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Nutrition in vulnerable groups

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Nutrition in vulnerable groups

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Editorial: Nutrition in vulnerable groups

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Editorial on the Research Topic
Nutrition in vulnerable groups

To maintain good health and prevent disease, essential and adequate nutrition is warranted, particularly among vulnerable people at different life stages. Uncertain physical, social, cultural, and economic situations limit access to nutrition and influence the health of those living in conditions of poverty, unemployment, lack of schooling, addiction, and ethnic minorities (1). Furthermore, individuals or families facing financial insecurity are restricted in their ability to acquire knowledge regarding proper nutrition (2). Struggling to adhere to healthy diets and often selecting cheaper and unhealthy options lead to excessive consumption of inappropriate supplements. Malnutrition affects individual health and productivity, inversely impacting a country's economic growth (3).

This Research Topic features the role of nutrition science in dietary behavior, food quality, and nutrients, not only in their associations with health outcomes but also for education, knowledge, and practice of vulnerable populations. It also published 14 articles, covering the most relevant topics in both developing and developed countries, and providing novel findings and recommendations on healthy nutrition practices.

First, Shreffler et al. reported in a cohort study of pregnant women with low-income mothers in a south-central US state that periconception food insecurity was positively associated with parenting stress at 2 months postpartum, suggesting that these negative impacts on parental wellbeing and parent-child relationship early in the infant's life. In a review of published data between 2011 and 2023, Assaf et al. demonstrated that exclusive breastfeeding was 24.4% in the Gaza Strip compared to a national rate of 39.9% in 2020 in Palestine. The authors appeal to governments for strategies that prioritize nutritional interventions to attain sustainable development goals. It should be noted that on the date of writing the editorial, the Israel and Palestine War was ongoing in Gaza, and homeless people were suffering from poor nutrition.

This Research Topic contains eight articles on children. Assaf et al. also reported that 7.3, 14.5, and 15.7% of schoolchildren in the West Bank of Palestine were underweight, overweight, and obese, respectively. Similarly, Vastrad et al. observed in a study of 2,700 school-age children in India that the prevalence of stunting and severe stunting was 19.5 and 7.6%, respectively, whereas Kalinda et al. observed rates of 19.2 and 12.2%, respectively, in 2,788 children under 5 years old in Rwanda. Both studies revealed that socio-demographic and environmental factors were significant determinants of childhood stunting. To manage 402 outpatients aged <5 years with severe acute malnutrition in East Ethiopia, Yadeta et al. reported a 0.7% death rate and an 89.6% cure rate, which remain

below the universal target for curing children. Enhanced health education packages and community engagement are necessitated to improve early recovery. Meanwhile, through dietary patterns identified in a survey of 510 adolescents, Gedamu et al. reported that 22.5% of overweight and 6% of obese adolescents were in East Ethiopia, highlighting that overnutrition is associated with dietary consumption patterns, eating behaviors, wealth status, literacy, and level of physical activity among adolescents. In a cross-sectional study of African American adolescents, Ardakani et al. confirmed that developing culture-based nutritional education programs is crucial among parents and youth.

Malnutrition continues to exist among adult ethnic groups and has increased in Thailand since 2014. Pechdin and Bunditsakulchai investigated the causes of malnutrition risk among 981 people with income insecurity using telephone-based survey data from the United Nations Food and Agriculture Organization. Among women aged 30–44 years, 11.5% did not have access to adequate nutrition. The authors propose the development of mid- and long-term programs and vocational training opportunities for enhancing employment and income stability. In a 3,491-household survey, Hernández-Vásquez et al. first reported that 39% of Venezuelan immigrant households in Peru experienced moderate-to-severe food insecurity, as established by the Food Insecurity Experience Scale. In a study of 497 prisoners in Ethiopia, Wondimu et al. reported that 20% were undernourished and that financial support, duration of imprisonment, dietary diversity, and depression were associated with undernourishment. The aforementioned study of Assaf et al. also indicated that 57.8% of overweight and 26.8% of obese adults were in Palestine, emphasizing the double burden of malnutrition associated with social determinants.

Furthermore, malnutrition among older adults is a highly prevalent condition; the incorporation of nutritional guidelines is inadequate, and low-value care is common (4). Cataracts are one of the leading causes of visual impairment and blindness in the elderly. Niazi et al. observed in a meta-analysis of 16 prospective cohort studies conducted in developed countries that every 5 kg/m^2 increase in body mass index was associated with a 6 and 27% increased risk of age-related cataracts and posterior subscapular cataracts in adults, respectively. Interestingly, Ma et al. observed from 10 waves of the Chinese Longitudinal Healthy Longevity Survey for 16,954 individuals aged 65 and above that drinking tea almost daily was protective against disability, shedding light on good nutritional practice.

The COVID-19 pandemic has significantly affected human society, exacerbating difficult life conditions among vulnerable groups and worsening their adherence to healthy lifestyles, food security, and choices. Dietary changes during COVID-19 have enhanced the burden of malnutrition, with children and older people in low-income households being the most affected, promoting infection, disease progression, and potential death (5). Approximately 30% of children and 60% of adults worldwide are vitamin D deficient and insufficient, respectively (6). Parra-Ortega et al. observed 171 Mexican patients, aged 9–14 years, with chronic kidney disease, decreased serum vitamin D levels, and increased deficiency frequency during the COVID-19 pandemic. Pechdin and Bunditsakulchai also studied that the increased level of malnutrition due to COVID-19 presents an imminent challenge to the government in addressing effective policies, strategies, and interventions. Mattei et al. conducted a double-blind randomized community-based pilot trial to assess the improvement in dietary quality and behaviors through the adaptation and implementation of the Latinos United for Cultural Health Alimentation. The recommendations obtained from this trial include that deep structural messages, in line with evidence-based behavioral theory, should be incorporated into nutrition programs. This study, which was conducted using an electronic technique for data collection during the COVID-19 period, warrants a specific introduction.

In summary, as featured in this Research Topic and available literature, malnutrition remains highly prevalent among vulnerable people. To reduce malnutrition and related health outcomes, increasing food security and accessibility for vulnerable people is essential in both developing and developed countries. Preparedness is of high priority, particularly during pandemics and social crises. The promotion and implementation of educational programs on healthy eating behaviors among children should be strengthened, and dietary quality among adults needs to be improved. Additionally, electronic techniques are recommended for research and promotion of healthy eating behaviors in communities. The suggestions for nutritional interventions and practice programs demonstrated in these articles are supportive.

