability and lack of familial support are critical factors exacerbating caregivers' psychological distress. Gender was not identified as a significant predictor, but age and being the sole caregiver emerged as significant factors, with older caregivers or those without additional support experiencing heightened stress. Lower socioeconomic status was associated with higher odds of experiencing depressive symptoms, underscoring the link between economic hardship and mental health challenges among caregivers. The study reveals a high prevalence of depressive symptoms among caregivers of children with ASD in Oman, highlighting the urgent need for targeted supportive interventions and resources. Improving financial stability and fostering supportive networks within families could significantly reduce the psychological burden on caregivers	Well-being and mental health Support systems and interventions Socioeconomic status

HRQOL, health-related quality of life.

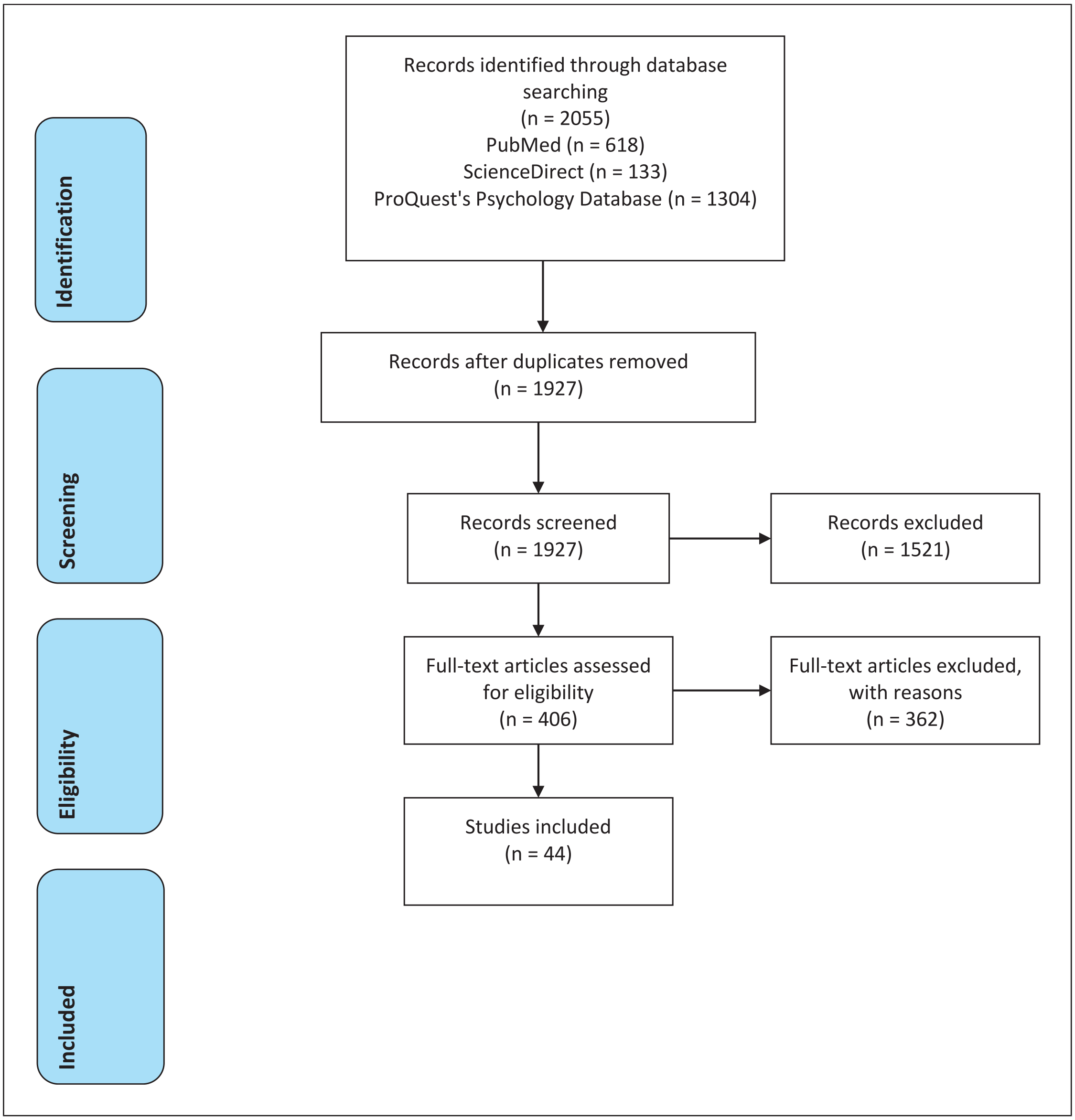

Fig. 1. PRISMA-ScR flow diagram.

such as “depression,” “stress,” and “mental,” as well as relational terms like “children,” “mother,” and “family.” Additionally, support systems are represented by terms like “support,” “education,” and “coping.” These terms align with established key themes and their discussed context in the following section.

The general characteristics of caregiving included studies in Table 2, highlighting key demographic and thematic trends. Most studies were conducted in Saudi Arabia (29 studies), followed by Oman (7), Kuwait and Qatar (3 studies each), and the UAE (2 studies). The distribution of care recipients’ age groups reveals a higher focus on children (19 studies), with 16 studies examining caregiving for adults and the elderly, and 2 studies addressing both groups. In terms of the medical conditions of care recipients, cognitive disorders were the most prominent studied (21 studies), followed by chronic conditions (12), cancer (7), and other conditions (4). The research focus varied, with 11 studies addressing caregiver burden and burnout, 10 focusing on quality of life (QoL), and 9 exploring mental health concerns such as anxiety, depression, and stress. A smaller number of studies examined social support and coping mechanisms (3), while 11 studies explored other areas, including caregivers’ experiences and specific needs.

Table 2. General characteristics of the studies

Characteristic	Frequency
Country	Kuwait: 3 Oman: 7 Qatar: 3 Saudi Arabia: 29 UAE: 2
Age of the care recipient	Children: 19 Adults and elderly: 16 Children and adults: 2 Not defined: 7
Condition of the care recipient	Cancer: 7 Chronic conditions: 12[a] Cognitive disorders: 21[b] Other conditions: 4[c]
Research focus	QoL: 10 Burden and burnout: 11 Other mental health (including anxiety, depression, and stress): 9 Social support and coping: 3 Others (including experiences and needs): 11

[a] Patients who had type II diabetes, hemodialysis, stroke, sickle cell disease; patients diagnosed with chronic diseases during COVID-19 (including cardiovascular disease, diabetes, cancer, etc.); and patients with hypertension, diabetes, and/or asthma, chronic disabilities, MS, cerebral palsy, PD, and hemodialysis. [b] Mental disorders, ASD, schizophrenia, dementia, Alzheimer's, ADHD, other intellectual disability, Down syndrome. [c] Registered in the Home Health-Care Unit, requiring hospitalization, end-of-life care, stroke.

Thematic Analysis

Well-Being and Mental Health

Caregiving exerts a substantial influence on the physical health, psychological well-being, QoL, and overall life satisfaction of ICs. This complex issue is particularly pronounced in the context of GCC countries, where caregiving and familial obligations are deeply embedded in the cultural fabric. The cultural norms prevalent within the GCC region serve to amplify the pressures experienced by ICs, giving rise to heightened levels of stress, fatigue, and diminished engagement in social activities associated with caregiving responsibilities. The intensified burden faced by ICs involved in the care of individuals suffering from chronic or terminal illnesses, such as cancer or Alzheimer's disease is very demanding in nature which necessitates constant vigilance and attention to the care recipient's needs. Multiple studies have underscored the challenges, explaining the tendency of ICs to prioritize the needs of their family members at the expense of their own social lives [24, 25, 35, 41, 52]. Consequently, this self-neglect contributes to an overall decrease in the QoL experienced by ICs, as substantiated [32]. Moreover, it has been observed that younger ICs or those belonging to smaller households often report elevated levels of tension and worry [26]. The cultural norms in the GCC region might intensify the pressures on caregivers leading to worsening their challenges. This increase in pressure is especially apparent in the form of social isolation, especially among ICs who look after individuals with stigmatized conditions, such as mental health disorders [46].

Socioeconomic Status

The socioeconomic status, such as education and income levels, of ICs is another critical factor in determining the caregiving experience. The extracted studies suggested that ICs from lower income brackets or with less education face greater challenges in providing care [53]. These individuals who are already at a disadvantage may have limited access to information, support services, and coping resources, exacerbating the stress and burden associated with caregiving. Moreover, ICs' financial constraints can restrict access to quality healthcare for the care recipient, further increasing these caregivers' burden which has a direct correlation with ICs' stress. Reduced work hours or leaving employment altogether to provide care

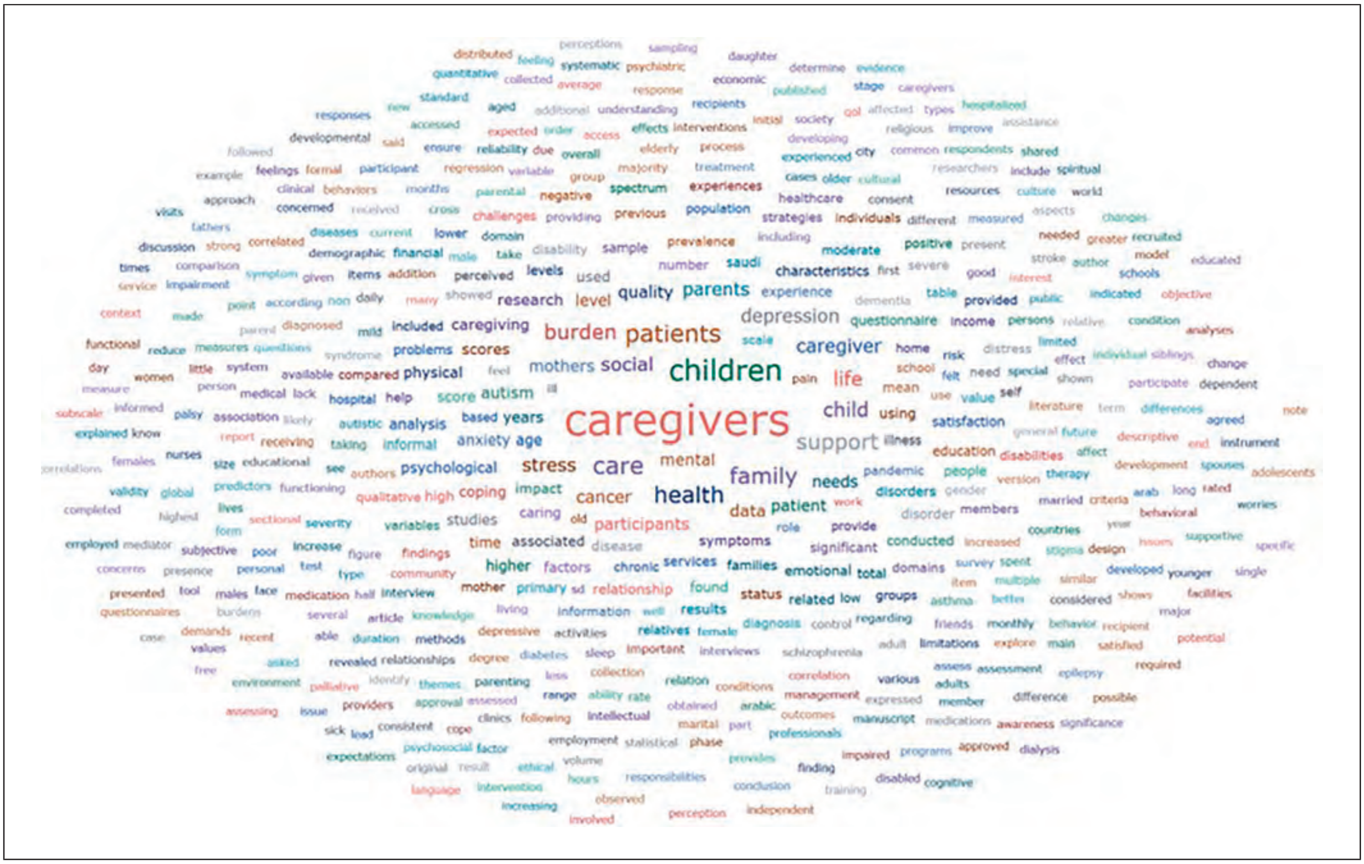

Fig. 2. Word cloud analysis for the most common words across the 44 articles.

exacerbates economic hardship [60]. Studies have shown that financial stress, combined with the severity of the care recipient's condition, contributes to depressive symptoms among ICs [60]. This finding highlights the intricate interplay between economic factors and mental health within the caregiving context. The need for continuous care often results in reduced working hours or job loss, leading to financial strain [25, 28]. Moreover, it was noted that the gender of the IC also plays a role, as women, who often serve as primary ICs, may experience greater economic vulnerability due to lower workforce participation rates in some GCC countries [30, 66]. The financial implications extend beyond immediate economic concerns, impacting long-term savings, investment in children's education, and overall family financial stability [51].

Coping Mechanisms

Despite the challenges they face, ICs exhibit resilience and employ various coping strategies, with a strong emphasis on religious and spiritual coping, as well as social support from family and the community. Religion emerges as a significant source of comfort and strength for ICs, deeply rooted in the cultural fabric of the GCC, helping ICs navigate and overcome the hardships associated with their roles [37, 38, 40]. Additionally, the environmental domain of QoL often scored higher, indicating a satisfactory level of family and social support [31, 64]. This points to a strong family-oriented culture in the GCC that may buffer against the adverse effects of caregiving. This support includes sharing caregiving duties among family members and offering emotional encouragement and understanding. Studies indicate that ICs with strong family support networks experience lower levels of stress and burden and report a higher QoL [37]. Social support from family members and support groups is correlated with improved mental health outcomes, mitigating feelings of isolation and stress [48]. This support not only offers practical help but also serves as a vital source of emotional sustenance, reducing feelings of isolation and providing valuable coping strategies [45].

Studies also suggested that employing diverse coping strategies, other than religion and family support like

“Acceptance,” and ”Positive Reframing” as ICs’ tendency to interpret thoughts negatively more positively and constructively instead helped in enhancing mental health [37–39]. Still, the effectiveness of these coping strategies may vary. Relying solely on one approach may offer temporary relief but it often fails to address the complex needs of ICs who are dealing with severe and long-term conditions [59].

Support Systems and Interventions

The results showed a significant impact that the absence or insufficiency of formal and structured support systems has on recognizing and supporting informal ICs and their crucial role in providing care [30]. These structured support systems are organized through systematic frameworks specifically tailored to provide comprehensive assistance and resources to ICs based on their specific needs. This includes educational resources, financial support, and other essential aids. The lack of such support systems creates a critical gap, exacerbating the IC’s burden and negatively affecting their mental and physical health, finances, and overall well-being and QoL [29, 31]. Consequently, many studies advocate for tailored support and interventions to address the specific needs of these ICs in the GCC [24, 56, 57, 61]. This includes the creation of support groups that offer emotional support and share caregiving strategies, along with training programs designed to equip ICs with the necessary skills, financial support, and educational resources to alleviate their burdens [24, 31, 37, 43, 48]. For instance, interventions such as IC allowances and subsidized healthcare services aim to address the financial pressures faced by ICs. Although insurance was not thoroughly addressed in most studies, a key finding revealed that the lack of insurance, especially among housewife mothers, placed significant stress on caregivers [51]. Furthermore, the limited access to essential services, such as respite care and financial aid, adds to their stress and diminishes the QoL for both ICs and care recipients [60].

Additionally, the need for educational support is highlighted, revealing a significant gap in ICs’ understanding of the health conditions they manage and the barriers to accessing educational resources [45, 63]. This gap could increase their burden and stress, underlining the necessity for educational programs that enhance ICs’ knowledge and management of these conditions [59, 61]. The studies also point out the variation in needs depending on both the IC and care recipient, suggesting that more effective recognized caregiver support should include IC assessments as part of routine medical care to provide more tailored support [49]. Therefore, healthcare systems and policies need to acknowledge the integral role of ICs and establish structured support systems [24, 32, 50, 61].

Discussion

There were diverse types of chronic conditions for the care recipients covered by the extracted studies, including Alzheimer’s disease, cancer, dementia, diabetes, Down syndrome, mental health issues, multiple sclerosis, Parkinson’s disease, and stroke among others. It is notable that a significant portion of studies, nearly 44%, focus on ICs for children, particularly those with conditions like autism and attention deficit hyperactivity disorder. This emphasis reflects the growing concern and awareness of developmental disorders within the region. Autism spectrum disorder, a common concern in several of the studies reviewed, has been identified as a significant health concern among the GCC population, with prevalence rates ranging widely from 1.4 to 59 per 10,000 persons [67]. The prevalence of autism and related disorders signifies not only the direct impact on affected individuals and their families but also highlights broader societal and healthcare system challenges. These challenges include the need for early diagnosis, effective intervention strategies, and support systems for ICs [68].

The majority of the research on ICs in this review originates from Saudi Arabia. This can be attributed to several factors, including Saudi Arabia’s larger population size compared to other GCC countries [69]. This larger population likely contributes to a higher volume of research output and a greater diversity of healthcare challenges that necessitate investigation of the needs of informal ICs and the role they play [70].

When looking at the characteristics of the ICs, the prevalence of female ICs, especially mothers across the studies underscores the critical yet often underappreciated contributions they make to family well-being and the broader economic landscape [71]. Female ICs embody the gatekeep of informal care systems, providing essential, compassionate, and personalized care to family members in need, which, in turn, significantly reduces the demand for formal healthcare services [72]. Their contributions, while invaluable, often come with substantial personal sacrifices, including financial instability, career disruptions, and emotional and physical stress, highlighting a gap in social and economic policies that fail to recognize and support their sacrifices [73]. The reliance on female

ICs reflects deep-rooted cultural and social norms about gender roles within the family and society at large [74]. This dynamic not only reinforces traditional gender roles but also places a disproportionate burden on women, potentially limiting their personal and professional opportunities [73, 75]. Acknowledging the pivotal role of female ICs is crucial for informing policy decisions that aim to provide adequate support systems, including financial incentives, healthcare benefits, and employment protections, to mitigate the challenges they face. Such measures would not only improve the QoL for ICs and those they care for but also contribute to the broader economic stability by enabling women to participate more fully in the workforce [76].

Examining the tools used in studies, such as questionnaires or scales, is essential because they are fundamental to the research process, serving as the primary means of collecting data and shaping the overall findings. Given their central role, it is crucial that these instruments are properly validated and adapted to the culture and language of the population being studied. The tools used in the included studies as presented in Table 1 showed that various tools have been used to assess the ICs' status based on each study's aim and objectives. Aside from the use of demographic information, instruments like the Arabic Zarit Burden Interview (ZBI) have been translated and validated for aspects like psychometric properties [77]. Instruments like the WHOQOL-BREF, specifically its Arabic version, and culturally adapted questionnaires ensure that the assessment of the QoL, IC burden, and stress levels are relevant and sensitive to the cultural norms and values of the Arab countries including GCC [78–80]. Translation validity and cultural adaptation of the tools, which were ensured in most of the included studies, are crucial in ensuring that the tool captures the constructs it is intended to measure in the context of different cultural norms, values, or expressions [81].

Although there appeared to be quite an interest in ICs' experience and condition in the GCC countries, there is still a considerable gap. For instance, there appears to be negligence of personal health among ICs that incurs long-term psychological effects, underscoring the imperative of a more comprehensive examination of the support systems available within societies to aid these individuals [82]. This issue transcends geographical boundaries and is not limited to the GCC countries alone; it represents a global concern [82]. In addition, the effect of caregiving on socioeconomic status ICs findings correlate with research from other countries on the frequent encounter of significant economic challenges due to the demands of their role which can greatly affect the caregiving experience and cause financial and psychological stress [73, 83, 84]. Even with cultural norms like the ones found in the GCC which encourage a strong network of family and social support, in terms of giving care, it can place an excessive burden on families that lack the financial means to hire external help or access additional resources [39, 85].

Caregiving is an emotionally demanding role that significantly affects the psychological well-being of ICs. Therefore, coping mechanisms are vital not only for the immediate health and effectiveness of the ICs but also for the overall quality of care they provide and their long-term ability to continue in their caregiving roles. There are a variety of coping mechanisms employed by ICs, which can be broadly categorized into problem-focused coping, involving direct actions to address the source of the problem, and emotion-focused coping, which manages emotional responses to stress. Additionally, social coping focuses on seeking social support, and dysfunctional coping includes emotional disengagement behaviors such as self-blame and denial [86, 87]. The effectiveness of these strategies is influenced by several individual and social factors. However, the GCC scoping review primarily highlights coping mechanisms related to social and emotional support, with less emphasis on those related to problem-focused strategies or dysfunctional behaviors.

While some challenges faced by ICs are specific to their local contexts, others are universal, and experienced by ICs across the globe [88]. Still, there is consensus across literature that ICs are an overlooked population, often compromising their health while helping others. Therefore, collaborative efforts among healthcare providers, policymakers, and community organizations are essential to implement supportive systems and interventions. Such initiatives can bridge the gaps identified in research, ultimately improving the caregiving experience, and promoting better outcomes.

Conclusion

Caregiving significantly impacts the physical and mental health, QoL, and overall well-being of ICs. In the GCC countries, caregiving responsibilities are deeply rooted in religious and societal norms. While ICs employ various coping mechanisms, particularly drawing on religion, family, and community support, there remains an urgent need for formal, structured support systems to fill the gaps in care provision and caregiver assistance. Therefore, a collaborative effort among healthcare providers, policymakers, and community organizations is essential to understand the hidden challenges of informal caregiving and establish comprehensive support systems to enhance the well-being of both caregivers and care recipients, ensuring the sustainability of caregiving.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Q.A. designed and led the data collection and analysis. B.H., M.A., and H.A. worked on study selection, data extraction, theme generation, and the first draft review of the manuscript. S.B. and S.A. reviewed the manuscript and provided critical feedback. All authors contributed to, read, and approved the final manuscript.

Data Availability Statement

All data used in this scoping review are included in this article. Further inquiries can be directed to the corresponding author.

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Probabilistic Mathematical Model for Dietary Consumption and Exposure Assessment in the Absence of Data from National Nutrition Surveys: A Case Study on Saudi Arabia

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Keywords
Noncommunicable diseases · Nutrient exposure · Food balance sheets · Food patterns · Probabilistic method

Abstract
Introduction: Noncommunicable diseases, which account for 71% of annual global deaths, necessitate the implementation of targeted legislative measures to reduce exposure to risk factors, particularly those related to nutrition. Accurately assessing these risk factors is challenging owing to infrequent national surveys, high costs, and uncertainties from human behavior. Thus, addressing these issues is crucial. This study aimed to develop a model for estimating dietary exposure. ***Methods:*** Our study utilizes the National Nutrient Consumption (NNC) model, which employs a probabilistic and cost-effective approach. This model leverages open data and focuses on supply chain dynamics and uncertainties, integrating import, production, and stock levels. It estimates commodity supply, consumption, and nutrient intake using predictive coefficients from historical data. Model accuracy was assessed using mean absolute error, correlation coefficient, and one-sample *t* test. The findings were evaluated against the recommended intake outlined in the Technical Regulation of Food Labeling (SFDA.FD 2233). ***Results:*** The model demonstrated high accuracy in estimating dietary intake, with minimal error margins. For both genders, the 50th percentile nutrient exposure exceeded the reference values – with males consuming 3,310 kcal (+65%), 144 g of total fat (+105%), 33.8 g of saturated fat (+69%), 86 g of free sugar (+72%), and 2,545 mg of sodium daily (+0.06%); females consumed 3,306 kcal (+65%), 143 g of total fat (+104%), 33.5 g of saturated fat (+67%), 86 g of free sugar (72%), and 2,500 mg of sodium (+4%). ***Conclusion:*** The model, both cost-effective and accurate, identifies elevated nutritional risk factors in Saudi Arabia, informing targeted health policies.

Introduction

According to the World Health Organization (WHO), noncommunicable diseases (NCDs) such as heart disease and cancer account for 41 million deaths annually and 71% of all global deaths [1]. The prevalence of NCDs is often considered a complex phenomenon or system, characterized by multiple interacting components and agents in a non-linear manner. This complexity may necessitate addressing multiple components simultaneously rather than relying solely on one while neglecting

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others [2]. This composition may encompass biological factors such as an individual's body composition, as well as environmental factors such as lifestyle, psychological state, and food system regulations [3]. In the context of NCDs, these components can be categorized as environmental, legislative, and behavioral factors that increase an individual's exposure to risk factors associated with the increased incidence of these diseases [3]. Nutrients and dietary habits are significant contributors that can increase the risk of developing these diseases [2, 3]. Consequently, many public health interventions concentrate on the environmental, legislative, and behavioral components expected to positively impact exposure to nutritional risk factors by enhancing food systems [2].

The food system encompasses multiple elements from production to consumption and is influenced by various risk factors such as food quality, safety, and broader economic and political considerations [4]. Consequently, deficiencies in the food system can increase exposure to risk factors associated with NCDs, leading to adverse public health outcomes [5]. Current observations have indicated that the existing food system may not consistently deliver adequate diets, contributing to malnutrition and obesity [2, 4, 6].

To continuously improve the food system and monitor risk factors associated with NCDs, it is essential to conduct ongoing assessments of these factors [3, 5, 7]. One significant risk factors for NCDs is daily nutrient intake [8, 9]. Therefore, dietary exposure plays a fundamental role in NCD management [10]. Nutrient exposure refers to the quantity of a nutrient ingested through diet and can be evaluated using various methods, each based on different core assumptions [11]. Food balance sheets (FBS), National Nutrition Survey, and Probabilistic Methods are among popular approaches [8, 11–14].

The FBS method provides a comprehensive overview of a country's food supply over a specific period [8]. It begins by examining the total food availability in a country, including imports and local production. Factors such as exports, industrial usage, and storage changes are subtracted to estimate the total food available for consumption [8, 15]. This approach is based on the assumption that food is evenly distributed, thereby resulting in a uniform food distribution that reflects the absence of disparity in consumption among individuals or within the same individual's diet over time [15, 16]. Unlike other techniques for assessing food exposure, this method offers information on food items at various stages of their supply chains, including production, import, and export, and their use in manufacturing or nonhuman consumption such as feed and seeds [8]. This approach is particularly useful for tracking food exposure across the supply chain, even with significant variation such as in assessing pesticide exposure on food [17]. However, the FBS method can lead to either overestimation or underestimation, depending on the situation [8, 15, 16].

The National Nutrition Survey is primarily concerned with individual food consumption, typically gathered through dietary recall methods where participants attempt to recall and provide detailed information about their food intake over the past 24 h or another specified period [12]. In contrast to FBS, this method accounts for the variability in consumption across different individuals by gathering consumption data over 24 h for multiple days [17, 18]. It can be supplemented with techniques involving multiple passes through the checking process, asking about food and additives that may have been forgotten. This approach helps mitigate the recall bias associated with such tools [18]. In prospective studies such as cohort studies, this method can offer a significant advantage as it allows for establishing a dose-response relationship with chronic elements and diseases, which cannot be achieved with the FBS method alone [12, 17, 18]. Furthermore, it is customarily assumed that there is no daily variation within the same individual, and thus, the collocated pattern signifies the daily average intake for the individual [17]. The use of such methodologies makes outcomes more deterministic, and does not account for significant uncertainty [19]. Furthermore, the requirement for basic resources, including Food Compositions Tables, before initiating the study can significantly increase costs [20, 21]. National Nutritional Survey is often considered more accurate than the FBS method but tends to be more deterministic and may not account for all possible food consumption pattern [19, 20]. Additionally, conducting such surveys could incur substantial costs [21].

Probabilistic modeling is a technique that uses statistical methods to integrate data from various sources and represent food consumption, offering deeper insights into current patterns and potential exposure [13, 14]. This method accounts for uncertainty by using different probability distributions, such as normal, lognormal, or uniform distributions, for input data [17, 19, 22, 23]. Monte Carlo simulations, combined with probability distributions, simulate the variation between individuals, similar to the data from the National Nutrition Survey method [19]. Additionally, this technique can analyze the impact of changes in the food supply chain and associated transformations, akin to the FBS method, without causing overestimation or underestimation [17]. This approach does not assume a constant daily food consumption pattern among individuals, thereby offering a more practical and realistic pattern of consumption as opposed to the FBS and National Nutrition Survey. It can also benefit from a broad range of data, including surveillance data such as National Nutritional Survey and economic data combined with food supply data [13, 17, 23–26].

The effectiveness of the probabilistic model was demonstrated in a study comparing it to point-estimate methods, such as nutritional surveys, which provide a single measurement value from a representative sample at a specific time [19]. The study showed that the point-estimate approach resulted in higher pesticide exposure estimates than the probabilistic approach, which represents the data as a distribution of consumption levels and their likelihood of occurrence [19]. Unlike the point-estimate approach, the probabilistic approach accounts for variability through different methods and uses a statistical distribution that reflects the most realistic scenario [19]. Furthermore, it enables comprehensive risk assessment by considering manufacturing processes, expected changes in consumption levels, and residue levels, all of which can impact the overall assessment.

In Saudi Arabia, the absence of a consistent and ongoing National Nutritional Survey offering information on food consumption or exposure to nutritional risk factors can limit decision-makers to rely solely on FBS data from Food and Agriculture Organization (FAO) database or rely on small-scale survey studies. This lack of data complicates decision-making and hinders the assessment of legislation's impact on risk factors. However, probabilistic modeling could be suitable for application in Saudi Arabia due to the availability of detailed data on the supply chain, economy, spending, and prices. While more cost-effective than the National Nutritional Survey, selecting this approach requires careful consideration of several factors.

The use of probabilistic models is cost-effective and flexible in addressing uncertainties in measuring food consumption, as demonstrated by the aforementioned methodologies. However, challenges are associated with incorporating these models into legislative work. First, sustaining data sources and ensuring accessibility are crucial for reproducing and enhancing the transparency of these models before their use as decision-support systems [27]. Second, the accuracy of mathematical models depends on the assumptions made during their construction, which requires thoroughly tested to maintain model verification. Moreover, separate datasets are needed for model building and verification. The accuracy of models relying on statistical distributions derived from scientific literature and local data is crucial for representing phenomena like supply chains [27]. If the data and statistical distributions used are unreliable or processed incorrectly, the model's predictions may not align with reality [28]. To ensure accuracy, it is essential to test the model's predictions against real-world data using statistical methods such as null hypothesis tests and by assessing the agreement and correlation between the model's results and actual outcomes [29–31]. These challenges and validation considerations emphasize the importance of pairing the model with a sustainable data source and a well-defined accuracy testing methodology to ensure accurate results.

This study aimed to improve decision-making by developing a probabilistic model to assess exposure to nutritional risk factors. To achieve this, a probabilistic graph model (PGM) was implemented to represent the variables involved in the transformation process, from food supply to consumption to nutritional risk factors. Additionally, the model will incorporate a validation method for accuracy testing, leveraging historical data from FBS, global dietary database (GDD), and consumer purchase information to streamline the conversion process.

Methods

Modeling Description

The National Nutrient Consumption (NNC) model NNC model utilizes data from the supply chain to estimate food intake and nutrient exposure through a probability-based approach. This study employed a PGM, a structured framework with nodes and edges as its integral components [14]. As illustrated in Figure 1, the nodes represent distinct variables or states, and the edges symbolize the relationships, dependencies, or conversion predictive coefficients between these variables. In our model, the node embodied the conversion process from food commodity supply to actual food consumption, and the edges interpreted the coefficients necessary for this transformation. The coefficient values were determined by training the model with comprehensive historical data, including FBS, GDD, and accumulated consumer purchase data.

The model's processes involve a series of equations that mathematically represent the food supply chain from supply to consumption. These equations extract predictive coefficients during the training phase and utilize the knowledge gained to forecast future patterns in the food supply chain. To comprehend the relationship between the model's elements and parameters, these processes were divided into 11 stages. Each stage includes a description of the equation and variable, the rationale behind the calculation or extraction method, and its unit, as illustrated in Table 1.