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Socio-demographic and environmental determinants of under-5 stunting in Rwanda: Evidence from a multisectoral study

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Child stunting is an important household, socio-economic, environmental and nutritional stress indicator. Nationally, 33% of children under 5 in Rwanda are stunted necessitating the need to identify factors perpetuating stunting for targeted interventions. Our study assessed the individual and community-level determinants of under-5 stunting essential for designing appropriate policy and program responses for addressing stunting in Rwanda. A cross-sectional study was conducted between September 6 and October 9, 2022, in five districts of Rwanda including, Kicukiro, Ngoma, Burera, Nyabihu and Nyanza. 2788 children and their caregivers were enrolled in the study and data on the individual level (child, caregiver/household characteristics), and community-level variables were collected. A multilevel logistic regression model was used to determine the influence of individual and community-level factors on stunting. The prevalence of stunting was 31.4% (95% CI: 29.5–33.1). Of this, 12.2% were severely stunted while 19.2% were moderately stunted. In addition, male gender, age above 11 months, child disability, more than six people in the household, having two children below the age of five, a child having diarrhea 1–2 weeks before the study, eating from own plate when feeding, toilet sharing, and open defecation increased the odds of childhood stunting. The full model accounted for 20% of the total variation in the odds of stunting. Socio-demographic and environmental factors are significant determinants of childhood stunting in Rwanda. Interventions to address under-five stunting should be tailored toward addressing individual factors at household levels to improve the nutritional status and early development of children.

KEYWORDS

childhood stunting, multilevel analysis, undernutrition, under-five children, Rwanda

Introduction

Under-five malnutrition is an important sociodemographic, environmental, and healthcare utilization indicator which plays a critical role in influencing the development of healthcare programs and policies (1). A recent joint UNICEF/WHO/World Bank report showed that the global burden of under-five malnutrition remains high with about 149.2 million (22%) being stunted, 45.4 million (6.7%) wasted while 38.9 million (5.7%) are overweight (2). Significant efforts to re-delineate the global nutrition model and make nutrition pivotal in the development agenda have been made. However, regional and country-level disparities remain; with Asia and Africa carrying the heaviest burden, exacerbating the risks of failure to attain the universal right to healthy food as advocated for by the United Nations (3), World Health Assembly target of reducing stunting by 40% by 2025 and achieving the Sustainable Development Goals by 2030 (2, 4). Thus, addressing child malnutrition necessitates designing multidisciplinary and multisectoral approaches to steer the development of national policies aimed at refocusing countries on the elimination path.

In sub-Saharan Africa, the prevalence of stunting at the sub-region and country levels has remained persistently high with a threshold >30% for most of the countries (2, 5, 6). In Rwanda, emerging evidence suggests that one in every three children is stunted (7), with sub-regional disparities in its distribution also reported (8). Reducing the prevalence of under five stunting remains a priority in Rwanda. To achieve this, several programs and policies have been developed and implemented through a public-private partnership. Notable programs include the USAID/*Gikuriro Kuri Bose* (Inclusive Nutrition and Early Childhood Development) and *Isoko y'Ubuzima* (The Thrive WASH) and the health systems strengthening policies including the community-based health insurance plan (*Mutuelles de Santé*), incorporation of community health workers into the healthcare system and performance-based financing of health care facilities (9, 10). However, stunting persists, increasing the need to understand the factors perpetuating stunting to recast policy decision-making and design more specific actions to address it.

Given the limited availability of resources needed to address various health challenges in Rwanda, evidence of key drivers of stunting among under-five children remain critical in designing effective and sustainable programs for addressing stunting. Earlier studies determining the prevalence of stunting in Rwanda have used DHS data. Due to the high geographical level analysis used in these studies, there may have been potential masking of local level variations that may be vital in understanding the effect of both geographical locations, and socio-demographic and environmental factors influencing stunting. Using five model districts where the *Gikuriro Kuri Bose* project is being implemented, the current study examined individual (child's factors, maternal/household factors), and environmental factors associated with child stunting in Rwanda to provide nuance evidence for policymaking and program design to address child stunting in Rwanda.

Methods

Study design and setting

This was a cross-sectional study conducted between September 6 and October 9 2022, in five districts of Rwanda including, Kicukiro, Ngoma, Burera, Nyabihu, and Nyanza. *Gikuriro Kuri Bose* is a multisectoral and transdisciplinary project being implemented in five districts of Rwanda, each being drawn from one province. Rwanda has four geopolitical provinces and the City of Kigali. The provinces and the City of Kigali are further subdivided into 30 districts and districts subdivided into sectors (416 sectors in total) and sectors subdivided into cells (2,148 cells) and cells subdivided into villages (14,837 villages). Villages comprise about 100 households while cells constitute between five-seven villages. The study districts included Nyabihu from the western province, Burera from the northern province, Kicukiro from the city of Kigali, Nyanza in the south and Ngoma in the eastern province (Figure 1).

Data collection, sampling technique, and ethics

This study was based on 2,788 children and their mothers/legal guardians. To determine the sample size, the current prevalence of stunting (33%) (7) was considered as an indicator of the nutritional status. Using a 95% confidence interval and the equation proposed by Lwanga et al. (11) as $n = Z^2_{1-\frac{a}{2}}$ *(1-p)/* $\varepsilon^2 p$, where $p =$ prevalence, $\varepsilon =$ relative precision, and $n =$ sample size with a relative precision for the study to be between 5 and 10% of the true prevalence ($0.05 < \varepsilon < 0.10$), a sample size of 713–2,854 pairs of mothers/guardians and children as adequate. From each household, children under five and their legal guardians were selected for inclusion in the study. In this study, the sampling unit was a cell. To obtain a representative sample, the study used a two-stage probabilistic sampling method. The first stage involved the random selection of cells from the sector and the second stage involved a systematic sampling of households from the selected cells.

Approval to conduct the study was granted by the University of Global Health Equity Institutional Review Board (UGHE-IRB: Ref: UGHE-IRB/2022/034). Furthermore, legal guardians of children were asked for consent, and this was provided in writing.

Study variable

Dependent and independent variables

The dependent variable in this study was stunting, and this was a categorical binary variable (yes = 1 or no = 0). Stunting was defined as height for age *z*-score <-2 standard deviations using the WHO growth standards (12). Furthermore, using WHO classifications, children with height for age z-score of ≤-2 standard deviations and ≥-3 standard deviation were classified as moderately stunted while those with height for age

FIGURE 1
Map of Rwanda showing the administrative districts and project implementation areas.

z-score <-3 standard deviations were classified as severely stunted (13). There were three levels of the independent variables. These were categorized as individual (child and maternal/household) characteristics, community and environmental factors which included topography of the area, water, hygiene, and sanitation variables. To collect this information, a structured pre-tested questionnaire was administered to mothers/legal guardians of the children who had been included in the study. The questionnaire collected information on the child's age, sex, maternal/guardian's age, level of education, socio-economic class also called *Ubudehe,* breastfeeding and complementary feeding practices, hygiene and handwashing practices, household water availability and access, availability, and types of sanitary facilities, and socio-economic characteristics of the household. Additionally, information about the guardian and child's illnesses and disabilities (yes = 1 or no = 0) was collected. The classification of *Ubudehe* in Rwanda has been explained further in Supplementary material 1.