The key stages include: (1) the identification of the list of food commodities and their values; (2) the determination of

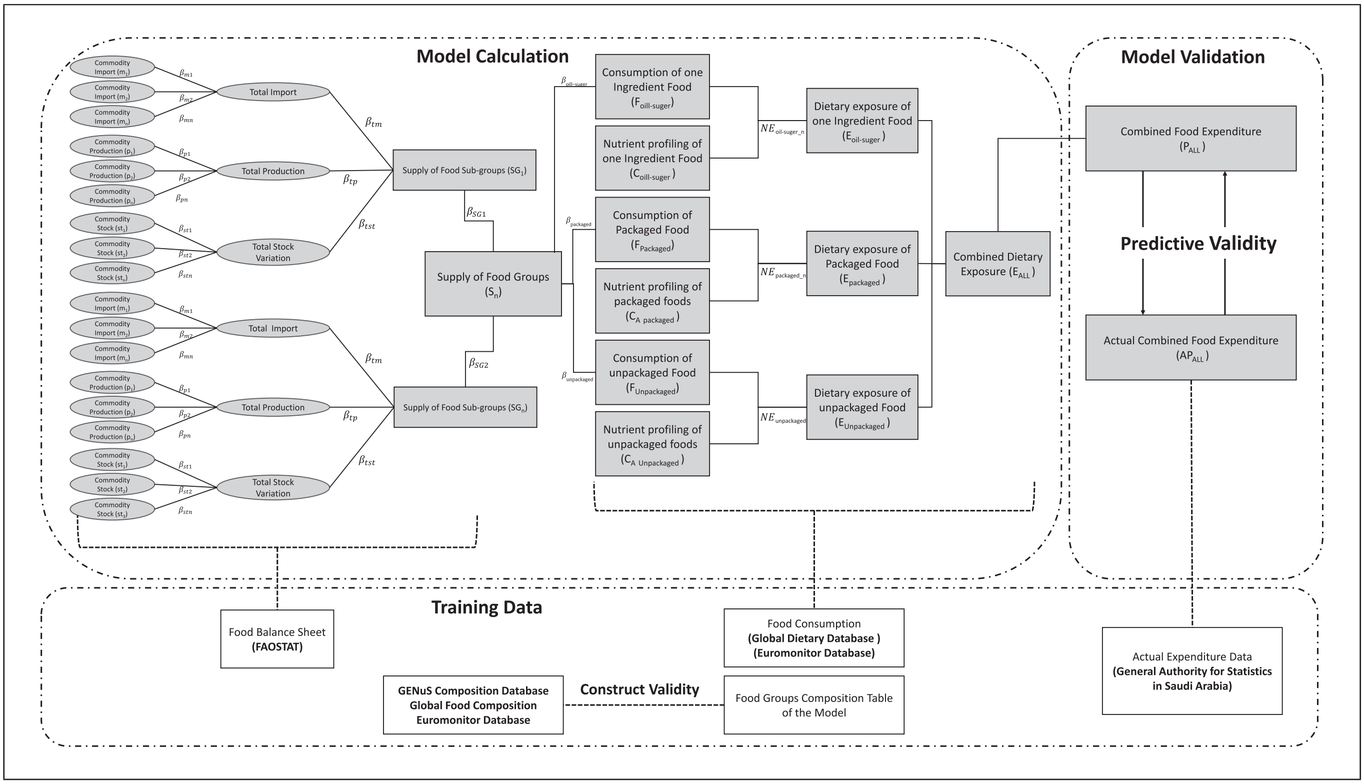


Fig. 1. Conceptual model describing the process and parameters, and external validation.

food commodity subgroups and their associated predictive coefficients; (3) prediction of the value of commodity subgroups; (4) identification of total supply for commodity subgroups and predictive coefficients; (5) prediction of the value of the total supply of commodity subgroups; (6) identification of total supply for commodity groups and predictive coefficients; (7) prediction of the total supply of commodity groups; (8) identification of consumed and non-consumed quantities from supply; (9) prediction of the consumed and non-consumed quantities of groups; (10) integration of consumption data with food composition and pricing data; (11) estimation of nutrient exposure and expenditure rates in Saudi Riyals.

Identification of Food Commodities

The first stage of building this model involved the identification of food commodities list and their values. Initially, a distinct identifier was assigned – referred to as the commodity identifier (CO_n) – to each commodity, where n indicates the food item number or index. For example, apples, apple juice, and concentrated apple juice are allotted to the category of apples (excl. Cider) and are classified under the group of fruits. The classification of the FAO is followed to determine the list of commodities, subgroups, and groups, which is included in online supplementary material 1 (for all online suppl. material, see https://doi.org/10.1159/000540437) [5]. These commodities are designated as CO_1, CO_2, and CO_3, respectively, and can be mathematically expressed as follows:

$$\text{Food Commodities} = \{\text{CO}_1, \text{CO}_2, \cdots, \text{CO}_n\} \tag{1}$$

In deriving the value for each identified commodity, the FAO database (FAOSTAT) was used to obtain information on the import, production, and stock variation of various food commodities. These values for each commodity are represented by m_n, p_n, and st_n, respectively. For instance, the first commodity is denoted as CO_1, with values m_1, p_1, and st_1. This process is uniformly applied to all commodities in the given order. The value for each commodity can be expressed as follows:

$$\text{CO}_n = [\, m_n \quad p_n \quad st_n] \tag{2}$$

Identification and Prediction of Food Commodities Subgroups

Following stage 1, stage 2 involves identifying and calculating the value of each food commodity subgroup. Stage 3 establishes prediction equations for commodity subgroups, each referred to as SG_n, where n signifies the subgroup number or index. During these stages, the subgroups and their commodities were identified and classified using the FAO classification system outlined in online supplementary material 1 [5].

The total values for import, production, and stock variation are calculated by summing each commodity's value under the respective subgroups. This can be expressed as follows:

$$\text{Import}_{\text{ total}} = m_1 + m_2 + \cdots + m_n \tag{4}$$

$$\text{Production}_{\text{ total}} = p_1 + p_2 + \cdots + p_n \tag{5}$$

Table 1. Model input parameters

Variable	Description	Calculation/input	Units
Stage 1: Identification of food commodities list and their values			
Food Commodities	Identified food items list within commodities subgroups	$FoodCommodities = \{CO_1, CO_2, \ldots, CO_n\}$	Ton
CO_n	One food item	$CO_n = \begin{bmatrix} m_n & p_n & st_n \end{bmatrix}$	Ton
m_n	Amount of import for given food commodities or COn	Extracted data from Food and Agriculture Organization database (FAOSTAT) [8]	Ton
p_n	Amount of production for given food commodities or COn	Extracted data from FAOSTAT [8]	Ton
st_n	Amount of stock variation for given food commodities or COn	Extracted data from FAOSTAT [8]	Ton
Stage 2: Identification of food commodities subgroups and predictive coefficients			
$\mathrm{Import}_{\mathrm{total}}$	Total amount of import for given food commodities subgroups	$\mathrm{Import}_{\mathrm{total}} = m_1 + m_2 + \ldots + m_n$	Ton
$\mathrm{Production}_{\mathrm{total}}$	Total amount of production for given food commodities subgroups	$\mathrm{Production}_{\mathrm{total}} = p_1 + p_2 + \ldots + p_n$	Ton
$\mathrm{Stock}_{\mathrm{total}}$	Total amount of stock variation for given food commodities subgroups	$\mathrm{Stock}_{\mathrm{total}} = st_1 + st_2 + \ldots + st_n$	Ton
β_m	The coefficient utilized for predicting imports	$\beta_m = \frac{m_n}{Import_{\ total}}$	Fraction
β_p	The coefficient utilized for predicting production	$\beta_p = \frac{p_n}{\mathrm{Production}_{\ \mathrm{total}}}$	Fraction
β_{st}	The coefficient utilized for predicting stock variation	$\beta_{st} = \frac{st_n}{\mathrm{Stock}_{\ \mathrm{total}}}$	Fraction
Stage 3: Prediction of value of commodities subgroups			
m_n	Predicted amount of import for given CO*n*	$m_n = \beta_m \times \mathrm{Import}_{\mathrm{total}}$	Ton
p_n	Predicted amount of production for given COn	$p_n = \beta_p \times \mathrm{Production}_{\mathrm{total}}$	Ton
st_n	Predicted amount of stock variation for given COn	$st_n = \beta_{\mathrm{st}} \times \mathrm{Stock}_{\mathrm{total}}$	Ton
$\mathrm{Import}_{\mathrm{total}}$	Predicted total amount of import for given food commodities subgroups	$\mathrm{Import}_{\mathrm{total}} = \beta_{m1}(\mathrm{Import}_{\mathrm{total}}) + \beta_{m2}(\mathrm{Import}_{\mathrm{total}}) + \ldots + \beta_{mn}(\mathrm{Import}_{\mathrm{total}})$	Ton
$\mathrm{Production}_{\mathrm{total}}$	Predicted total amount of production for given food commodities subgroups	$\mathrm{Production}_{\mathrm{total}} = \beta_{P1}(\mathrm{Production}_{\mathrm{total}}) + \beta_{P2}(\mathrm{Production}_{\mathrm{total}}) + \ldots + \beta_{Pn}(\mathrm{Production}_{\mathrm{total}})$	Ton

Table 1 (continued)

Variable	Description	Calculation/input	Units
$Stock_{total}$	Predicted total amount of stock variation for given food commodities subgroups	$Stock_{total} = \beta_{St1}(Stock_{total})+\beta_{St2}(Stock_{total})+\ldots+\beta_{Stn}(Stock_{total})$	Ton
Stage 4: Identification of total supply for commodities subgroups and predictive coefficients			
SG_n	Total amount of supply for given food commodities subgroups	$SG_n = Import_{total}+Production_{total}+Stock_{total}$	Ton
β_{tm}	The coefficient utilized for predicting total imports	$\beta_{tm} = \frac{Import_{\ total}}{SG_n}$	Fraction
β_{tp}	The coefficient utilized for predicting total production	$\beta_{tp} = \frac{Production_{total}}{SG_n}$	Fraction
β_{tst}	The coefficient utilized for predicting total stock variation	$\beta_{tst} = \frac{Stock_{\ total}}{SG_n}$	Fraction
Stage 5: Prediction of value of total supply of commodities subgroups			
SG_n	Predicted total amount of supply for given food commodities subgroups	$SG_n = \beta_{tm}(SG_n)+\beta_{tp}(SG_n)+\beta_{tst}(SG_n)$	Ton
Stage 6: Identification of total supply for commodities groups and predictive coefficients			
S_n	Total amount of supply for given food commodities groups	$S_n=SG_1+SG_2+\ldots+SG_n$	Ton
β_{SGn}	The coefficient utilized for predicting total supply for given subgroups	$\beta_{SGn} = \frac{SG_n}{S_{\ n}}$	Fraction
Stage 7: Prediction of total supply of commodities groups			
S_n	Predicted total amount of supply for given food commodities groups	$S_n = \beta_{SG1}(S_1)+\beta_{SG2}(S_2)+\ldots+\beta_{SGn}(S_n)$	Ton
Stage 8: Identification of consumed and non-consumed quantities from supply			
S_n	Supply for given consumed and non-consumed quantities of groups	$S_n=F_n+UF_n$	Ton
UF_n	Total non-consumed quantities for given food commodities groups	$UF_n = S_{\ n} - F_n$	Gram
F_n	Total consumed quantities for given food commodities groups	$F_n = F_{packaged\ food\_n} + F_{unpackaged\ food\_n} + F_{oil-suger\_n}$	Gram
$F_{packaged\ food\_n}$	Consumed quantities for given food commodities groups in packaged form	Extracted data from Euromonitor [34]	Gram

Table 1 (continued)

Variable	Description	Calculation/input	Units
$F_{\text{unpackaged food\_}n}$	Consumed quantities for given food commodities groups in unpackaged form	Extracted data from Global Dietary Database (GDD) [35]	Gram
$F_{\text{oil−suger\_}n}$	Consumed quantities for given food commodities groups in single-ingredient forms (consisting of sugar and oil)	$F_{\text{oil−suger\_}n} = \frac{\text{DSF}_{\text{oil−suger\_}n} \times 100g}{\text{RS}_{\text{oil−sugar\_}n}}$	Gram
$\text{RS}_{\text{oil−suger\_}n}$	Price data of the nutrient in single-ingredient foods (sugar, oil) (accounting for inflation and taxation)	Extracted price data from General Authority for Statistics in Saudi Arabia (GASTAT) [32], inflation from World Bank Database [37], and taxation from Zakat Income and Customs Authority [38]	Saudi Riya
$\text{DSF}_{\text{oil−suger\_}n}$	Expenditure rate of single-ingredient foods (accounting for inflation and taxation)	Extracted price data from GASTAT [32], inflation from World Bank Database [37], and taxation from Zakat Income and Customs Authority [38]	Saudi Riyal
β_{UF_n}	The coefficient utilized for predicting food non-consumed quantities	$\beta_{\text{UF}_n} = \frac{\text{UF}_n}{S_n}$	Fraction
$\beta_{\text{packaged}_n}$	The coefficient utilized for predicting packaged food consumed quantities	$\beta_{\text{packaged}_n} = \frac{F_{\text{packaged food\_}n}}{S_n}$	Fraction
$\beta_{\text{unpackaged}_n}$	The coefficient utilized for predicting unpackaged food consumed quantities	$\beta_{\text{unpackaged}_n} = \frac{F_{\text{unpackaged food\_}n}}{S_n}$	Fraction
$\beta_{\text{oil−suger}_n}$	The coefficient utilized for predicting single-ingredient food consumed quantities	$\beta_{\text{oil−suger}_n} = \frac{F_{\text{oil−suger\_}n}}{S_n}$	Fraction
Stage 9: Prediction of the Consumed and Non-consumed Quantities of Groups			
S_n	Predicted supply for given consumed and non-consumed quantities of groups	$S_n = \beta_{packaged_n}(S_n) + \beta_{unpackaged_n}(S_n) + \beta_{oil-suger_n}(S_n) + \beta_{UF_n}(S_n)$	Ton
UF_n	Predicted total non-consumed quantities for given food commodities groups	$UF_n = S_n \times \beta_{UF_n}$	Gram
$F_{packaged\ food\_n}$	Predicted consumed quantities for given food commodities groups in packaged form	$F_{packaged\ food\_n} = S_n \times \beta_{packaged_n}$	Gram
$F_{unpackaged\ food\_n}$	Predicted consumed quantities for given food commodities groups in unpackaged form	$F_{unpackaged\ food\_n} = S_n \times \beta_{unpackaged_n}$	Gram

Table 1 (continued)

Variable	Description	Calculation/input	Units
$F_{oil-suger\_n}$	Predicted consumed quantities for given food commodities groups in a single-ingredient forms (consisting of sugar and oil)	$F_{oil-suger\_n} = S_{\ n} \times \beta_{oil-suger_n}$	Gram
Stage 10: Integration of Consumption Data with Food Composition and Pricing Data			
$C_{\mathrm{packaged\ food\_n}}$	Concentration of the nutrient in packaged food	Extracted data from Euromonitor [34]	Gram
$C_{\mathrm{unpackaged\ food\_}n}$	Concentration of the nutrient in unpackaged food	Extracted data from Global expanded nutrient supply (GENuS) [36] and global average [36]	Gram
$C_{\mathrm{oil-suger\_}n}$	Concentration of the nutrient in single-ingredient foods (sugar, oil)	Extracted data from GENuS [36] and global average [36]	Gram
$\mathrm{RS}_{\mathrm{packaged\ food\_}n}$	Price data of the packaged food (accounting for inflation and taxation)	Extracted price data from GASTAT [32], inflation from World Bank Database [37], and taxation from Zakat Income and Customs Authority [38]	Saudi Riyal
$\mathrm{RS}_{unpackaged\ food\_n}$	Price data of the unpackaged food (accounting for inflation and taxation)	Extracted price data from GASTAT [32], inflation from World Bank Database [37], and taxation from Zakat Income and Customs Authority [38]	Saudi Riyal
$\mathrm{RS}_{oil-suger\_n}$	Price data of the single-ingredient foods (sugar, oil) (accounting for Inflation and taxation)	Extracted price data from GASTAT [32], inflation from World Bank Database [37], and taxation from Zakat Income and Customs Authority [38]	Saudi Riyal
Stage 11: Estimation of Nutrient Exposure and Expenditure Rates in Saudi Riyals			
$E_{\mathrm{unpackaged\ food\_}n}$	Dietary exposure from unpackaged food for given nutrient	$E_{\mathrm{unpackaged\ food\_}n} = \sum C_{\mathrm{unpackaged\ food\_}n} \times F_{\mathrm{unpackaged\ food\_}n}$	Gram/day or Milligram/day
$E_{\mathrm{packaged\ food\_}n}$	Dietary exposure from packaged food for given nutrient	$E_{\mathrm{packaged\ food\_n}} = \sum C_{\mathrm{packaged\ food\_}n} \times \mathrm{F}_{\mathrm{packaged\ food\_}n}$	Gram/day or milligram/day
$E_{\mathrm{oil-suger\_}n}$	Dietary exposure from single-ingredient foods (sugar, oil) for given nutrient	$E_{\mathrm{oil-suger\_}n} = \sum \mathrm{C}_{\mathrm{oil-suger\_}n} \times F_{\mathrm{oil-suger\_}n}$	Gram/day or milligram/day
E_{ALL}	Total dietary exposure from all food items for given nutrient	$E_{\mathrm{ALL}} = E_{\mathrm{unpackaged\ food\_}n} + E_{\mathrm{packaged\ food\_}n} + E_{\mathrm{oil-suger\_}n}$	Gram/day or milligram/day
$P_{\mathrm{unpackaged\ food\_}n}$	Expenditure from unpackaged food for given nutrient	$P_{\mathrm{unpackaged\ food\_}n} = \sum \mathrm{C}_{\mathrm{unpackaged\ food\_}n} \times F_{\mathrm{unpackaged\ food\_}n}$	Saudi Riyal/day
$P_{\mathrm{packaged\ food\_}n}$	Expenditure from packaged food for given nutrient	$P_{\mathrm{packaged\ food\_}n} = \sum C_{\mathrm{packaged\ food\_}n} \times \mathrm{F}_{\mathrm{packaged\ food\_}n}$	Saudi Riyal/day
P_{ALL}	Expenditure from all food items for given nutrient	$P_{\mathrm{ALL}} = P_{\mathrm{unpackaged\ food\_}n} + P_{\mathrm{packaged\ food\_}n} + \mathrm{DSF}_{\mathrm{oil-suger\_}n}$	Saudi Riyal/day

$$\text{Stock}_{\text{total}} = st_1 + st_2 + \cdots + st_n \tag{6}$$

For predictive coefficients, which help the model learn from historical data and forecast future values, it is crucial to develop equations that assist the model in this context. This study developed multiple equations utilizing the usual rate of import, production, and stock to determine these coefficients. This is represented by β_m, β_p, and β_{st} for import, production, and stock variance, respectively, and can be calculated as follows:

$$\beta_m = \frac{m_n}{\text{Import}_{\text{total}}} \tag{7}$$

$$\beta_p = \frac{p_n}{\text{Production}_{\text{total}}} \tag{8}$$

$$\beta_{st} = \frac{st_n}{\text{Stock}_{\text{total}}} \tag{9}$$

Since the objective was to utilize the coefficient for forecasting purposes, the average coefficient for the years 1990–2019 was computed for these stages.