The weight of the children was measured using the SECA electronic scales to a precision of 0.1 kg while the height was taken to the nearest 0.1 cm using a UNICEF height/length board. To measure the height, children between the age of 24–59 months were made stand-upright without shoes and their height was taken using a stadiometer in a Frankfurt vertical position and to the nearest 0.1 cm. For children aged 0–23 months, their height/length was taken using a vertical measuring board while in a horizontal position. Before the measurements, it was ensured that the head, shoulders, and buttocks touched the board. To ascertain the validity of the anthropometry measurements, duplicate measurements were done for 10–15% of the sample and the variations for the duplicate measurements were below 5%. The age of the children was obtained from the *Ifishi Y'Ubuzima Bw'umwana* (vaccination card). The study included children aged between 0 and 59 months who were attending routine hospital outpatient visitations. Furthermore, the study included those without medical complications and those

whose legal guardians consented to participate and signed the consent forms. All children in this age category but not fulfilling the inclusion criteria were excluded from the study.

To enhance the precision of the measurements, the SECA weighing scales were calibrated daily before the commencement of data collection. All data collectors were trained in the taking of child anthropometric measurements and administration of the face-to-face questionnaire interviews before data collection. Community health workers who were part of the data collection teams assisted with the taking of anthropometric measurements on all children. For children who could not be weighed on the SECA scale, the weight of the mother/legal guardian was initially taken. Thereafter, the weight of the mother/legal guardian while holding the child was taken. The difference between the two weights was taken as the weight of the child.

Data analysis

Descriptive analysis was used to summarize continuous and categorical variables, showing their distribution with the outcome variable. The *Z*-score value for height-for-age was calculated using the ANTHRO PLUS software (14). In the bivariate and multivariate analysis, the response variable, stunting, was turned into a binary variable thus allowing us to logistic models. To determine the relationship between the various individual, community and environmental factors, a bivariate analysis was used. A multivariate multilevel logistic regression was used to examine the individual, community and environmental factors associated with under-five stunting. The multilevel models were deemed suitable for the analysis because of the hierarchical structure of the data and its ability to allow for the determination of the residual components associated with each level of the hierarchy. Furthermore, the multilevel models also allow for the estimation of group-level variables while estimating the group effects.

Three models were fit in the overall analysis. The first model was a null model, and this included the response variable only without any predictor variable and this was done to estimate its variance. In the second model which was a fixed effects model, we controlled for individual-level variables, and this included the children's demographic characteristics, history of diarrhea, breastfeeding and complementary feeding practices and child morbidity. In this model, district and sector were added as random intercept terms. Maternal (legal guardian) variables included education level and feeding structure, age and morbidity and water, hygiene, and environmental variables such as sanitation practices were also included. District and place of residence were added as random effects. The final model included both individual and contextual level factors which were the place of residence and district. The results demonstrating measures of association have been presented as adjusted odds ratios (aOR) together with their corresponding 95% confidence intervals (CIs) and *p*-values. The intraclass correlation coefficient (ICC), median odds ratio (MOR) and proportional change in variance (PCV) were used as a measure of the random effect. The ICC, which shows the proportion of total variance in the outcome attributable to districts, sectors and cells was calculated as shown by Merlo et al. (15). MOR is the measure of heterogeneity, and the PVC is the measure of the total variation of stunting in the final model (models with individual and environmental variables) comparative to the null model and was determined as described elsewhere (16, 17). Data analysis was carried out using StataSE STATA version 17 (StataCorp, College Station, TX, USA).

Results

Individual (child/maternal/household) level characteristics of study participants

Table 1 shows the child and maternal/household characteristics. The mean age (±SD) of the children was 26.4 (±16.2) months. The majority (n = 1,541, 55.3%) were aged between 24 and 59 months while only 7.6% (n = 211) were aged 0–5 months. In terms of gender, 50.4% (n = 1,404) of children were female while 49.6% (n = 1,384) were males. About 23.6% (n = 659) of the children had suffered from diarrhea 1–2 weeks before the study and of these, diarrhea lasted for 1–7 days among 93.6% (n = 617). Child characteristics; Child gender (p = 0.003), children with disability (p = 0.018), child age (p < 0.001) and morbidity factors; suffering from diarrhea (p < 0.001) were observed to be associated with stunting (Table 1).

The median age (±IQR) of the guardians/mothers was 30 (±11) years. Most of the guardians (n = 1,607, 57.6%) had primary education. In terms of marital status, 44.7% (n = 1,246) were cohabiting while 38% (n = 1,060) were married. The median number of people in the households was 5 (±2) and most households (n = 2,258, 81%) had one child below the age of five. Furthermore, 1.7% (n = 48) of the guardians were living the disabilities and in terms of the *Ubudehe* category, 57.7% (n = 1,607) were in category 2. In addition, 47.9% (n = 1,336) exclusively breastfed their children and of these, 78.9% (n = 1,054) breastfed on the child's demand while 5.1% (n = 68) breastfed according to a schedule. Maternal and household characteristics such as the number of people living in a household (p = 0.001), number of under-five children in a household (p = 0.004), maternal level of education (p < 0.001), exclusive breastfeeding (p < 0.001), complementary feeding (p < 0.001), and frequency of complementary feeding (p < 0.001) were observed to be associated with stunting (Table 1).

About 52.4% (n = 1,461) had tap-pipped water as their main drinking water source while 2.2% (n = 65) relied on water tankers. Furthermore, most households (n = 1,690) did not treat their water. In terms of monthly water availability, 68.2% (n = 1,899) did not have adequate water while 31.8% (n = 889) had adequate water. In terms of sanitation, 57.8% (n = 1,610) used pit latrines with concrete floors while 2.9% (n = 80) used open defecation. In addition, 25.2% (n = 701) were sharing sanitation facilities with non-family members. For maternal handwashing practices, 50.1% (n = 1,397) reported to have been washing their hands before eating and 39.6% (n = 1,103) before eating and feeding the child. Source of main drinking water (p < 0.001), time taken to fetch water (p < 0.001), water treatment (p = 0.027) and type of facility used (p = 0.005) were associated with stunting (Table 2).

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TABLE 1 Prevalence of childhood stunting at various individual (child/maternal and household) level characteristics.

Variable	Normal (*n*, %)	Stunted (*n*, %)	*p*-value
Gender of child			
Male	914 (66%)	470 (34%)	0.003
Female	1,001 (71.3%)	403 (28.7%)	
Child disability			
No	1,898 (68.9%)	856 (31.1%)	0.018
Yes	17 (50%)	17 (50%)	
Child age category			
0–11 months	467 (83%)	26 (17%)	0.001
12–23 months	443 (64.7%)	242 (35.3%)	
24–47 months	756 (65.5%)	398 (34.5%)	
48–59 months	249 (64%)	138 (36%)	
Number of people in a family			
1–5	1,380 (71%)	574 (29%)	0.001
> 6	535 (64.2%)	299 (35.8%	
Gender of guardian			
Male	127 (63%)	75 (37%)	0.064
Female	1,788 (69%)	798 31%)	
Age category of guardian			
15–24 years	386 (71%)	157 (29%)	0.217
25–49 years	1,464 (68%)	678 (32%)	
50–78 years	65 (63%)	38 (37%)	
Employment status of guardian			
Farmers	1,151 (68%)	542 (32%)	0.38
Self employed	124 (73%)	46 (27%)	
Domestic worker	7 (63.6%)	4 (36.4%)	
Unemployed	402 (71%)	164 (29%)	
Others	231 (66%)	117 (34%)	
Socio-economic class (*Ubudehe* category)			
Category 1	183 (66%)	93 (34%)	0.157
Category 2	1,092 (68%)	515 (32%)	
Category 3	584 (70%)	250 (30%)	
No category/don't know	53 (79%)	14 (21%)	
Guardian marital status			
Never married	190 (69.6%)	83 (30.4%)	0.054
Married	758 (71.5%)	302 (28.5%)	
Formerly married	136 (65%)	73 (35%)	
Co-habiting	831 (66.7%)	415 (33.3%)	
Guardian education level			
None	376 (66%)	193 (34%)	0.001
Primary	1,073 (66.8%)	534 (33.2%)	
Secondary	437 (75.6%)	141 (24.4%)	
Tertiary	29 (85.3%)	5 (14.7%)	
Guardian living with disability			
No	1,887 (69%)	853 (31%)	0.119
Yes	28 (58%)	20 (42%)	
Exclusive breastfeeding			
No	948 (65%)	504 (35%)	0.001
Yes	967 (72%)	369 (28%)	
Child with diarrhea in the past 2 weeks			
No	1,500 (70.5%)	629 (29.5%)	0.001
Yes	415 (63%)	244 (37%)	
Guardian access breastfeeding information			
No	620 (66.5%)	312 (33.5%)	0.081
Yes	1,295 (69.8%)	561 (30.2%)	
Child given vitamin A			
No	538 (74.9%)	180 (25.1%)	0.001
Yes	1,377 (66.5%)	693 (33.5%)	
Child given multinutient powder			
No	1,574 (70%)	685 (30%)	0.02
Yes	341 (64.5%)	188 (35.5%)	
Who feeds the child (complementary feeding)			
Mother	1,657 (69.3%)	733 (30.7%)	0.154
Siblings	131 (63%)	77 (37%)	
Caretaker	105 (67%)	51 (33%)	
Schedule of child complementary feeding			
Childs demand	681 (73%)	258 (27%)	0.001
According to schedule	489 (71%)	199 (29%)	
Caretaker availability	55(73%)	20 (27%)	
Availability of food	690 (64%)	396 (36%)	
Child feeding from own or communal plates			
Communal plate	607 (70%)	261 (30%)	0.341
Own plate	1,308 (68%)	612 (32%)	
Maternal morbidity			
No	1421 (70%)	620 (30%)	0.078
Yes	494 (66%)	253 (34%)	

Figure 2A shows the prevalence of stunting in the five study sites. The prevalence of stunting was 31.4% (95% CI: 29.5–33.1). Of this, 12.2% were severely stunted while 19.2% were moderately stunted. Stunting was high in Nyabihu (37.8%) followed by Burera (34.1%) and was least in Kicukiro (23.8%) (Figure 2B).

TABLE 2 Prevalence of childhood stunting at various environmental and WASH characteristics.

Variable	Normal (*n*, %)	Stunted (*n*, %)	*p*-value
Parents hand washing practices			
Before eating	958 (69%)	439 (31%)	0.964**
Before eating and feeding the baby	763 (69%)	340 (31%)	
Before eating, feeding the baby and toilet use	12 (67%)	6 (33%)	
Before eating and after toilet use	21 (70%)	9 (30%)	
Before feeding the baby	75 (65%)	41 (35%)	
Before feeding the baby and after toilet use	3 (60%)	2 (40%)	
After toilet use	83 (70%)	36 (30%)	
Toilet sharing			
No	1,443 (69%)	644 (31%)	0.347
Yes	472 (67%)	229 (33%)	
Toilet facility available			
Pour flash	45 (80%)	11 (20%)	0.005
Pit latrine with slab	1,121 (70%)	489 (30%)	
Pit latrine no slab	706 (68%)	336 (32%)	
Open defecation	43 (54%)	37 (46%)	
Water availability			
No	1,322 (69%)	583 (31%)	0.191
Yes	595 (67%)	294 (33%)	
Time spent fetching			
0–30 min	1,499 (70%)	639 (30%)	0.010
31–60 min	338 (64%)	193 (36%)	
61–180 min	74 (65%)	40 (35%)	
Source of drinking water			
Tap water	1,051 (72%)	410(28%)	0.001
Borehole	583 (63%)	344 (37%)	
Water tanker	43(66%)	22(34%)	
River/lake/rainwater	238(71%)	97(29%)	
Topography/terrain of the area			
Highland	305 (64%)	171 (36%)	0.059
Flat terrain	1,162 (70%)	505 (30%)	
Low land	448 (69%)	197 (31%)	

**Fishers exact tested used.

Multilevel modeling

The results from the multilevel models show that individual and environmental level factors influenced stunting (Table 3). In the final multilevel model controlling for factors, individual-level factors, female children were about 76% (aOR: 0.76, 95% CI: 0.64–0.90) less likely to be stunted compared to male children. Furthermore, the odds of stunting increased with age; children aged 24–47 months were 3.6 (95% CI: 2.00–6.49) more likely to be stunted compared to those <6 months of age. Also, children who came from households where they were at least two children below the age of five (aOR: 1.29; 95% CI: 1.02–1.62) and those coming from families with more than six people (aOR: 1.35; 95% CI: 1.10–1.66) were more likely to be stunted than those from households with 1–5 people. In addition, children who reported having had diarrhea 2 weeks before the study (aOR: 1.32; 95% CI: 1.07–1.62) and those who fed themselves from their plates (aOR: 1.45; 95% CI: 1.19–1.78) were also more likely to be stunted (Table 3). Among the environmental factors, the use of tap water reduced the odds of stunting by 75% (95% CI: 0.59–0.94) while children from households that had no sanitation facilities (aOR: 3.35; 95% CI: 1.38–8.10) were more likely to be stunted than those who had flush pour toilets (Table 3). Among the contextual factors, children from Nyabihu (aOR: 1.95; 95% CI: 1.33–2.86) and Burera (aOR: 1.77; 95% CI: 1.16–2.71) were more likely to be stunted than those from Kicukiro.