By using the coefficient values in equations 4, 5, and 6, the prediction equation for the commodity subgroups can be derived. Thus, the model can predict the amount of import, production, or stock variation for a given commodity, or CO_n, as follows:

$$m_n = \beta_m \times \text{Import}_{\text{total}} \tag{10}$$

$$p_n = \beta_p \times \text{Production}_{\text{total}} \tag{11}$$

$$\text{st}_n = \beta_{\text{st}} \times \text{Stock}_{\text{total}} \tag{12}$$

Given that these equations consist of two sides and the coefficients are established from historical data, having information about any aspect of the equation or its components allows the prediction of remaining elements. For instance, knowing the overall import enables us to calculate the remaining components for each food item. Conversely, knowing the value of a single food item enables the determination of the overall import and subsequently estimates the remaining elements using their respective coefficients. This significantly enhances the predictive capability of the model, which is one of the advantages of using a PGM. This can be expressed as follows:

$$\begin{aligned}\text{Import}_{\text{total}} = {} & \beta_{m1}(\text{Import}_{\text{total}}) + \beta_{m2}(\text{Import}_{\text{total}}) + \cdots \\ & + \beta_{mn}(\text{Import}_{\text{total}})\end{aligned} \tag{13}$$

$$\begin{aligned}\text{Production}_{\text{total}} = {} & \beta_{\text{P1}}(\text{Production}_{\text{total}}) + \beta_{\text{P2}}(\text{Production}_{\text{total}}) \\ & + \cdots + \beta_{\text{P}n}(\text{Production}_{\text{total}})\end{aligned} \tag{14}$$

$$\begin{aligned}\text{Stock}_{\text{total}} = {} & \beta_{\text{St1}}(\text{Stock}_{\text{total}}) + \beta_{\text{St2}}(\text{Stock}_{\text{total}}) + \cdots \\ & + \beta_{\text{St}n}(\text{Stock}_{\text{total}})\end{aligned} \tag{15}$$

Identification and Prediction of Total Supply for Commodities Subgroups

For stage 4, determination of the overall supply of subgroups, it is necessary to aggregate the import, production, and stock variation values and then calculate the coefficient for each variable. The subgroups are represented by SG_n, where n represents the number of subgroups. To calculate the total supply for each group, the respective subgroups were summed. The aforementioned operations were conducted for each subgroup listed in online supplementary material 1. This can be expressed as follows:

$$\text{SG}_n = \text{Import}_{\text{total}} + \text{Production}_{\text{total}} + \text{Stock}_{\text{total}} \tag{16}$$

These coefficients represent the average fraction of the total import, total production, or total stock variation relative to the total supply for subgroups from 1990 to 2019. They are denoted as β_{tm}, β_{tp}, and β_{tst}, respectively, and expressed as follows:

$$\beta_{\text{tm}} = \frac{\text{Import}_{\text{total}}}{\text{SG}_n} \tag{17}$$

$$\beta_{\text{tp}} = \frac{\text{Production}_{\text{total}}}{\text{SG}_n} \tag{18}$$

$$\beta_{\text{tst}} = \frac{\text{Stock}_{\text{total}}}{\text{SG}_n} \tag{19}$$

Stage 5 involved developing a prediction equation for the total supply of commodities in different subgroups. This was accomplished by employing the coefficient values in equation 16, enabling the derivation of a prediction equation for the supply of subgroups. This facilitates the prediction of any value on either side of the equation. The equation can be expressed as follows:

$$\text{SG}_n = \beta_{\text{tm}}(\text{SG}_n) + \beta_{\text{tp}}(\text{SG}_n) + \beta_{\text{tst}}(\text{SG}_n) \tag{20}$$

Identification and Prediction of Total Supply for Commodities Groups

Stage 6 focused on calculating the total supply for each group. The groups are represented by S_n, where n denotes the number of subgroups. The value of a given group was calculated by aggregating the supply of subgroups within their respective groups. For instance, within the fruits group, subgroups such as apples and products were combined with other subgroups. This can be expressed as follows:

$$S_n = \text{SG}_1 + \text{SG}_2 + \cdots + \text{SG}_n \tag{21}$$

Subsequently, the coefficient for each subgroup was calculated, representing the average fraction of the supply from each subgroup to the total supply for the groups from 1990 to 2019. This coefficient is denoted by β, where n denotes the group number. Therefore, the average coefficients are calculated as follows:

$$\beta_{\text{SG}n} = \frac{\text{SG}_n}{S_n} \tag{22}$$

The focus of stage 7 was the development of a prediction equation for the total supply of commodities across various groups. This was accomplished by using the coefficient values from equation 22, enabling the derivation of a prediction equation for the groups' supply. This facilitates the prediction of any value on either side of the equation. The equation can be stated as follows:

$$S_n = \beta_{\text{SG1}}(S_1) + \beta_{\text{SG2}}(S_2) + \cdots + \beta_{\text{SG}n}(S_n) \tag{23}$$

Identification of Consumed and Non-Consumed Quantities from Supply

Notably, for stage 8, the total supply does not always reflect actual food consumption, as a portion of the supply may be used for industrial purposes or wasted. Consequently, it is necessary to differentiate between consumed quantities, donated as F_n, and non-consumed quantities, and as UF_n within the total supply. Since the supply is equal to the sum of consumed and non-consumed quantities, the equation could be represented as follows:

$$S_n = F_n + \mathrm{UF}_n \tag{24}$$

The following equation estimates non-consumed quantities based on the relationship among these three variables:

$$\mathrm{UF}_n = S_n - F_n \tag{25}$$

Given that F_n represents the total consumption of the food groups, sourced from different consumption categories including packaged, unpackaged, and single-ingredient foods such as sugar and oil. This could be represented as follows:

$$F_n = F_{packaged food\_n} + F_{unpackaged food\_n} + F_{oil-suger\_n} \tag{26}$$

The quantities for packaged food commodities were denoted as $F_{packaged food\_n}$, while the quantities for unpackaged food commodities were denoted as $F_{unpackaged\ food\_n}$. These values were extracted from EuroMonitor and GDD, respectively. Extracting these two variables involves minimal mathematical operations or derivations beyond standard data cleaning. However, $F_{\text{oil-suger}}$ may require additional extraction processes. Determining the consumption of individual food ingredients such as sugar and oil requires data from monthly expenditure surveys conducted by the General Authority for Statistics in Saudi Arabia (GASTAT) [34]. This is because these types of foodstuffs are typically used either for culinary purposes or as household additives. Thus, this research has formulated the following mathematical equation to represent this:

$$F_{\text{oil-suger\_}n} = \frac{\mathrm{DSF}_{\text{oil-suger\_}n} \times 100g}{\mathrm{RS}_{\text{oil-sugar\_}n}} \tag{27}$$

Where $DSF_{oil-suger\_n}$ represents the expenditure rate of single-ingredient foods, and $RS_{oil-suger\_n}$ is the price data of the nutrient in single-ingredient foods (sugar, oil). All data account for inflation and taxation. Their values were extracted or obtained from GASTAT [34], the World Bank Database [35], and the Zakat Income and Customs Authority [36].

Accordingly, the preceding rates as detailed in equations 24 to 27, can be modified to provide a comprehensive supply representation, clearly outlining its components as follows:

$$S_n = \left(F_{\text{packagedfood\_n}} + F_{\text{unpackaged food\_n}} + F_{\text{oil-suger\_}n} \right) + \mathrm{UF}_n \tag{28}$$

In stage 8, the computation of coefficients for supply and consumption was outlined, representing the average proportion of consumption to total supply for each group from 1990 to 2019. These coefficients were denoted by β_{UF_n}, $\beta_{packaged_n}$, $\beta_{unpackaged_n}$, and $\beta_{oil-suger_n}$ for non-consumed quantities, packaged, unpackaged, and single-ingredient items, respectively, where n indicates the food group's number or index. This calculation was performed using the following formula:

$$\beta_{\mathrm{UF}_n} = \frac{\mathrm{UF}_n}{S_n} \tag{29}$$

$$\beta_{\text{packaged}_n} = \frac{F_{\text{packaged food\_}n}}{S_n} \tag{30}$$

$$\beta_{\text{unpackaged}_n} = \frac{F_{\text{unpackaged food\_}n}}{S_n} \tag{31}$$

$$\beta_{\text{oil-suger}_n} = \frac{F_{\text{oil-suger\_}n}}{S_n} \tag{32}$$

To develop a prediction equation for both consumed and non-consumed quantities from supply data, we used the coefficient values from equations 29 to 32. This allows for predicting any value on either side of the equation, which can be expressed as follows:

$$S_n = \beta_{\text{packaged}_n}(S_n) + \beta_{\text{unpackaged}_n}(S_n) + \beta_{\text{oil-suger}_n}(S_n) + \beta_{\mathrm{UF}_n}(S_n) \tag{33}$$

The amounts of packaged and unpackaged items, as well as single-ingredient products that remain unused can be determined from equation 33 if the supply value for a group (S_n) has been calculated, other simplified equations can also be used for this purpose, as follows:

$$\mathrm{UF}_n = S_n \times \beta_{\mathrm{UF}_n} \tag{34}$$

$$F_{\text{packagedfood\_n}} = S_n \times \beta_{\text{packaged}_n} \tag{35}$$

$$F_{\text{unpackagedfood\_n}} = S_n \times \beta_{\text{unpackaged}_n} \tag{36}$$

$$F_{\text{oil-suger\_n}} = S_n \times \beta_{\text{oil-suger}_n} \tag{37}$$

Integration of Consumption Data with Food Composition and Pricing Data

Stage 10 involves determining the concentration of nutrients per volume, necessitating the development of a Food Composition Table tailored to the model's food groups and consistent with their consumption values ($F_{packaged food\_n} F_{\text{unpackagedfood\_}n}, F_{\text{oil-suger\_}n}$). This task entailed gathering average nutritional data for each group from various sources. For the concentration of groups where food is unpackaged or $C_{unpackaged food\_n}$, we relied on global averages for food categories [37, 38]. The same process was conducted for single-ingredient foods or $C_{oil-suger\_n}$. For $C_{packaged\ food\_n}$, the average nutritional elements were extracted from the food label for each product, and were obtained from the source database EuroMonitor [32].

Furthermore, this study conducted a data extraction process for packaged, unpackaged, and single-ingredient food items, identified as $RS_{packaged food\_n}$, $RS_{unpackaged food\_n}$, and $RS_{oil-suger\_n}$, respectively, from GASTAT [34]. To adjust for inflation and taxes, we sourced information from the World Bank Database [35] and the Zakat Income and Customs Authority [36].

Estimation of Nutrient Exposure and Expenditure Rates in Saudi Riyals

Dietary exposure was established by merging food consumption data with the nutritional composition and pricing tables. As most nutritional risk factors arise from nutrient exposure, key elements such as average calories, protein, fat, carbohydrates, saturated fat, monounsaturated fat, polyunsaturated fat, added sugar, fiber, and salt were calculated [32, 33, 37, 38]. Therefore, stage 11 was focused on integrating the nutrient concentration per volume, or nutrient profiling. This implies that each ($C_{packaged\ food\_n}$, $C_{unpackaged\ food\_n}$, $C_{oil-suger\_n}$) was linked to its corresponding food group and merged with values ($F_{packaged\ food\_n}$, $F_{unpackaged\ food\_n}$, $F_{oil-suger\_n}$) to yield exposure. Dietary exposure was evaluated using the following equations:

$$E_{unpackaged\ food\_n} = \sum C_{unpackaged\ food\_n} \times F_{unpackaged\ food\_n} \tag{38}$$

$$E_{packaged\ food\_n} = \sum C_{packaged\ food\_n} \times F_{packaged\ food\_n} \tag{39}$$

$$E_{oil-suger\_n} = \sum C_{oil-suger\_n} \times F_{oil-suger\_n} \tag{40}$$

$$E_{\mathrm{ALL}} = E_{unpackaged\ food\_n} + E_{packaged\ food\_n} + E_{oil-suger\_n} \tag{41}$$

This configuration provides detailed insights into nutrient exposure from various food sources, thereby providing a deeper understanding of consumption patterns and their implications for overall health.

Additionally, all types of exposure can be translated into food expenditure or food spending. This conversion is crucial because it enables the validation of the model against actual data. With actual food supply data, it becomes a reliable basis for testing the model's predictability and accuracy. The calculations were performed using the following equations:

$$P_{unpackaged\ food\_n} = \sum RS_{unpackaged\ food\_n} \times F_{unpackaged\ food\_n} \tag{42}$$

$$P_{packaged\ food\_n} = \sum RS_{Packaged\ food\_n} \times F_{packaged\ food\_n} \tag{43}$$

$$P_{\mathrm{ALL}} = P_{unpackaged\ food\_n} + P_{packaged\ food\_n} + DSF_{oil-suger\_n} \tag{44}$$

where $P_{\mathrm{unpackaged\ food}}$ denotes the spending on unpackaged foods, $P_{\mathrm{packaged\ food}}$ denotes the spending on packaged foods, and $DSF_{oil-suger\_n}$ denotes the spending on single-ingredient foods.

Model Validation

To ensure the accuracy of a model's predictions, it is crucial to test its efficacy by comparing its results with independent, real-world data. One approach is to compare the model's estimation of food consumption or related values such as expenditure rates or dietary exposure to specific food items, with actual data collected from representative national surveys [39–42].

To test the accuracy of the P_{all} or expenditure rate model in estimating food consumption, an analysis was conducted to compare the results of the model with the actual food expenditure data obtained from National Budget and Expenditure Surveys in Saudi Arabia [34]. This methodology was selected based on three main reasons: the absence of National Nutrition Survey data for comparison, the potential to reverse-engineer expenditure data into food consumption when price data is available, and the well-documented methodology of the National Budget and Expenditure Survey in Saudi Arabia, which uses a representative sample. For this study, data from surveys conducted in 2013 and 2018 were included, and interpolation was used for the remaining years in this period. Thus, the hypothesis for testing the accuracy of consumption suggests that F_n is accurate if it allows us to predict that the daily spending rate matches the actual spending rate. This can be formulated as follows:

H_1: True $\Leftrightarrow P_{Acual} = P_{all}$

To assess this hypothesis and validate the model's results alignment with real-world data over multiple years, rather than relying on a single year or an average of all years – which may not be highly representative – we employed the mean absolute error (MAE) and correlation coefficient techniques [43, 44]. MAE is calculated by averaging the absolute differences between the predicted values and the actual values for each year separately, which helps evaluate the accuracy of the model. Conversely, the correlation coefficient is determined by measuring the degree of linear relationship between the predicted and actual values. This coefficient ranges from −1 to 1, where 1 indicates a perfect positive correlation, −1 indicates a perfect negative correlation, and 0 indicates no correlation. These methods were selected to ensure that the model provided consistent and accurate predictions that matched real-world data over an extended period, thereby supporting hypothesis 1.

The second aspect of dietary exposure involves the nutritional content derived from the Food Composition Table, as demonstrated by the aforementioned equations. Thus, it is crucial to select a Food Composition Table that contains information on the nutritional content of each food group in the model. In this study, it was assumed that the nutrient intakes calculated using different Food Composition databases would yield similar results under constant dietary intake. Consequently, utilizing two different Food Composition Tables would yield comparable outcomes without significant difference. This assumption was based on the results of an analysis of the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort, which aimed to test this hypothesis [45].

For this study, the Global Expanded Nutrient Supply (GENuS) Project database for food composition was selected [37]. To assess whether this choice significantly affects exposure, a hypothesis test compared this table with another created by calculating the global average for food composition from a different study [38]. This test ascertained if the GENuS and the Global Average databases provided similar nutrient amounts for equivalent servings from the food groups. Thus, the hypothesis for testing the accuracy of nutrient concentration from ($C_{unpackaged\ food\_n}$, $C_{oil-suger\_n}$) is accurate if the difference between the amounts that yield the same nutritional value, as given by the global average table and another data source table, does not exceed one serving and is not statistically significant [37, 38]. This can be represented as: H_2: True $\Leftrightarrow |FCT_A\text{-}FCT_B| \approx 1 servingsize$

where FCT_A and FCT_B are the amounts from the GENuS and Global Average databases, respectively. If the difference in servings is within one serving, the tables are considered similar, supporting the assumption. However, a difference exceeding one serving with statistical significance implies non-comparability, indicating distinct food compositions in each group. Consequently, adopting a Food Composition Table that includes general food groups (as in this model) and excludes local Food Composition Tables for non-packaged foods may affect the overall accuracy of the mode. Statistical confirmation included a one-sample *t* test in the GENuS Database to verify that the difference was statistically significant [46]. This test was restricted to $C_{\mathrm{unpackaged\ food\_n}}$ and the $C_{\mathrm{oil-suger\_n}}$. Packaged foods ($C_{\mathrm{packaged\ food\_n}}$) were excluded from this analysis due to their reliance on exact nutritional data specific to each food product, which differs from the data utilized in the other two groups.

Data Sources

We utilized several integrated databases such as the GDD and EuroMonitor database, ensuring the reliability and comprehensiveness of our data for both packaged and unpackaged food supplies and consumption. These databases were chosen strategically to enable researchers to replicate our study while ensuring optimal accessibility and utility. The primary criteria for selecting these databases were accessibility through publicly available sources, whether freely or through purchase, and possess comprehensive documentation to address data gaps and errors. Additionally, the focus was on selecting databases with a global scope to facilitate the adoption and use of this model by analysts in other policy contexts, except the GASTAT database, which is limited to Saudi Arabia.

The training data for the model were obtained from various authoritative databases. Population data were derived from the GASTAT, which are crucial for acquiring essential insights into the overall population [34]. The GDD was instrumental in providing data on food consumption patterns, offering detailed daily averages across 19 food categories for Saudis aged 15–80 between 1990 and 2019 [33].

When the GDD lacked data on packaged foods, the EuroMonitor database was used [32]. It supplies average daily consumption data and nutrient composition for various categories such as snacks, sugars, sauces, and dressings. Nutrient composition data for unpackaged foods were obtained from the GENuS Project database, which organized each item within specified 19 food groups to facilitate the modeling process [38, 37].

Nutrient composition data for packaged foods were sourced exclusively from the EuroMonitor database [32]. Additionally, pricing data were acquired from GASTAT [34], wherein monthly reports detailing average food prices were merged with nutritional data, thus culminating in a comprehensive table consolidating data on food items, their prices, nutritional values, and nutritional profiles.

The data utilized for the accuracy testing process, including inflation levels in Saudi Arabia and value-added tax amounts were obtained from reputable sources such as the Saudi profile in the World Bank Database [35], and the report published by the Zakat, Income, and Customs Authority [36].

The model used in our analysis accounts for the randomness of individual dietary behaviors, which vary daily and between individuals within the same community. This variability is significant due to differences in nutrition and food. The model addresses the inherent randomness in the dataset, either indirectly by accounting for it in the original research from the data source or directly when it is not considered in the data source. The model processed actual food consumption data from the GDD using the Markov Chain Monte Carlo method and adjusted the commodity supply data from the FBS by identifying trends and patterns [33, 47]. This dual approach ensures that the model captures the real-world variability in food consumption and supply metrics.

Population Characteristics

The information on community dietary exposure in Saudi Arabia is derived from adult individuals aged 15 years and older, sourced from the GASTAT database [34]. These data provide a comprehensive overview of the general population. Table 2 displays the demographic characteristics, highlighting the distribution of gender and the number of deaths per year caused by various diseases. The study population comprises 25,828,254 individuals, with males constituting 60% (15,466,150) and females accounting for the remaining 40% (10,362,104). Cancer is responsible for 15% of annual deaths (79,303), followed by kidney failure at 10% (50,034), liver failure at 5% (28,004), and diabetes at 5% (22,684). However, the largest proportion is attributed to cardiovascular disease, amounting to a striking 65% of deaths (334,222), totaling 514,247 annual deaths. The data are presented in numerical and percentage form, with the currency unit “SR” representing Saudi Riyal, suggesting a potential financial context to the data provided.

Table 2. Population characteristics of modeling study

Variables	*n*	%
Gender		
Male	15,466,150	60
Female	10,362,104	40
Total	25,828,254	100
Annual number of deaths[a]		
Cancer	79,303	15
Kidney disease	50,034	10
Liver disease	28,004	5
Diabetes	22,684	5
Cardiovascular disease	334,222	65
Total	514,247	100

Data presented as number and percentage. [a]Global Burden of Disease (GBD) 2019.

Saudi Dietary Reference Value

The model compared the exposure results to the recommended values or the reference values for these risk factors, identifying those exceeding these limits in Saudi Arabia and to what extent. Considering that the model aims to assess dietary exposure to nutrients, which are critical risk factors for chronic diseases, it is essential to compare nutrient levels and exposures to the recommended reference values published in the Saudi Technical Regulation No. SFDA.FD 2233, which provides these reference values for nutrients [48]. These nutrients fall into two categories [33, 49]. The first category involves nutritional risk factors that require reduction, such as high-energy intake, total fat, trans fat, sodium, sugar, and cholesterol [33, 49]. According to the Saudi Technical Regulation No. SFDA.FD 2233, the recommended daily intake for this category is: 2,000 kcal, 70 g fat, 20 g saturated fat, 50 g free sugars, 2,400 mg salt, and 300 mg cholesterol. Notably, exceeding these values may increase the risk of various health problems. The second category includes nutrients with recommended intake levels that should be consumed without reaching toxic levels, which are generally much higher than the reference values [33, 49]. Examples include vitamins and minerals.

Results

Model Accuracy

The first hypothesis evaluates the model’s predictive accuracy in estimating the actual monthly spending rate based on consumption and price data. As shown in Table 3, the model accurately predicted all values between

Table 3. Hypothesis 1 for testing accuracy of food consumption estimation

Year	Inflation rate (%)*	VAT rate (%)**	Actual data (Saudi Riyal)##	Model result# (Saudi Riyal)	Difference (Saudi Riyal)	Difference (%)	Mean absolute error (MAE)	Correlating coefficient
2010	5.3	0	424	447	23	6	–	–
2011	5.8	0	433	453	20	5	–	–
2012	2.9	0	442	481	39	9	–	–
2013	3.5	0	451	507	56	12	–	–
2014	2.2	0	460	482	22	5	–	–
2015	1.2	0	469	503	34	7	–	–
2016	2.1	0	478	508	30	6	–	–
2017	−0.8	0	487	510	23	5	–	–
2018	2.5	5	496	525	29	5	–	–
Means	–	–	460	491	31	7	29	0.74

*Inflation rate from Saudi Arabia profile in Word Bank Database. **The Zakat, tax, and customs authority of Saudi. #Result after accounting for inflation and taxation.

2010 and 2018, with an average error rate of 7%. The MAE, which represents the discrepancy or absolute error rate over this period, was 31 Saudi Riyals compared to the average actual monthly expenditure of 460 riyals and a projected value of 491 Saudi Riyals. The correlation coefficient was almost equal 0.74, indicating a strong positive relationship between the predicted and actual spending data. This high correlation suggests the model reliably forecasts spending trends, adding credibility to its predictions.

The primary objective of the second hypothesis was to validate the assumption that Food Composition Tables, which provided information on nutrient concentrations, having no statistically significant bearing on the necessary number of food portions required to achieve the same nutritional exposure. The second hypothesis aimed to test the assumption that using different Food Composition Tables does not affect the exposure outcome for unpackaged food items. In the study, adopting a Food Composition Table for unpackaged food and nutritional label information for packaged food obtained from the Euromonitor database did not affect the outcome. As depicted in Table 4, the observed differences were not substantial, with the variations between each group amounting to no more than one serving. Furthermore, the results of the one-sample *t* test did not reveal any statistically significant disparities. Consequently, it can be inferred that the utilization of diverse Food Compositions Tables does not impact dietary exposure from foods in the various food categories, except for packaged foods that are consumed following their nutritional information labels.

Nutrient Exposure Estimation

Table 5 presents a comprehensive analysis of nutrient exposure across various percentile categories for both genders. The calorie intake at the 25th percentile for males and females was 2,100.6 and 2,098.1 kcal, respectively, with a slight increase at the 50th percentile and a substantial rise at the 95th percentile, reaching 4,850.5 kcal for males and 4,885.1 kcal for females. The protein intake was relatively consistent across percentiles, ranging from 65.6 to 107.46 g for males and from 67.0 to 99.14 g for females.

Conversely, carbohydrate and dietary fiber intakes display a consistent upward trend across percentiles. Total fat intake follows a similar pattern, particularly at the 95th percentile, where it was over twice that at the 25th percentile for both genders. The distribution of all fat types also increased, with polyunsaturated fats almost doubling from the 25th to the 95th percentile.

The model also presents specific fatty acid profiles such as linoleic, linolenic, EPA, DHA, and stearic acid, exhibiting incremental increases across percentile categories. Cholesterol intake exhibits a marked rise from the 25th to the 95th percentile, with a notable gender difference at higher percentiles.

For minerals, calcium intake ranges from 461.5 mg at the 25th percentile to over 1,000 mg at the 95th percentile. Similarly, iron, magnesium, phosphorus, potassium, sodium, zinc, copper, manganese, and selenium showed incremental increases at higher percentiles.

Moreover, a comprehensive range of vitamins was quantified, including vitamin A, E, D, C, thiamin (B1), riboflavin (B2), niacin (B3), vitamin B-6, vitamin B-12,

Table 4. Hypothesis 2 for testing accuracy of concentration of nutrient

Food groups	Subgroups	Serving size	Global average per 100 g					US average per 100 g					Adjusted amount[#]	Difference[a,b]	Z-score	*p*-value
			amount, g	calories, kcal	protein, g	carbohydrate, g	fat, g	amount, g	calories, kcal	protein, g	carbohydrate, g	fat, g				
Fruit	Fruit	80.0	100.0	77.0	1.0	18.0	0.0	100.0	122.5	1.4	30.8	0.4	159.1	59.1	−20.9	>0.05
Vegetables	Vegetables	80.0	100.0	26.0	1.0	5.0	0.0	100.0	41.4	1.7	8.7	0.6	159.1	59.1	−20.9	>0.05
Grains	Whole grains	80.0	100.0	317.8	9.0	66.8	1.8	100.0	115.0	4.1	21.8	1.6	36.2	−63.8	−16.2	>0.05
	Refined grains	80.0	100.0	317.8	9.0	66.8	1.8	100.0	106.3	3.0	19.9	1.5	33.4	−66.6	−13.2	>0.05
Protein foods	Meats	30.0	100.0	164.0	14.0	0.0	0.0	100.0	163.3	23.7	0.3	6.7	99.6	−0.4	−29.6	>0.05
	Poultry	30.0	100.0	144.0	14.0	0.0	0.0	100.0	170.0	26.0	0.7	6.3	118.1	18.1	−11.9	>0.05
	Fish	30.0	100.0	130.0	21.7	0.7	2.0	100.0	140.0	21.0	0.3	5.5	107.7	7.7	−22.3	>0.05
	Eggs	50.0	100.0	143.0	13.0	2.0	9.0	100.0	156.0	12.6	1.2	10.6	109.1	9.1	−40.9	>0.05
	Nuts/seeds	30.0	100.0	344.0	13.0	13.0	27.0	100.0	290.0	10.3	10.7	25.0	84.3	−15.7	−14.3	>0.05
Dairy	Dairy	240.0	100.0	58.0	4.0	2.0	4.0	100.0	32.1	3.6	3.5	0.4	55.3	−44.7	−195.3	>0.05
Other	Oils	1.0	100.0	900.0	0.0	0.0	100.0	100.0	900.0	0.0	0.0	100.0	100.0	0.0	−1	>0.05
	Solid fats	1.0	100.0	800.0	0.0	0.0	90.0	100.0	800.0	0.0	0.0	90.0	100.0	0.0	−1	>0.05
	Added sugars	1.0	100.0	400.0	0.0	100.0	0.0	100.0	400.0	0.0	100.0	0.0	100.0	0.0	−1	>0.05

[#] Adjusted amount equal to the global amount per 1 g equivalent to 100 g of US average. [a] There is no statistical difference between the adjusted amount and US average. [b] Significant difference means that there is a difference between the adjusted amount and US average that is enough to change the food pattern by a single serving size for the food group.

choline, vitamin K, and folate. Each nutrient demonstrates a clear progressive increased from the 25th to the 95th percentile. Notably, vitamins C and B exhibited a marked increase at higher consumption levels, reflecting their water-soluble nature and higher concentrations in fortified or nutrient-dense foods.

Exposure and Health-Based Exposure Limit

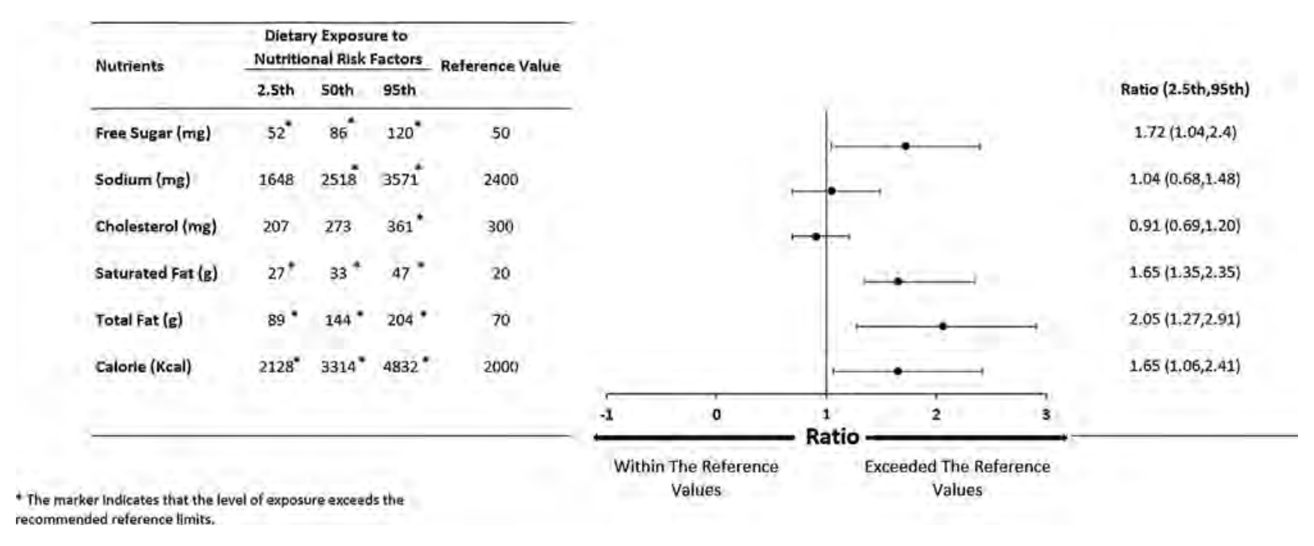
The analysis of exposure levels to various nutritional risk factors, including calories, total fat, trans fats, cholesterol, sodium, and free sugar, revealed that many of these factors exceeded the recommended levels from the reference values, as depicted in Figure 2. The ratio demonstrated that the consumption level was proportional to the recommended reference values. A value below one indicated that the exposure was within the recommended levels, whereas a value above one signified that the exposure exceeded the recommended level from the reference values. For instance, a value of 1.5 implied that the consumption was 50% or 1.5 times more than the recommended quantity, while a value of 2.0 indicated that the quantity exceeded the recommended level by 100% or twice as much.

The recommended intake for free sugar was 50 mg, with the 25th, 50th, and 95th percentiles of intake being 52, 86, and 120 mg, respectively. The ratios of the median, 2.5th, and 95th percentile intakes exceeded the reference, indicating a high risk of excessive intake. The reference intake was 2,400 mg, and the 2.5th, 50th, and 95th percentiles of intake were 1,648 mg, 2,518 mg, and 3,571 mg, respectively. Only the 95th percentile surpassed the reference value when the ratio exceeded reference values by 48%. The reference intake was 300 mg, and the 25th, 50th, and 95th percentiles of intake were 207, 273, and 361 mg, respectively. The 95th percentile exceeded the reference, indicating that higher cholesterol intake at this level exceeds the reference values by 20%. The reference intake was 20 g, and the 2.5th, 50th, and 95th percentiles of intake were 27 g, 33 g, and 47 g, respectively. All percentiles exceeded the reference, suggesting widespread high saturated fat intake, with ratios of 1.35, 1.65, and 2.35, respectively. The reference intake was 70 g, and the 2.5th, 50th, and 95th percentiles of intake were 89, 144, and 204 g, respectively. All observed values and ratios exceeded the recommended intake. The reference intake for calories was 2,000 kcal, and the 2.5th, 50th, and 95th percentiles of intake were 2,128 kcal, 3,314 kcal, and 4,832 kcal, respectively. These values, with high ratios, indicated significant caloric intake beyond the recommended levels across all percentiles.