On the measures of variation in the random effect, the results of the Akaike Information Criterion (AIC), Intraclass Correlation Coefficient (ICC), Median Odds Ratio (MOR), and proportional change in variance (PCV) suggest that the final model best fit the data. In the null model, ICC indicated that 4.4% of the variance in stunting was attributed to the community or contextual factors and this was reduced to 3.6% in the final model. In the final model, as shown by the PVC, 20% of the variance in the odds of stunting was accounted for by the model (Table 3).

Discussion

This study sought to understand the individual and environmental determinants of stunting in Rwanda using data collected from a cross-sectional study of five districts. The study has shown that both individual and community-level factors are critical in determining the linear growth of children. The fit model further showed that 20% of the variation in stunting was accounted for by individual-level factors, environmental-level factors, and contextual-level factors such as place of residence. Stunting increased with age, with children aged 24–59 months having the highest odds of stunting. This finding corroborates pooled results from East Africa (18), Rwanda (1, 19), Ethiopia (20), and Kenya (21) and elsewhere (22) which observed an increase in the risk of stunting with age before a subsequently reduced after the age of 48 months. The observed rise in the risk of stunting with age in our study as well as others may be due to reduced milk intake and weaning of children together with increased risks of infection because of increased exposure of children to unhygienic environments (18, 23).

Several earlier studies (1, 8, 24, 25) including ours have reported child gender as being an important determinant of stunting. Our results as well as those by Mzumara et al. (25), Binagwaho et al. (1), and Adekanmbi et al. (24) have shown that male children are more likely to be stunted as compared to female children. According to several authors, growth among male children is affected by

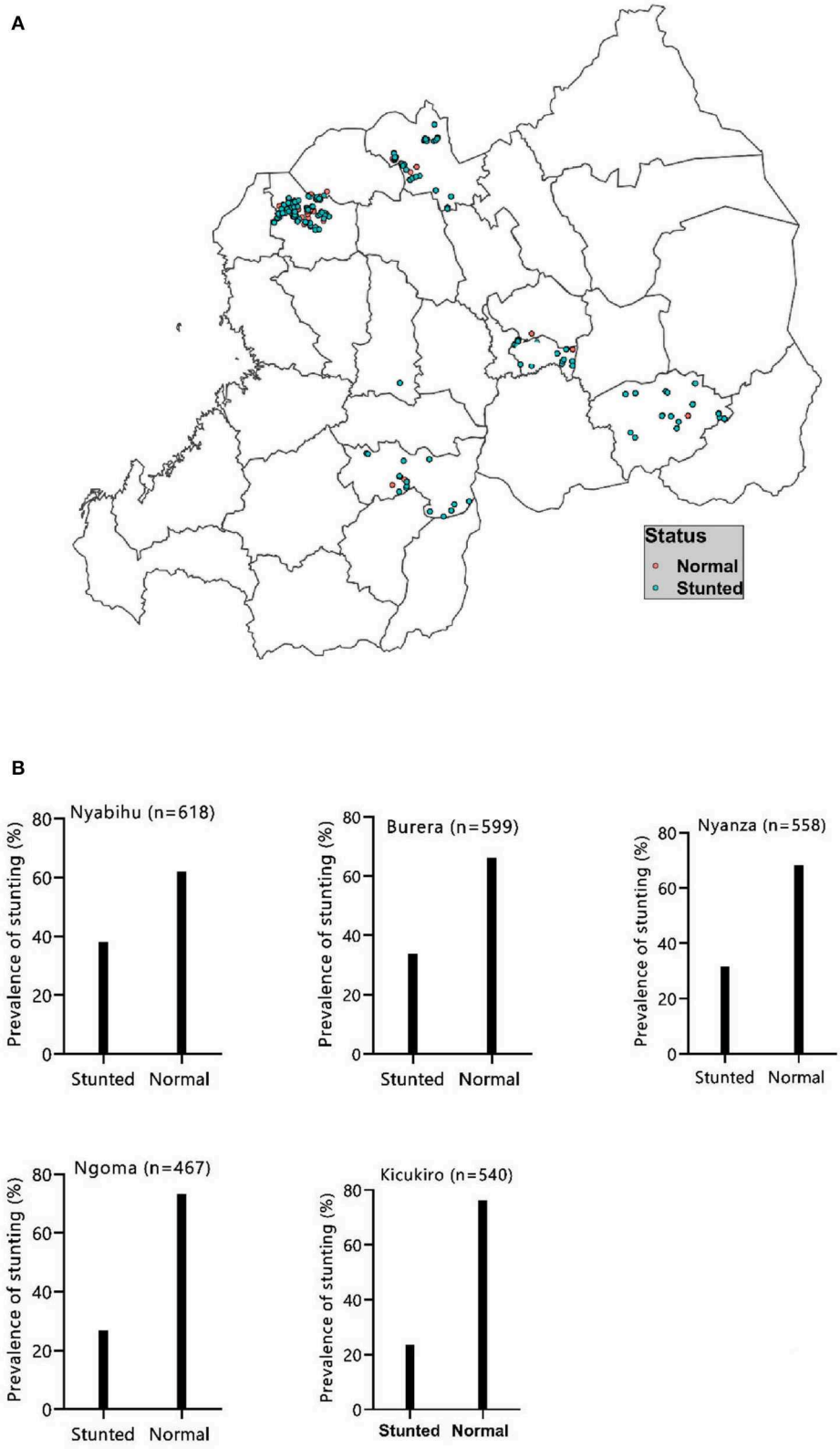

FIGURE 2
Distribution **(A)** and proportion **(B)** of childhood stunting in the study areas.

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TABLE 3 Factors associated with childhood stunting in a multilevel logistic regression.