Table 5. Nutrient exposure

Calorie level	25th			50th			95th			Saudi Dietary Reference Value[#]
	male	female	all	male	female	all	male	female	all	
Macronutrients										
Calories, kcal	2,100.6*	2,098.1*	2,128.0*	3,310.6*	3,306.6*	3,314.6*	4,880.5*	4,885.1*	4,832.0*	2,000
Protein, g	68.6	67.0	68.9	101.4	99.1	100.7	149.7	147.6	146.7	50
Carbohydrate, g	265.7	249.6	252.4	417.3	393.5	392.2	631.0	595.7	584.3	260
Fiber, dietary, g	23.3	23.9	24.3	36.3	36.8	36.7	58.9	59.7	57.8	28
Total lipid (fat), g	89.8*	88.9*	89.8*	144.4*	143.2*	144.1*	206.0*	204.6*	204.5*	70
Trans fatty acids, g	0.0	0.0	0.0	0.03	0.03	0.03	0.1	0.1	0.1	–
Saturated fats, g	27.3*	27.0*	27.2*	33.8*	33.5*	33.7*	47.7*	47.4*	47.4*	20
Monounsaturated fats, g	25.0	24.6	25.0	40.2	39.5	39.8	58.2	57.6	57.6	–
Polyunsaturated fats, g	26.9	26.7	27.0	43.8	43.5	43.7	62.6	62.2	62.2	–
Linoleic acid, g	23.0	22.8	23.0	37.6	37.3	37.5	53.7	53.4	53.4	–
Linolenic acid, g	3.3	3.3	3.3	5.2	5.2	5.2	7.5	7.5	7.5	–
EPA, g	0.10	0.10	0.10	0.15	0.14	0.15	0.20	0.23	0.21	–
DHA, g	0.22	0.20	0.21	0.33	0.32	0.32	0.50	0.50	0.50	–
Stearic acid, g	14.8	14.7	14.8	24.05	23.97	24.02	33.6	33.5	33.5	–
Cholesterol, mg	208.6	198.7	207.0	277.5	266.6	273.5	372.9*	361.3*	364.0*	300
Minerals										
Calcium, mg	461.5	478.5	480.0	689.3	712.1	701.2	1,055.5	1,085.7	1,046.3	1,000
Iron, mg	11.6	11.6	11.9	17.6	17.5	17.7	27.3	27.2	26.7	14
Magnesium, mg	249.5	252.8	257.5	380.9	383.2	383.2	601.3	605.5	590.2	310
Phosphorus, mg	939.4	935.1	957.8	1,419.5	1,409.2	1,420.1	2,198.6	2,194.5	2,154.4	700
Potassium, mg	2,910.3	2,990.6	3,016.5	4,274.8	4,357.0	4,325.2	6,580.8	6,717.6	6,496.1	2,000
Sodium, mg	1,656.4	1,622.9	1,648.6	2,545.4*	2,500.1*	2,518.2*	3,639.9*	3,587.5*	3,571.3*	2,400
Zinc, mg	7.7	7.6	7.8	10.9	11.0	11.0	17.2	17.0	16.8	11
Copper, mg	956.9	983.5	996.4	1,455.5	1,480.6	1,471.8	2,325.6	2,363.6	2,286.9	900
Manganese, mg	2.4	2.4	2.5	3.6	3.6	3.6	5.8	5.8	5.6	3
Selenium, mg	75.6	72.9	75.7	108.8	105.6	107.7	156.2	152.8	152.6	60
Vitamins										
Vitamin A, µg	656.3	687.1	681.6	849.4	888.9	868.2	1,135.6	1,186.8	1,135.3	800
Vitamin E, mg AT	11.7	11.8	11.9	17.9	18.0	18.0	25.6	25.7	25.48	9
Vitamin D, µg	3.2	3.2	3.3	4.6	4.6	4.6	6.9	6.9	6.7	5
Vitamin C, mg	138.0	147.4	145.1	178.5	190.7	184.1	240.6	256.5	242.7	100
Thiamin, mg	1.3	1.3	1.3	2.0	2.0	2.1	3.2	3.2	3.1	1.2
Riboflavin, mg	1.2	1.2	1.2	1.74	1.75	1.75	2.5	2.5	2.5	1.2
Niacin, mg	18.2	17.8	18.3	26.56	25.88	26.35	39.2	38.6	38.4	15
Vitamin B-6, mg	1.9	1.9	1.9	2.69	2.70	2.71	4.1	4.1	4.0	1.3
Vitamin B-12, µg	3.3	3.2	3.3	4.70	4.56	4.65	6.7	6.6	6.6	2.4
Choline, mg	306.7	302.5	310.2	427.70	422.40	426.70	613.8	610.2	602.3	–
Vitamin K, µg	314.9	331.2	326.9	410.66	430.48	419.87	537.7	563.6	539.5	60
Folate, µg	2.9	2.8	2.9	4.03	4.01	4.03	5.8	5.8	5.7	400
Other										
Free sugar	52.6*	52.6*	52.7*	86.5*	86.0*	86.4*	120.4*	120.4*	120.5*	50
Cost per day	12.7	12.6	12.8	17.4	17.3	17.5	24.4	24.3	24.0	–

[#] Reference values are the recommended values according to Saudi Technical Regulation No. SFDA.FD 2233. *A nutritional risk factor that has exceeded the reference value.



Nutrients	Dietary Exposure to Nutritional Risk Factors			Reference Value	Ratio (2.5th,95th)
	2.5th	50th	95th		
Free Sugar (mg)	52*	86*	120*	50	1.72 (1.04,2.4)
Sodium (mg)	1648	2518*	3571*	2400	1.04 (0.68,1.48)
Cholesterol (mg)	207	273	361*	300	0.91 (0.69,1.20)
Saturated Fat (g)	27*	33*	47*	20	1.65 (1.35,2.35)
Total Fat (g)	89*	144*	204*	70	2.05 (1.27,2.91)
Calorie (Kcal)	2128*	3314*	4832*	2000	1.65 (1.06,2.41)

* The marker indicates that the level of exposure exceeds the recommended reference limits.

Fig. 2. Exposure to nutritional risk factors.

Discussion

The primary aim of this study was to develop a PGM to accurately measure exposure to specific population dynamics. Mathematical modeling has increasingly established its significance as an essential tool in the field of nutrition science, providing a precise analytical approach beyond conventional dietary assessment methods. The probabilistic modeling approach was selected for its cost-effectiveness, reliance on open data sources, and focus on supply chain dynamics and uncertainties. This approach facilitates the evaluation of exposure to nutritional risk factors, aiding policymakers in implementing targeted legislative measures to minimize these risk factors, particularly in nutrition-related context.

This methodology differs from conventional dietary assessment techniques such as National Nutritional Survey and FBS, leveraging regularly updated accessible data sources to estimate food consumption and exposure [8, 11–14]. Furthermore, it integrates algorithmic components to test the results' accuracy.

Although various models utilize open data sources such as GDD, GENuS, and FABIO, ours possesses distinct advantages [33, 37, 50]. Notably, our model considers a broader range of food sources. Typically, other models primarily rely on data sources that concentrate on non-packaged foods such as FBS, or a limited number of food items, through the use of a dietary frequency questionnaire (FFQ). For example, the GDD model was developed using a Markov chain Monte Carlo based on surveys and FBS from each country [33]. In Saudi Arabia, a study titled "Premature biological aging in Saudi adults with Type 2 diabetes and the influence of endotoxemia" was conducted by the King Saud University using an FFQ [33]. The GENuS and FABIO models utilized data from the FBS and other sources in their estimation, but did not account for packaging and single food ingredients, and the accuracy of these data was not evaluated [37, 50]. Despite using the GDD model to train the NNC model on some estimates for unpackaged food, the NNC model differed in its approach of incorporating data for packaged foods and single-ingredient foods such as sugar and oil.

Another advantage of the current model differs is its use of an equations-based probabilistic approach to estimate all the elements of the supply chain (Table 1). For example, the total supply for a large food group can be applied to estimate supplies for subgroups, enabling detailed assessment of food stock, production, and imports for a specific food or food group. This increased capability allows the model to have a greater impact on nutrition, food security, and food safety decisions by providing information on the availability of targeted foods, thereby enhancing the usefulness and representation of the supply chain.

The model's accuracy was evaluated through hypothesis testing, which assessed its predictive capabilities for consumption, supply, and nutrient concentration. The results indicated that the model's estimate of consumption had an MAE averaging 7% for the period between 2010 and 2018 (Table 3). Furthermore, the study determined the suitability of the Food Composition Table utilized in the model for non-packaged foods by comparing it with the GENuS Food Composition Table, revealing no significant difference between the two tables (Table 4).

The model's simulation of the current dietary patterns in the community estimated the percentage of excess nutritional risk factors, including caloric intake, fat, saturated fat, cholesterol, sugar, and sodium (Table 5). Excessive levels were observed in most reference values – except cholesterol, which was high only in the 95th percentile, and sodium, which was only in the 50th and 95th percentiles but was statistically insignificant in the 2.5th percentile. These outcomes suggest that the appropriate volume and levels of fat and salt in Saudi Arabia may result from implemented policies and efforts [51, 52]. Further research is required to determine whether these patterns of exposure are directly attributable to these policies.

Although the model is likely to provide accurate estimates of food consumption, certain aspects must be considered. The model estimated total consumption ranging from 2.5% to 95%, but the geographic distribution data for consumption may not currently be available. For example, it may be difficult to determine which areas of Saudi Arabia consume the most of certain foods or the spatial distribution of these food commodities. Thus, the model treats Saudi Arabia as a complete unit. Additionally, it cannot estimate the consumption of specific vulnerable groups based on economic or demographic characteristics. Thus, necessitating further study and research.

The objective of the proposed model was to expand its applications beyond estimating direct exposure to nutritional risk factors from food. The NNC model includes additional estimates, including the impact of vitamins, minerals, and fiber, enhancing decision-making in fortification policy evaluation [53]. Additionally, the risk factor exposure estimates from the NNC model can be combined with the dose-response model to predict the effects of nutritional interventions on mortality rates from NCDs, such as by utilizing the Peter algorithm in the prime model [49]. These models provide valuable insights for decision-making by highlighting the consequences of nutritional interventions and subsequent changes in mortality rates. They can also be applied to food security to prioritize staple food items and predict future demand [53–55]. The model's results can further guide nutritional prioritization using decision matrices based on the exposure results, such as the three-pronged approach matrix, to determine nutritional priorities [56].

Conclusions

This study developed a computational model that effectively addressed limited and unreliable data in Saudi Arabia, essential for measuring dietary intake. The probabilistic mathematical model for dietary consumption and exposure assessment showed that high levels of nutritional risk factors such as calories, saturated fats, salt, and sugar were found in the 50th and 95th percentiles, highlighting the need for better policies and legislation. The model results can serve as a baseline for monitoring the impact of future regulations and policies on these factors and provide insights into which foods have the most significant impact, aiding in targeted modifications of their compositions. Additionally, it relies on sustainable and accessible data sources, offering a scalable solution to the limitations of national dietary surveys. This progress is a critical step toward enhancing public health strategies and nutritional planning in Saudi Arabia.

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Statement of Ethics

This research was approved by the Regulatory Research Committee of the Saudi Food and Drug Authority (Reference No. FD-2023-006) concerning all ethical considerations involving the data. The data of all participants were obtained and documented in open databases by government authorities, and written informed consent was obtained from all study participants for participation in the study. With regard to data related to operations overseen by government agencies such as sales, purchases, and imports, it must be noted that written authorization was secured before disclosing the information by accessing the relevant databases. We confirmed that all methods were performed by the relevant guidelines and regulations.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Conceptualization, writing – review and editing, supervision, and project administration: Omar A. Alhumaidan; methodology, Omar A. Alhumaidan, Shihana A. Alakeel, Sarah M. Alkhunein, and Ghadir A.Fallata; writing, Omar A. Alhumaidan, Shihana A. Alakeel, Sarah M. Alkhunein, and Ghadir A. Fallata. All the authors have read and agreed to the published version of this manuscript.

Data Availability Statement

The data that support the findings of this study are all Open Access and available on their respective official, General Authority of Statistics (https://database.stats.gov.sa/), Food and Agriculture Organization database (https://www.fao.org/faostat/en/#data), Global Dietary Database (https://globaldietarydatabase.org/data-download), and Global Expense Nutrient Supply (https://dataverse.harvard.edu/dataverse/GENuS). Euromonitor database, which consists of purchased data and available on request from corresponding author Omar A. Alhumaidan via email oahumaidan@sfda.gov.sa, upon obtaining permission from Euromonitor.

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Burnout and Work Engagement Concerning Dental Malpractice among Saudi Dentists: A Cross-Sectional Study

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Keywords
Dental malpractice · Burnout · Work engagement · Dentists

Abstract

Introduction: Dental malpractice is becoming an increasing concern in the health care sector. Dentistry is a highly stressful profession, and neglecting stress and burnout can harm patients, dentists, and the quality of their work. This study estimated the prevalence of dental malpractice, evaluated the association between burnout, work engagement, and dental malpractice, and identified other potential risk factors. ***Methods:*** Between May 2023 and May 2024, a cross-sectional study was conducted using a convenience sample of 259 Saudi dentists working in public dental clinics in Jeddah. Dentists completed an online self-administered anonymous questionnaire that included four sections: sociodemographics and occupational characteristics, a previously valid and reliable Maslach Burnout Inventory, Areas of Worklife Survey, and self-reported dental malpractice questions. Data were analyzed using STATA 18, including descriptive statistics, bivariate analysis, and multivariate analysis. ***Results:*** Among the 259 responding Saudi dentists, 27% reported malpractice concerns, and 20.8% reported that they had a malpractice claim. Multivariate logistic regression analysis revealed that dentists with high levels of depersonalization (OR = 2.44, $p = 0.012$) and low levels of community engagement (OR = 2.92, $p = 0.011$) were more likely to have malpractice concerns. Additionally, dentists working in primary health care centers (OR = 4.62, $p \leq 0.001$), dentists experiencing high emotional exhaustion (OR = 2.58, $p = 0.033$), and those with low-value engagement (OR = 2.99, $p = 0.017$) were more likely to be involved in malpractice claims. ***Conclusion:*** This study provides in-depth information on dentists' characteristics, burnout levels, work engagement levels, and their association with dental malpractice. Saudi dentists experience high emotional exhaustion and low personal accomplishment. In addition, various workplace factors have been associated with dental malpractice.

Plain Language Summary

Dental malpractice is becoming a growing concern in health care. Dentistry is a high-stress job, and ignoring stress and burnout can negatively affect patients, dentists, and the quality of their work. This study examined the prevalence of dental malpractice, burnout, and work engagement among

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dentists, explored the association between dental malpractice and burnout, and identified other possible risk factors. From May 2023 to May 2024, a study was conducted of 259 Saudi dentists working in public clinics in Jeddah. The dentists completed an anonymous online survey that included questions about their backgrounds, job characteristics, burnout levels, work engagement levels, and dental malpractice experiences. Stata 18 software was used to analyze the data. Of the 259 dentists, 27% were concerned about malpractice, and 20.8% had faced malpractice claims. The analysis showed that dentists who felt detached from their work and who had low community engagement were more likely to worry about malpractice. Dentists working in primary health care centers, those feeling emotionally exhausted, and those with low job satisfaction were more likely to have malpractice claims. This study provided detailed information about the work conditions and burnout levels of Saudi dentists and how these relate to malpractice. It also found that Saudi dentists often experience high levels of emotional exhaustion and lack of personal achievement. Various workplace factors have been linked to dental malpractice.

Introduction

Dentistry as an occupation is considered to possess many positive qualities; however, it can be a stressful profession that can lead to emotional and physical health issues [1]. Since burnout has emerged as a significant public health concern, neglecting the risk of burnout can adversely impact dentists, patients, and overall quality of work. Professional burnout is a psychological syndrome characterized by three types of feelings: emotional exhaustion (EE), depersonalization (DP), and a decreased sense of personal accomplishment (PA) [2]. On the other hand, work engagement is a positive, fulfilling, work-related state of mind characterized by vigor, dedication, and absorption in one's work [3]. Burnout and work engagement are two concepts that can influence a dentist's behavior, leading to positive or negative outcomes. The negative effects of burnout and work disengagement can lead to dental malpractice, a type of professional malpractice, along with medical and legal malpractices. Generally, dental malpractice refers to the professional negligence of a dentist or another dental professional resulting in harm to the patient. Negligence can occur because of failure to properly diagnose a condition, provide appropriate treatment, or obtain informed consent from the patient [4].

In the Kingdom of Saudi Arabia (KSA), researchers assessing the status of medical malpractice lawsuits found a rapid rise in the number of lawsuits involving dentists in Saudi Arabia [5, 6]. Moreover, a national study found that 29.2% of the cases were in Riyadh, followed by Jeddah at 14.9%; they had the highest number of malpractice lawsuit cases compared with other regions [7]. Regarding specialties, researchers found that prosthodontics (35%) and endodontics (31%) had the highest number of claims [5, 8]. However, litigation studies on malpractice have solely examined the prevalence of malpractice claims based on the common causes or reasons for lawsuits and compensations. These findings underscore the need to study and define the root causes of dental malpractice. A survey conducted in the USA found that 46.1% of the dentists were concerned that they may have made an error, and those with a high burnout risk proportion were significantly associated with self-reporting a perceived dental error within the previous 6 months when compared to those with a low burnout risk proportion [9]. Burnout among dental professionals is another significant concern in the health care sector. As previously mentioned, burnout comprises three types of feelings. The first is EE, which refers to emotional exhaustion and overextension caused by work. The second is DP, which involves an unfeeling and impersonal response toward those who receive one's service, care, treatment, or instructions. The final type is low PA, which refers to the feeling of incompetence and unsuccessful achievement in one's work with others [2]. A previous study reported that Saudi dentists experience higher levels of burnout than non-Saudi dentists ($p < 0.05$), and in terms of specialties, prosthodontics at 57.9% and endodontics at 37.7% showed more burnout than others [10], same specialties were had the most frequent malpractice cases in Riyadh [5, 8]. A recent systematic review reported that the prevalence of burnout among dentists was 13%, with the EE subscale showing high burnout levels [11]. Previously, similar findings showed that dentists exhibited high scores in the EE subscale [12]. Researchers have identified six key areas that contribute to employee' well-being when studying workplace burnout and job stress. These areas, known as the Six Areas of Worklife, form a framework that includes workload, control, reward, community, fairness, and values. Workload refers to the amount of work performed at a given time. Control represents an opportunity to make decisions. Reward pertains to the recognition of contributions to the job. A community involves the quality of the workplace's social environment, support, and positive feelings. Fairness is related to the extent to which the workplace has equitable rules for everyone. Lastly, values come into play when workplace and personal values align and lead to shared success; mismatches occur when differences exist between a workplace's values and the values of its staff, or if the organization does not practice its stated values [2]. In a previous study, burnout and work engagement were negatively correlated ($\chi^2 = 22.51$, $p < 0.0001$) [13]. Additionally, work engagement does not affect the error rate [9]. Examining the work engagement of Indonesian dentists, it was discovered that they experienced high levels of workload and moderate levels of work engagement in the five other areas [14]. A local qualitative study identified several workplace challenges, including supervisors' attitudes, a lack of equitable rewards, handling a large number of patients, and limited advancement and leadership opportunities. The study also highlighted that engaged employees feel capable of managing job demands [15].

Although some studies have been conducted to determine how common malpractice and burnout are among dentists in KSA, the currently available literature is insufficient to establish causal relationships between dental malpractice, burnout, and work engagement. Our understanding of the causes and consequences of dental malpractice remains limited. This study aimed to estimate the prevalence of dental malpractice, evaluate the association between burnout, work engagement, and dental malpractice, and identify other risk factors associated with dental malpractice among Saudi dentists.

Methods

This cross-sectional study was conducted in public dental clinics between May 2023 and May 2024. This study was conducted at various dental facilities to provide a comprehensive view of the dental practice environment. These facilities include dental clinics in primary health care centers (PHCs), dental departments of hospitals, and specialized dental centers. The target population for this study included Saudi male and female dentists across all dental specialties in public clinics. The sample size was calculated using STATA 18 software at a 95% confidence level and a test power 0.95. The minimum required sample size was 213. We increased this by 20%–256 to account for nonrespondents. The study tool used was an online, self-administered English questionnaire divided into four sections to gather relevant data from participants comprehensively. The first section consisted of 14 items: gender, age, marital status, number of children, dentist qualification, dental specialties, current workplace, years of experience in the current workplace, years of experience in their position, the number of work sessions and patients, work shift, work system, and medical malpractice insurance.

The second section was the Maslach Burnout Inventory Human Services Survey for Medical Personnel (MBI-HSS [MP]), which was designed to measure personal feelings and attitudes towards work. It comprises 22 items categorized into three dimensions: EE (9 items), DP (5 items), and PA (8 items). Respondents indicated how often they experienced each feeling using a frequency scale ranging from 0 (never) to 6 (every day).

The third section was the Areas of the Worklife Survey (AWS) used to investigate work engagement levels. It consists of 28 items divided into six dimensions: workload (5 items), control (4 items), rewards (4 items), community (5 items), fairness (6 items), and values (4 items). Each item is rated on a 5-point Likert-type scale to represent the degree of match between a dentist and their work environment. The ratings ranged from 1 (strongly disagree) to 3 (hard to decide) to 5 (strongly agree). Due to copyright restrictions by Mind Garden, a provider of psychological assessment tools, no items from the MBI and AWS instruments may be included in any publication. Permission was obtained to administer these tools via an online survey using a platform other than Mind Garden.

The fourth section included five previously validated, self-reported dental malpractice questions with yes/no responses [9]. In this study, dental malpractice was examined as a dependent variable, defined by two aspects: dental malpractice concerns and dental malpractice claims. Dental malpractice concerns occur when a dentist worries about making errors, committing acts that could be considered professional misconduct, or receiving feedback from the staff about potential errors. It includes the following three questions: "Are you concerned you have made an error in the last 6 months?', "In the past year, have you been concerned a malpractice complaint might be brought against you?", and "Have any dental assistants or staff informed you that you may have committed an error in the last 6 months?'. Dental malpractice claims were defined as formal complaints by a patient that a dentist's negligence, error, or omission caused harm. Such claims often lead to investigations and may result in legal action or compensation. This aspect includes the following two questions: "In the past year, have you actively been involved in a malpractice claim against you or your practice?', and "In the past year, has a complaint been filed against you or your practice with the (937) service center?'.

The reliability of the current study depended on the MBI-HSS (MP) and AWS; both instruments are valid and reliable tools purchased from Mind Garden. MBI has been used in numerous studies involving Saudi dentists. However, because of limited use of the AWS among Saudi dentists, a pilot study was conducted to check its reliability by assessing Cronbach's alpha for each dimension to ensure its applicability in this cultural context. Cronbach's alpha value ranges from 0 to 1, with a higher value indicating a higher level of survey reliability. Generally, a Cronbach's alpha of ≥0.7 is acceptable for most research purposes.

A sample of 22 dentists working in public dental clinics in Jeddah were invited to participate in the pilot study and were not included in the main study. The calculation was 10% of the main study's sample size calculated at $213 \times 0.10 = 21.3$. Therefore, approximately 22 participants were required the pilot study. The results revealed that the AWS has an acceptable level of reliability. The Cronbach's alpha for the AWS dimensions ranged from 0.702 to 0.882. These results indicate that the AWS can be reliably used for data collection in the current study (online suppl. Table 1; for all online suppl. material, see https://doi.org/10.1159/000541263).

For the current study, data were collected using non-probability/convenience sampling. The study settings were selected based on the density of dentists' numbers and the variety of their qualifications and specialties. Dentists were invited to participate in the survey through their official email addresses, sent by the Internal Communication Department. Additionally, five volunteers working in the dental field used WhatsApp and QR code scanning to collect data from the dentists. The recruitment of dentists was based on their accessibility and availability to the five volunteers. The Research and Studies Department of King Abdullah Medical Complex selected the volunteers from the official Health Volunteering Platform for a volunteering opportunity listed under "Data Collectors of the Research and Studies Department of King Abdullah Medical Complex."

Statistical analyses were performed using STATA 18. In the descriptive analysis, we used frequencies and percentages for categorical variables. The χ^2 test was used to determine the relationship between dental malpractice and categorical variables, and multivariate logistic regression was used to identify the independent predictors of dental malpractice. The statistical significance level was set at $p \leq 0.05$.

Table 1. Distribution of sociodemographic characteristics among dentists (n = 259)

Sociodemographic characteristics	*n*	%
Gender		
Female	183	70.7
Male	76	29.3
Age		
≤30 years	62	23.9
31–39 years	101	39.0
40–49 years	66	25.5
50–59 years	30	11.6
Marital status		
Single	81	31.3
Married	158	61.0
Divorced	20	7.7
Number of children		
None	103	39.8
One child	20	7.7
Two children	53	20.5
Three children	42	16.2
Four children	27	10.4
Five children or more	14	5.4

Results

This study included 259 Saudi dentists, mostly females (70.7%). The age distribution showed that 39.0% were between 31 and 39 years old, and 25.5% were between 40 and 49 years old. Most participants were married (61.0%). Additionally, 39.8% reported having no children, 20.5% had two children, and 16.2% had three children. Based on the occupational characteristics distribution, the results revealed that most participants were general dentists (43.6%), with consultants accounting for 26.3%. Regarding dental specialties, 38.6% identified as general dentists, while the rest represented nine different dental specialties. The most common workplace setting was specialized dental centers (47.1%), followed by hospitals (33.2%). The participants had varied levels of experience in their current workplaces and positions. According to work environment characteristics, 32.4% of participants work 5–6 sessions per week, while 24.7% work 9–10 sessions. Regarding daily patients, 31.3% manage 5–6 patients, and 32.1% deal with more than eight patients. Most participants (62.6%) worked in the morning shift. In relation to employment status, 70.3% were civil service employees, and 29.7% were self-employed. Regarding medical malpractice insurance, 80.3% had coverage, whereas 19.7% did not have it (Tables 1–2).

Table 2. Distribution of occupational and work environment characteristics among dentists (*n* = 259)

Occupational and work environment characteristics	*n*	%
Qualification		
General dentist	113	43.6
Consultant	68	26.3
Specialist	46	17.8
Postgraduate training program	32	12.4
Specialty		
General dentist	100	38.6
Pedodontist	41	15.8
Restorative dentistry	26	10.0
Endodontist	24	9.3
Orthodontist	22	8.5
Prosthodontist	17	6.6
Periodontist	12	4.6
Family dentistry	10	3.9
Oral and maxillofacial surgeon	6	2.3
Dental public health	1	0.4
Current workplace		
Specialized dental center	122	47.1
Hospital	86	33.2
Primary health care center	51	19.7
Years of experience in the current workplace		
<A year	38	14.7
1–2 years	49	18.9
3–5 years	45	17.4
6–10 years	37	14.3
11–15 years	46	17.8
16–20 years	19	7.3
>20 years	25	9.7
Years of experience in the present position		
<A year	39	15.1
1–2 years	61	23.6
3–5 years	52	20.1
6–10 years	45	17.4
11–15 years	39	15.1
16–20 years	10	3.9
>20 years	13	5.0
Number of sessions per week		
2–4 Sessions	61	23.6
5–6 Sessions	84	32.4
7–8 Sessions	50	19.3
9–10 Sessions	64	24.7
Number of patients seen per day		
Less than 5 patients	46	17.8
5–6 patients	81	31.3
7–8 patients	49	18.9
More than 8 patients	83	32.1
Work shift		
Morning shift	162	62.6
Rotating	80	30.9
Night shift	17	6.6
Work system		
Civil service employee	182	70.3
Self-employment	77	29.7

Table 2 (continued)

Occupational and work environment characteristics	*n*	%
Medical malpractice insurance		
Yes	208	80.3
No	51	19.7

Table 3. Distribution of burnout and work engagement levels among dentists (*n* = 259)

MBI dimensions	MBI cutoff point[a]	*n*	%
EE			
Low	0–16	82	31.7
Moderate	17–26	48	18.5
High	≥27	129	49.8
DP			
Low	0–6	158	61.0
Moderate	7–12	49	18.9
High	≥13	52	20.1
PA			
Low	≥39	118	45.6
Moderate	32–38	56	21.6
High	0–31	85	32.8
Areas of work life dimensions	**AWS cutoff point[b]**		
Workload			
Low	2.40	41	15.8
Moderate	3.00	158	61.0
High	3.50	60	23.2
Control			
Low	2.67	42	16.2
Moderate	3.33	136	52.5
High	4.00	81	31.3
Reward			
Low	2.67	65	25.1
Moderate	3.25	111	42.9
High	3.75	83	32.0
Community			
Low	2.75	25	9.7
Moderate	3.40	128	49.4
High	3.80	106	40.9
Fairness			
Low	2.25	37	14.3
Moderate	2.83	147	56.8
High	3.25	75	29.0
Values			
Low	2.67	56	21.6
Moderate	3.25	117	45.2
High	3.75	86	33.2

[a]Source: [16]. [b]Source: [16].

Table 3 shows that 49.8% of participants experienced high EE, 61.0% showed low levels of DP, and 45.6% demonstrated low levels of PA. According to work engagement, the results showed that most study participants reported a moderate level in all six areas; more detailed information is provided in Table 3. Based on self-reported dental malpractice survey responses, the findings revealed that 20.1% expressed concerns about making an error in the last 6 months, 11.6% of participants indicated concern about the possibility of facing a malpractice complaint in the past year, and 6.6% acknowledged being informed by assistants or staff that they may have committed an error in the last 6 months. On the other hand, 19.3% of participants reported having a complaint filed against them in the past year by 937 service centers, and 4.6% reported direct involvement in a malpractice claim in the past year. Moreover, the results revealed that 27.0% of the participants expressed concerns about potential malpractice incidents, while 20.8% reported being involved in actual malpractice claims (online suppl. Table 2).

The results of Pearson's χ^2 tests indicated no significant association between dentists' malpractice concerns or malpractice claims and their sociodemographic characteristics (p value >0.05). However, a significant association was found between dentists' current workplace and malpractice concerns ($p = 0.040$). Additionally, there was a significant relationship between dentists' specialty ($p = 0.006$), current workplace ($p < 0.001$), and malpractice claims. No association was found between work environment characteristics and malpractice concerns, but a significant link was identified between malpractice claims and the number of patients treated daily ($p = 0.017$).

Regarding the association between burnout and dental malpractice, Table 4 shows a significant association between malpractice concerns with DP ($p = 0.006$) and PA ($p = 0.015$). Moreover, the results revealed a significant relationship between malpractice claims and both EE ($p = 0.004$) and DP ($p = 0.003$). Regarding work engagement, workload ($p = 0.023$) and community ($p = 0.001$) were associated with malpractice concerns. Furthermore, there were significant associations between malpractice claims

Table 4. Association between dental malpractice and burnout levels among dentists (n = 259)

MBI dimensions	Yes		No		χ^2	*p* value
	n	%	*n*	%		
Dental malpractice concerns						
EE						
Low	18	22.0	64	78.0	2.962	0.227
Moderate	11	22.9	37	77.1		
High	41	31.8	88	68.2		
DP						
Low	34	21.5	124	78.5	10.240	0.006*
Moderate	13	26.5	36	73.5		
High	23	44.2	29	55.8		
PA						
Low	22	18.6	96	81.4	8.363	0.015*
Moderate	17	30.4	39	69.6		
High	31	36.5	54	63.5		
Dental malpractice claims						
EE						
Low	8	9.8	74	90.2	11.039	0.004*
Moderate	9	18.8	39	81.3		
High	37	28.7	92	71.3		
DP						
Low	23	14.6	135	85.4	11.941	0.003*
Moderate	12	24.5	37	75.5		
High	19	36.5	33	63.5		
PA						
Low	26	22.0	92	78.0	0.992	0.609
Moderate	9	16.1	47	83.9		
High	19	22.4	66	77.6		

MBI, Maslach Burnout Inventory. *$p < 0.05$.

Table 5. Multiple logistic regression models for possible predictors of dental malpractice among dentists (N = 259)

Independent predictors	OR	CI	*p* value
Dental malpractice concerns			
DP level			
Low		Reference	
Moderate	1.35	0.62–2.93	0.437
High	2.44	1.21–4.90	0.012
Community level			
Low		Reference	
Moderate	0.31	0.14–0.66	0.002
High	0.34	0.14–0.78	0.011
Dental malpractice claims			
Current workplace			
Primary health care		Reference	
Hospital	0.52	0.23–1.16	0.112
Specialized dental center	0.21	0.09–0.49	<0.001
EE level			
Low		Reference	
Moderate	2.02	0.70–5.84	0.190
High	2.58	1.08–6.18	0.033
Value level			
Low		Reference	
Moderate	0.49	0.23–1.06	0.071
High	0.33	0.13–0.82	0.017

OR, Adjusted Odd Ratio (stepwise technique); CI, 95% Confidence Interval.

and the control, reward, community, and value dimensions, with *p* values ranging from <0.001 to 0.010 (online suppl. Tables 3, 4).

Table 5 shows that the multivariable logistic regression model was performed using the stepwise technique. Variables that showed significant associations with malpractice concerns were included in the model. The final model retained DP levels and community levels. The results indicated that Saudi dentists with high levels of DP (OR = 2.44, 95% CI = [1.21–4.90]) are more likely to have malpractice concerns compared to those with low levels of DP. Additionally, dentists with a high community level (OR = 0.34, 95% CI = [0.14–0.78]) are less likely to have malpractice concerns than those with a low community level. Whereas the multivariable logistic regression model for the independent predictors of malpractice claims revealed that dentists working in specialized dental centers (OR = 0.12, 95% CI = [0.09–0.49]) are less likely to have a malpractice claim compared to dentists working in PHCs. Furthermore, dentists with a high level of EE (OR = 2.58, 95% CI = [1.08–6.18]) are more likely to have a malpractice claim compared to their counterparts with a low level of EE. Regarding the value predictor, it shows that dentists with high levels of value (OR = 0.33, 95% CI = [0.13–0.82]) are less likely to have dental malpractice claims compared to those with a low level of value.