Variables	Model 0	Model I aOR (95%CI)	Model II aOR (95%CI)	Model III aOR (95%CI)
INDIVIDUAL FACTORS				
Gender of child				
Male		**1**		**1**
Female		0.76** (0.64–0.90)		0.76** (0.64–0.90)
Age in months				
0–11		**1**		1
12–23		2.65*** (1.57–4.46)		2.77*** (1.64–4.67)
24–47		3.42*** (1.90–6.17)		3.60*** (2.00–6.49)
48–59		3.31*** (1.79–6.14)		3.51*** (1.89–6.50)
Child has disability				
No		**1**		**1**
Yes		2.07* (1.00–4.26)		2.06* (1.00–4.25)
Number of people in household				
1–5		**1**		1
>6		1.33** (1.09–1.64)		1.35** (1.10–1.66)
Number of children under 5 years				
One		**1**		1
Two		1.30* (1.03–1.64)		1.29* (1.02–1.62)
Three		1.81 (0.83–3.95)		1.89 (0.86–4.14)
Gender of legal guardian				
Male		**1**		**1**
Female		0.96 (0.68–1.37)		0.99 (0.70–1.41)
Age of legal guardian				
15–24		**1**		**1**
25–49		1.12 (0.88–1.44)		1.13 (0.88–1.45)
50–78		1.01 (0.58–1.78)		1.03 (0.58–1.80)
Employment status of guardian				
Farmers		**1**		**1**
Self employed		0.87 (0.58–1.29)		0.89 (0.59–1.33)
Domestic worker		1.37 (0.37–5.14)		1.41 (0.38–5.27)
Unemployed		0.92 (0.71–1.20)		0.94 (0.71–1.24)
Others		1.12 (0.84–1.49)		1.14 (0.85–1.53)
Socio-economic category				
Category 1		**1**		1
Category 2		1.07 (0.79–1.46)		1.07 (0.79–1.45)
Category 3		0.97 (0.79–1.35)		0.98 (0.71–1.36)
No category given/don't know		0.70 (0.79–1.40)		0.71 (0.35–1.42)
Guardian marital status				
Never married		**1**		1
Married		0.83 (0.59–1.17)		0.82 (0.58–1.16)

(Continued)

TABLE 3 (Continued)

Variables	Model 0	Model I aOR (95%CI)	Model II aOR (95%CI)	Model III aOR (95%CI)
Cohabiting		1.16 (0.79–1.61)		1.13 (0.81–1.57)
Formerly married		1.05 (0.79–1.65)		1.05 (0.67–1.65)
Guardian level of education				
None		**1**		1
Primary		1.17 (0.93–1.48)		1.17 (0.93–1.47)
Secondary		0.83 (0.61–1.12)		0.81 (0.60–1.09)
Tertiary		0.50 (0.18–1.46)		0.54 (0.19–1.52)
Guardian has disability				
No		**1**		**1**
Yes		1.27 (0.67–2.42)		1.24 (0.65–2.35)
Breastfeeding child				
No		**1**		1
Yes		0.86 (0.63–1.19)		0.87 (0.63–1.20)
Child had diarrhea in past 2 weeks				
No		**1**		**1**
Yes		1.32** (1.07–1.62)		1.32** (1.07–1.62)
Mother has access to breastfeeding information				
No		**1**		**1**
Yes		0.96 (0.79–1.16)		0.96 (0.79–1.16)
Child given Vitamin A at 6 months				
No		**1**		**1**
Yes		1.11 (0.87–1.42)		1.10 (0.86–1.41)
Use of multinutient powder				
No		**1**		**1**
Yes		1.16 (0.92–1.46)		1.13 (0.90–1.42)
Who feeds baby				
Siblings		**1**		**1**
Mother		0.91 (0.66–1.27)		0.93 (0.67–1.29)
Caretaker		0.98 (0.59–1.61)		1.00 (0.61–1.65)
When is baby given food				
Child's demand		**1**		**1**
Schedule		0.95 (0.75–1.22)		0.94 (0.74–1.20)
Caretaker availability		0.72 (0.41–1.28)		0.67 (0.38–1.19)
Availability of food		1.06 (0.85–1.34)		1.04 (0.82–1.30)
Eating plate used by				
Common plate		**1**		**1**
Own plate		1.45*** (1.18–1.78)		1.45*** (1.19–1.78)
Maternal illness recorded				
No		**1**		**1**

(Continued)

TABLE 3 (Continued)

Variables	Model 0	Model I aOR (95%CI)	Model II aOR (95%CI)	Model III aOR (95%CI)
Yes		1.09 (0.89–1.33)		1.09 (0.89–1.32)
Parents washing their hands				
Before eating		**1**		**1**
Before eating and before feeding child		0.99 (0.81–1.21)		0.97 (0.79–1.19)
Before feeding		1.41 (0.90–2.21)		1.43 (0.91–2.25)
Before feeding child and after toilet		1.29 (0.86–1.93)		1.31 (0.87–1.97)
Toilet sharing				
No		**1**		**1**
Yes		1.11*** (0.89–1.37)		1.05** (1.12–1.43)
Type of toilet used				
Pour flash		**1**		**1**
Latrines with slab		2.02 (0.96–4.22)		2.06 (0.98–4.32)
Latrines with no slab		1.99 (0.94–4.23)		2.05 (0.96–4.38)
Open defecation		3.40** (1.41–4.21)		3.35** (1.38–8.10)
Family had adequate water last month				
No		**1**		**1**
Yes		1.06 (0.87–1.29)		1.04 (0.85–1.27)
Water treatment method				
Nothing		**1**		**1**
Boiling		0.66** (0.48–0.90)		0.66* (0.49–0.91)
Add chemicals		0.84 (0.69–1.02)		0.83 (0.68–1.01)
Filter		1.99 (0.61–6.50)		2.20 (0.67–7.23)
Others		0.93 (2.44–3.57)		1.01 (0.26–3.87)
Time spent fetching water				
0–30 min		**1**		**1**
31–60 min		1.22 (0.97–1.53)		1.20 (0.95–1.52)
61–180 min		1.08 (0.69–1.69)		1.04 (0.66–1.62)
Main source of family drinking water				
Borehole		**1**		**1**
Water tank		0.91 (0.50–1.66)		0.93 (0.51–1.70)
Tap water		0.73** (0.58–0.94)		0.75* (0.59–0.94)
River/lake/rainwater		0.91 (0.41–2.01)		0.92 (0.41–2.02)
CONTEXTUAL LEVEL FACTORS				
Place of residence				
Flat terrain			**1**	**1**
Highland			0.99 (0.74–1.31)	0.90 (0.66–1.22)
low land			0.91 (0.71–1.15)	1.00 (0.77–1.29)
District				
Kicukiro			**1**	**1**
Burera			1.65** (1.13–2.40)	1.77** (1.16–2.71)

(Continued)

TABLE 3 (Continued)

Variables	Model 0	Model I aOR (95%CI)	Model II aOR (95%CI)	Model III aOR (95%CI)
Ngoma			1.15 (0.78–1.68)	1.19 (0.78–1.81)
Nyabihu			2.01*** (1.40–2.88)	1.95*** (1.33–2.86)
Nyanza			1.43 (0.98–2.07)	1.21 (0.79–1.84)
Random effects				
Variance (CI)	0.10 (0.04–0.28)	0.09 (0.03–0.28)	0.09 (0.03–0.27)	0.08 (0.03–0.28)
ICC (%)	4.4	3.7	4.0	3.6
PCV (%)	Ref	10.0	10.0	20.0
MOR	1.35	1.32	1.34	1.32
Model fitness				
Log-likelihood	−1,715.1	−1,707.7	−1,714.1	−1,598.8
AIC	3,436.1	3,311.9	3,440.2	3,310.6
N	2,788	2,788	2,788	2,788

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; 1 = reference category; Model 0 contains no explanatory variables; Model I included individual-level factors only; Model II included community-level factors only; Model III included both individual-level and community-level factors: aOR, adjusted odds ratio; CI, confidence internal; ICC, intraclass correlation coefficient; PVC, proportional variance change; AIC, akaike information criterion; BIC, Bayesian information criterion.
Measures of variations. The bold values are just reference values for the models.

repeated respiratory infections due to slower lung maturation (26), cultural norms due to the usefulness of women in agricultural activities (27) and potentially hormonal and genetic determinants (20). Elsewhere, the gender-based differences in stunting have been suggested even after controlling for gestational age and body size, increased risks of morbidity among male children predispose them to stunt (28) and a higher proportion of male preterm births as compared to female preterm births (29) thus increasing the likelihood of stunting among male children. The current study further observed that stunting was higher among households where the family size had more than six people, those with at least two children under the age of five and children who were fed from communal or family food portions. This may be due to the reduced quality of life for children (25); the likelihood of potential struggle for nutrition (30) due to families' inability to meet the dietary requirements and inadequate healthcare-related services for children and other family members.

Our study shows that children who reported diarrhea 2 weeks before the study, those from households with no toilets and those that shared toilets had higher odds of stunting. Furthermore, of the environmental factors studied, the results suggested that the lack of sanitary facilities increased the risks of stunting, an observation corroborated by others (31, 32). This association may be linked to open defecation resulting in fecal contamination of food and water, especially untreated water which fuels diarrheal illness and reduces the rate of attainment of developmental milestones among children. Furthermore, Crocker and Bartram (31) and Modern et al. (32) suggested that sharing toilets among different households increased the risk of diarrhea in children thus increasing their odds of stunting. Other studies focusing on sanitation and stunting among children concluded that poor water, hygiene, and sanitation facilities may lead to diarrhea and intestinal worm infections (33, 34) affecting the nutritional status of children. The finding from our study and those of other authors indicate the importance of sanitation in improving child growth. Furthermore, our results have shown a high prevalence of some health behaviors such as handwashing and sanitation-related such as use of toilets. Thus, there is need to build on these behaviors by focusing on increasing access to piped and treated water. Also, designing of sustainable water and sanitation-related activities and including various community engagement activities would be vital in strengthening the community's ability to manage water and sanitation facilities. Furthermore, enhancing community health education and exposure to health messages promoting hygiene practices would be critical in reducing the risks of diarrhea among children.

This study used the multilevel method of analysis to understand the effect of socio-demographics, environmental determinants, and community-level factors on stunting in Rwanda. By using this approach, it was made possible to understand how community-level factors such as place of residence influence stunting. The results from the study show that community-level factors can interact with individual-level factors to influence stunting among children. Earlier studies by Adekanmbi et al. (24) and Frohlich et al. (35) applied similar methods in understanding and differentiating the contributions of community and individual level factors on the variation in the outcome variable. The results of the current study demonstrate that both individual-level and community-level factors are associated with childhood stunting. Furthermore, community-level factors account for more variation in stunting above than individual-level factors. This, suggests that community-level factors have a significant influence on stunting and this observation was also made by Pickett and Pearl (36).

Reducing stunting and addressing other undernutrition indicators necessitates understanding and altering several

underlying factors. Although several programs and policies have been implemented, there is a need to address nutritional security in a broader context. For instance, the provision of food interventions without addressing individual and environmental factors such as maternal education and socio-economic and health wellbeing, household sanitation and clean water, and access to adequate and quality health services would only lead to short or medium terms achievements in stunting reduction. An earlier study suggested that various factors that influence stunting interact in a complex and diverse way (37). Thus, cross-disciplinary and multisectoral approaches are vital in addressing it. For instance, programs or interventions meant to address factors influencing stunting would need to involve expertise from nutritionists to deal with child and maternal nutrition and feeding practices, healthcare services to manage poor health conditions, environmentalists to help prevent and control environmental contamination that may cause illnesses, while health promotion would be added to provide continuous health education to the community members. The results from the current study suggest that addressing stunting in Rwanda requires addressing both individual and environmental factors. While the government provides the framework for addressing these factors, it's important to design programs that incorporate strategies that address the problem in the short and medium terms and build on the short and medium-term achievements to devise long-term strategies. In addition, designing programs that target groups at high risk such as children older than 11 months and children from larger families can maximize outcomes.

Strengths and limitations

Unlike previous studies done in Rwanda, this study used a multilevel analysis which made it possible to identify factors influencing stunting at both individual and environmental levels. Furthermore, the high response rate from the participants drawn from different districts in the five provinces ensured that most information was captured. On the other hand, our study had the limitation of being cross-sectional thus it may be difficult to ascertain the causal relationship.

Conclusion

Addressing and preventing childhood stunting is crucial in averting potential future health, cognitive and economic development of the country and nations at large. The finding from the current study shows that stunting is prevalent and remains a public health challenge in Rwanda. This study suggests the need to design cross-sectoral and transdisciplinary approaches to address stunting. Furthermore, sustainable approaches addressing child's health and nutrition in long term should target places with a high rate of stunting, high-risk groups such as children from large households and enhance maternal health education. The current study further suggests the need to conduct in-depth qualitative studies to explore and identify reasons for the high levels of stunting in parts of Rwanda, especially the Northern and North-western where the prevalence of stunting is higher than in other regions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by University of Global Health Equity Institutional Review Board (Ref: UGHE-IRB/2022/034). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

CK, RW, AG, and AB conceptualized the study. CK and MP conducted the statistical analysis. CK wrote the manuscript. MQ and MI were involved in conceptualizing the study and carried out data extraction. RW, AB, and AG sourced for funding and contributed toward editing the manuscript. All authors have read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1107300/full#supplementary-material

SUPPLEMENTARY MATERIAL 1
Classification of the socio-economic (*Ubudehe*) in Rwanda.