Discussion

This study examined the prevalence of dental malpractice among Saudi dentists and its association with different factors such as sociodemographic characteristics, occupational factors, work environment, burnout, and work engagement. In this study, dental malpractice was evaluated through a self-reported survey of participants, which consisted of five questions. A good indication of participants' dental practice was reported, where most dentists (more than 70%) did not report any malpractice concerns or malpractice claims in the last year. However, a growing number of dental malpractice lawsuits in the KSA have been identified [5–7], prompting the need for action to tackle this issue. In addition, several dentists with a track record of malpractice altered their conduct toward patients; this shift in behavior was most frequent among dentists who had faced prior lawsuits; furthermore, the Saudi Ministry of Health has made reporting medical errors and malpractices easier by providing 24/7 availability for patients to submit their claims through phone calls, emails, and social media comments [17]. Since 2010, there has been an increase in both the frequency and payment amount of malpractice claims filed against dentists in the USA. Franklin et al. [18] determined that dentists should evaluate their own skills in providing treatment and handling any issues that may arise to reduce the chances of facing a malpractice claim.

To achieve the main goal of this study, the relationships between dental malpractice and different variables, namely, sociodemographic, occupational, work environment, professional burnout, and work engagement, were evaluated. A previous study revealed that most plaintiffs were female (62.6%), with most belonging to the age range of 30–49 years [8]. Compared to the current study, males accounted for 22.4%, and the age group of 31–39 made up 24.8% of the malpractice claims. However, no association was found between dental malpractice and the sociodemographic characteristics.

As an occupational component, the workplace was associated with dental malpractice concerns, whereas the workplace and specialty were associated with malpractice claims. Dentists with the most malpractice concerns work in PHCs. In addition, it was revealed that general dentists and dentists working in PHCs were participants with the most malpractice claims. However, Aldahmashi et al. [17] discovered that dentists in public clinics better understand dental regulations than those in private clinics. Few studies have examined occupational characteristics related to dental malpractice; therefore, comparing these findings is impossible.

The association between dental malpractice and work environment characteristics showed that the number of daily patients significantly affected dental malpractice claims. This is logical as an increase in the number of patients and the diversity of their treatment conditions increases the likelihood of medical errors. Technical negligence has contributed to an increasing number of malpractice complaints in medical services. When dentists fail to fulfill their duty, it can lead to injuries due to improper use of dental equipment or inadequate sterilization of dental instruments [19].

Our findings showed a dependency of dental malpractice concerns on two dimensions of professional burnout DP and PA, while dental malpractice claims were associated with the EE and DP dimensions. Yansane et al. [9] discovered that American dentists at high risk of burnout were more inclined to express concerns about potential errors in the past 6 months. Furthermore, Chinese doctors also mentioned experiencing heavy workloads, high burnout rates, and a high frequency of medical errors [20]. Burnout adversely affects organizations, clinics, and businesses by decreasing the quality of patient care, increasing rates of workplace absence, errors in clinical practice, and financial setbacks [2]. Additionally, a study indicated that burnout in health care workers is linked to job turnover, absenteeism, low morale, personal dysfunction, and medical errors [21]. However, all studies show that burnout syndrome affects individuals and leads to negative consequences such as decreased patient care, medical mistakes, lower quality of care, increased staff absences, and financial losses for the organization [22].

The current study found that dental malpractice was associated with work engagement levels, with malpractice concerns correlating with workload and community levels. In contrast, malpractice claims were associated with the control, community, value, and reward levels of surveyed dentists. However, none of the work engagement subscales showed significant associations with perceived dental errors among US dentists [9]. Recent research has shown that being highly engaged at work is linked to a lower likelihood of being concerned about making significant medical errors. Work engagement has also been suggested to lead to improved job performance and occupational functioning, ultimately contributing to a better quality of care. Patient safety is crucial for ensuring quality care, and reducing medical errors is the key to promoting patient safety [23]. Furthermore, a study investigated how medical staff engagement is connected to patient safety results and found a strong, consistent correlation between staff engagement levels, safety culture ratings, and error occurrences [24].

The predictors of dental malpractice concerns among the surveyed dentists were the level of DP and the community. In contrast, EE, current workplace, and value levels independently predicted dental malpractice claims. The research conducted by Wright et al. [25] demonstrated that most errors in dentistry stem from human factors rather than a lack of technical skills or knowledge. Human factors in health care focus on enhancing patient safety by improving the design of technologies, processes, and work systems to promote efficiency, safety, and effectiveness. This involves adopting standardization, identifying, and eliminating errors. In Saudi Arabia, a study identified the primary reasons for dental malpractice lawsuits linked to human errors, such as inadequate procedure execution, absence of treatment plans, and inadequate documentation [4].

In conclusion, the participants exhibited a relatively high level of burnout which directly affected their concerns regarding dental malpractice and claims. Furthermore, the study found that perceived dental malpractice could be associated with other variables, such as workplace, specialty, number of daily patients, workload, community, control, value, and reward conditions at work. Additionally, this research identified potential predictors of dental malpractice among Saudi dentists, including DP, EE, current workplace, community, and value levels. Based on these findings, we recommend performing qualitative research, especially for dentists involved in malpractice claims. This approach could provide valuable, in-depth insights into various potential risk factors contributing to malpractice incidents among dentists. In addition, we suggest conducting longitudinal studies to establish causal relationships and track changes over time.

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Statement of Ethics

The study was approved by the Institutional Review Board of Jeddah Health Affair (IRB Log No. A01626). The questionnaire included an introductory letter to dentists. The letter explained that they consented to participate in the research by completing the online questionnaire. It also emphasizes that participation is voluntary and anonymous. Additionally, the letter assures that all data collected will be kept confidential and used only for scientific research purposes.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

R.T.H. developed the research idea, designed the methodology, conducted the statistical data analysis, interpreted the findings, and drafted the manuscript. This study was performed under the supervision and review of I.K.R. and Z.S.N. They provided guidance and oversight throughout all the stages of the research process and manuscript preparation. This study is a requirement for a Master's degree in Epidemiology and Biostatistics, Public Health.

Data Availability Statement

Some data from this study are not publicly available due to copyright restrictions associated with the tools used, specifically the Maslach Burnout Inventory and Areas of Worklife Survey, which were purchased from Mind Garden, a provider of psychological assessment tools. The data contain proprietary information that can compromise the copyright of these instruments. The data are available from the corresponding author, R.T.H., upon reasonable request. Interested researchers may contact R.T.H. at rthalawani@moh.gov.sa.

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Are We Close Enough? An Examination of the Innovative Virtual Wards' Care Delivery

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Keywords
Virtual ward · Telemedicine · Remote care · Patient monitoring · Telehealth

It has been years since the passing of my beloved grandmother, who was like a second mother and so special to me because I was named after her. Although the memories I have of her are sweet to my soul, I still remember the sad circumstances of her passing – uncontrolled diabetes, hypertension, and painful-to-see bed ulcers. She stayed at home with my inexperienced aunt by her side because of her stubbornness – refusing to leave her home for a healthcare facility surrounded by strangers. Nowadays, we have been witnessing the employment of advanced healthcare, in a way that means place, time, or distance no longer hinders receiving timely care. I cannot help thinking wishfully of what might have been different in the past, mixed with enthusiasm for the present and future of healthcare around the world.

"Hospital from home" is the approach where care is delivered to patients by their healthcare provider virtually in the convenience of their own homes, in so-called virtual wards. Virtual wards came as a catalyst for the continuous strain on healthcare and were derived from telemedicine. Telemedicine is described as the healthcare provision through information technologies and telecommunication systems [1]. In virtual wards, hospital-level care is delivered to patients in the community through telemedicine. The virtual wards approach consists of multidisciplinary care delivered at a level similar to the ward while the patient is at home [2]. "People want to be managed in their own homes, and the technology allowed that to happen safely," according to Dr. Tom Clark, Chief Medical Officer at the Dartford and Gravesham NHS Trust [3]. The virtual wards approach was developed to bring care to patients in comfort while improving efficiency and alleviating the burden of a busy healthcare system like the NHS in the UK. A patient will be monitored and receive care and treatment through various technological models, as are necessary and suitable for their needs. For a virtual ward to be enabled and functional for a patient, NHS England has recommended minimum technological requirements to be present in such models. This includes the patients' ability to monitor and input their health data and feeding data into a digital platform or dashboard, while the clinical team is in the background to monitor them and act as appropriate [4]. A team of multidisciplinary specialists follows the patient throughout their journey from the point of triage or assessment to care and treatment until discharge or follow-up [5]. This continuum of care (shown in Fig. 1) accompanies the patient through regular contacts and checks, to ensure they are cared for by proficient clinicians, in a method that is as close as

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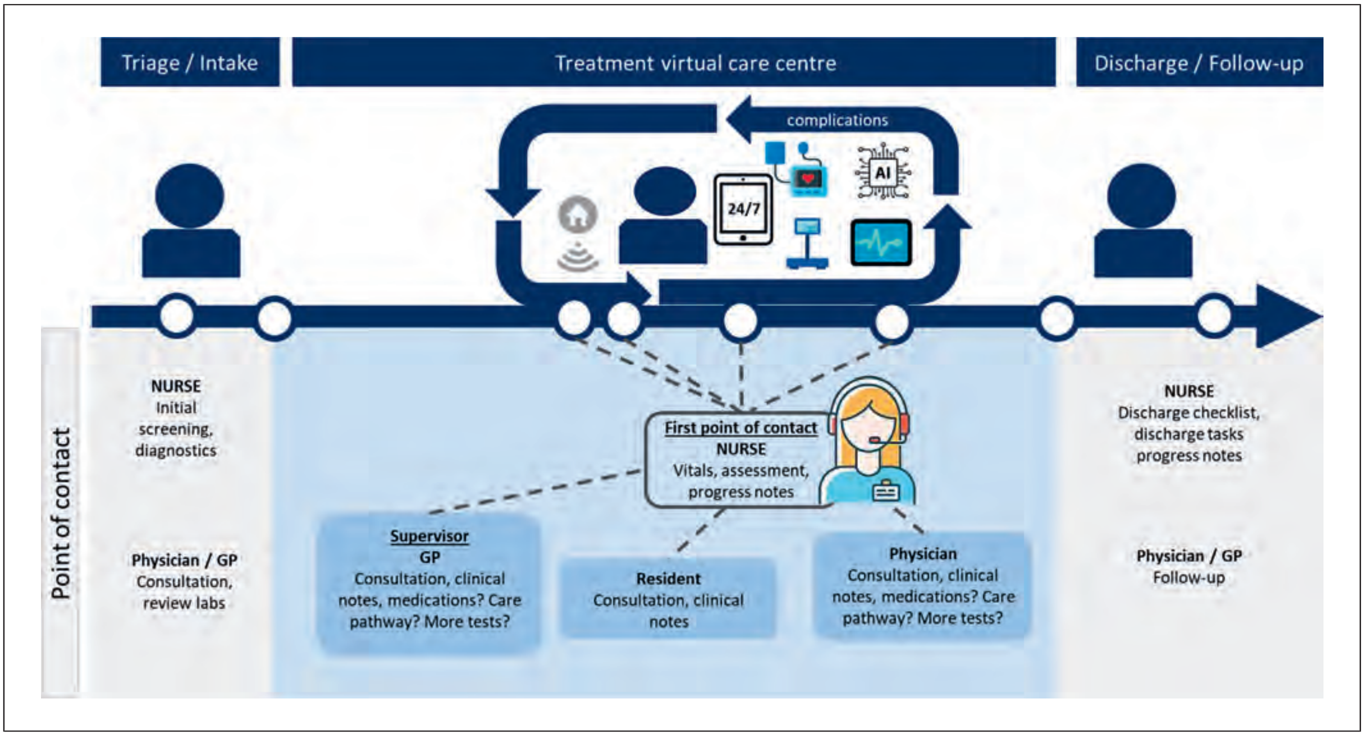

Fig. 1. Patients' journey in virtual care: a continuum of care [5].

possible to the hospital model of care, while being at home.

To date, virtual wards have been employed to care for those with frailty, respiratory infections, and heart failure cases [6]. These patients' state of being at home promotes their wellness and safe care as opposed to the acutely and critically ill who need hospital admission. Being cared for at home has a significant impact on efficiency and effectiveness, as cost, time, space, and other resources utilised during admission are minimised or avoided. In adopting this approach, efforts, and resources can be devoted to prioritising critical cases and unexpected emergencies.

The potential of adopting and implementing virtual care is receiving wide attention, due to several advantages: reducing the burden and efficiency in healthcare are the main driving forces. In addition, an increase in healthcare accessibility will serve patients of various geographical distributions or socioeconomic status. These include not only patients who prefer being at home or whose wellness relies on the comfort of their home but also disadvantaged individuals in rural or poor areas who cannot access a clinic or hospital. Thus, technology can provide care, regardless of time and place.

However, one cannot disregard the absence of the care provider's physical presence. Lack of face-to-face interaction plays a role in limiting the engagement between patients and their clinicians, which is a vital aspect in building trust and eventually achieving the desired outcome. We may be able to reach the furthest patient, yet are we close enough for the patient to be well and content?

Globally, virtual wards have been recognised for their potential to transform healthcare through innovative approaches. A recent report by the World Economic Forum has noted growing evidence of virtual care's efficacy and efficiency as a substitute for patients' visits to physicians and in reducing hospital admissions [7]. For instance, remote reach can be well employed for delivering care to disadvantaged areas around the world at times of unforeseen crisis. Conflict zones, areas massively affected by climate emergencies, quarantined regions in times of pandemics, as well as poor countries, are examples of where virtual care can fill the gap in service provision. The Food and Drug Administration (FDA) and Centres for Disease Control and Prevention (CDC) were major advocates of implementing telemedicine during the COVID-19 pandemic; they issued guidelines to ensure technology would prevent the spread of the disease and help manage patients at home [8]. In such times of pandemic or crisis, virtual care would enable accessibility to urgent healthcare. COVID-19 virtual care enabled this when presented in pre-hospital models (for patients referred by GPs, emergency departments, or hot hubs) and in post-hospital models for patients discharged from the hospital [9]. It is undeniable that virtual care in a global or humanitarian crisis can bring clinicians closer to the patient, by providing technology on-site when affected individuals are beyond the reach of basic healthcare.

A close examination of virtual care's implementation in the development journey of NHS hospitals provides a fine example of promising digital health delivery within a complex healthcare system. The Greater Manchester virtual ward project, launched in 2022, has gained positive feedback from both clinicians and patients. Regarding a patient receiving care via this project: "the patient, who would have been admitted to the hospital or regularly visit the GP, would much rather be at home with remote monitoring so that he could potter about in his garden. He was over the moon to be able to go home." [10]. In addition to patient comfort, privacy and autonomy were positive elements reported when the virtual ward example was rolled out in Cornwall [11]. As explained in the continuum of care, a patient in a virtual ward will be monitored regularly until their case improves and they are discharged. Surrounding patients with technology aims to connect individuals with their healthcare provider continuously and closely; however, the level of closeness we imagine is needed in an actual hospital setting may not be desired by a patient who seeks to return to their normal lifestyle.

The positive outcomes of virtual care have received attention, and it is to be expanded to other trusts through the 2025 NHS transition plan. This is expected to relieve part of the burden affecting the population's health on a national level, and at a global healthcare scale, as was seen in the burden created by the COVID-19 pandemic.

In the Middle East, countries such as Saudi Arabia and the UAE are considered ideal candidates for implementing virtual wards. The rise in chronic and lifestyle diseases demands more modern, timely, and continuous care strategies; therefore, virtual wards are an ideal and expected development in the region. In KSA, the employment of advanced medical technologies took a sophisticated turn in the Seha Virtual Hospital (SVH) [12] programme, which represents an exemplary project of Saudi Arabia's 2030 Vision. SVH plans to bring a variety of virtual services and multidisciplinary teams, including emergency and critical care, supportive medical services, and home care; as well as a comprehensive range of subspecialities, to collaboratively manage patients during their virtual journey. Advanced technologies will be fundamental in the hospital system: for instance, artificial intelligence for diagnostics and medical imaging, and augmented reality for transmission of surgeries and knowledge sharing. As the KSA Ministry of Health reported on SVH, "It will improve the quality of services provided and reduce the proportion of medical referrals between regions." The higher scale of virtual care initiated in KSA demonstrates that remote care is coming closer than ever to more patients' homes, regardless of place, time, and also their condition, in many cases.

In conclusion, current developmental trends in virtual care are showing numerous benefits, despite the long way to go for a deeper utilisation of technology. Admitting patients to virtual wards or hospitals will remain "virtual"; however, the distance between a patient and clinician is reasonable when considering the advantages of being at home, while they are regularly contacted and taken care of – whereas the clinical space can be utilised for the critically ill and emergency situations. Nonetheless, as humans are social creatures, human interaction is extremely important for healing, and this aspect cannot be fulfilled completely with dashboards and apps. Therefore, it is important to consider methods for improving the virtual ward care delivery and broaden its effectiveness. A wider range of specialities should be considered for virtual wards. In addition, supporting innovation, improving the implementation and choice of technological tools, and appropriate integration within the health system are required to expand the impact of virtual care. Further review and attention to these aspects would potentially improve the virtual ward experience; this would help achieve the overall aims of enhancing accessibility, increasing capacity – and most importantly, improving patient outcomes, while they enjoy the comfort of their own home.

Conflict of Interest Statement

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