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Prevalence and socioeconomic determinants of food insecurity among Venezuelan migrant and refugee urban households in Peru

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Introduction: Food insecurity (FI) is a public health problem affecting many regions of the world. In Venezuela, the political, social and economic situation experienced since 2010 has caused a mass migration of its population to other countries, including Peru, which, in turn, may have limited access to and availability of food leading to a high nutritional burden in this population. The objective of this study was to determine the prevalence and analyze the determinants of FI in the households of Venezuelan immigrants in Peru.

Methods: A cross-sectional study was conducted using the "Encuesta Dirigida a la Población Venezolana que Reside en el País" (ENPOVE 2022). The dependent variable was moderate–severe FI (yes/no), which was constructed from an eight-item Food Insecurity Experience Scale (FIES) to measure FI at the household level. Poisson log generalized linear regression models were fitted to assess the association between the independent variables and FI. In addition, the reliability of the FIES as a tool for measuring food insecurity in the target population was determined.

Results: A total of 3,491 households with Venezuelan migrants and refugees were included in the analysis. We found that 39.0% of Venezuelan immigrant households in Peru experienced moderate–severe FI. The determinants of FI included socio-demographic characteristics of the household head, and economic and geographical characteristics of the household. Regarding the FIES, we found that the inclusion of 7 of the 8 items had adequate internal consistency and its items assessed the same latent range.

Discussion: This study highlights the need to identify determinants associated with FI to design strategies that mitigate the consequences of health crises and strengthen regional food systems, making them more sustainable. Although several studies have evaluated the prevalence of FI in Venezuelan migrant populations in other countries, this study is the first to evaluate the determinants of FI in Venezuelan immigrant households in Peru.

KEYWORDS

food insecurity, refugees, emigrants and immigrants, prevalence, cross-sectional studies, Peru, Venezuela

1. Introduction

Food insecurity (FI) is defined as the situation in which a person lacks constant availability and access to sufficient food to lead an active and healthy life (1). FI is a public health problem in various regions of the world, especially among people living in poverty and vulnerability (1). Although FI is included in the Sustainable Development Goals (SDGs), specifically in SDG 2 to eradicate hunger and all forms of malnutrition by 2030, it is estimated that more than 900 million people worldwide experienced FI in 2021 (2).

It is estimated that around 2010, Venezuela's migratory profile started changing from that of a destination country to a country of origin. However, it is only since 2014 that Venezuelan emigration started reaching dramatic levels. In fact, the highest migration figures of the Venezuelan population were observed from 2016 around the world, with an exponential increase in the last five years (3–5). More than 7 million refugees and migrants from Venezuela have left their country in search of safety and stability. The vast majority, almost six million people, live in 17 countries in Latin America and the Caribbean. One of the most common destinations for Venezuelan migrants is Peru (only second to Colombia), where more than one million people have migrated in the last 10 years (6, 7). However, despite having left their home country due to precarious living conditions (e.g., food shortages, illegal food trade, unauthorized distribution networks, and high food prices), many of these migrants continue to suffer the consequences of FI due to the difficulties they face in accessing adequate and nutritious food in their destination country (8, 9).

The causes of FI in immigrant households are multiple and complex, ranging from lack of economic resources to buy food to lack of access to basic health and education services (10, 11). One report described some relevant indicators that explain the FI of Venezuelan migrants in Peru, including the lack of formal employment and precarious work, which limit their income and therefore their ability to purchase food. Additionally, the number of individuals residing in each household is a factor that also affects FI (12). However, institutions such as the United Nations High Commissioner for Refugees and the International Organization for Migration are carrying out various tasks (e.g., humanitarian assistance, protection, socioeconomic and cultural inclusion, integration, and reduction of xenophobia, among others) to improve the living conditions of Venezuelans in Peru (13).

On the other hand, the different dietary habits of the migrant population, the lack of nutritional education and information about healthy eating habits, as well as the availability of food at unaffordable prices, exacerbate FI in this migrant population, especially after the COVID-19 pandemic that worsened this situation (14). In addition, discrimination and xenophobia also play an important role in the availability, access, and consumption of food for adequate nutrition, as many Venezuelan migrants are excluded from jobs, housing, and basic public services due to their migratory status (10). Identifying modifiable factors associated with FI can serve as a basis for designing strategies that mitigate the consequences of disruptions caused by health crises (e.g., the COVID-19 pandemic) and the resulting FI and strengthen regional food systems, making them more sustainable (15).

Although several studies have evaluated the prevalence of FI in Venezuelan migrant populations in other countries, to our knowledge no study has evaluated the determinants of this problem in Peru (9, 10, 16). Therefore, the objective of this study was to determine the prevalence and analyze the determinants of FI in the households of Venezuelan immigrants in Peruvian territory, according to the "Encuesta Dirigida a la Población Venezolana que Reside en el País" (ENPOVE 2022).

2. Materials and methods

2.1. Data source and sampling

The analysis for this study was conducted based on data extracted from the ENPOVE 2022. The survey was carried out by the National Institute of Statistics and Informatics (INEI - acronym in Spanish) of Peru and collected representative data on household and individual information on the Venezuelan refugee and migrant population in Peru (17, 18). ENPOVE 2022 was conducted between February and March 2022, and it is the second version of the survey first conducted in 2018 (17).

The ENPOVE 2022 uses a probabilistic, stratified and independent sampling technique in urban areas of the main cities of Peru [Tumbes, Piura, Chiclayo, Trujillo, Chimbote, Ica, Arequipa, Metropolitan Lima (which includes the Constitutional Province of Callao)] (17). A sample frame of 236,074 households of the Venezuelan population in Peru was constructed and a total of 195,710 households were obtained (82.9% of the total number of households with Venezuelan population at the national level). The total sample size was 3,680 households with Venezuelan population with 12,487 participants usually residing in private and collective households. Face-to-face interviews were carried out during the months of survey (17, 18). Further specifications on the sample design, procedures and data collection can be found in the ENPOVE 2022 technical report (17).

2.2. Variables and measurements

2.2.1. Household food insecurity measurement

The ENPOVE 2022 used the Food Insecurity Experience Scale (FIES) with eight items to measure household FI (19). The items evaluated in the ENPOVE 2022 were collected with a reference period of the previous month before the survey. The respondents were asked whether they or any adult member of their household had experienced one of the following situations (abbreviated item names in parentheses): (1) Did you worry that your household would run out of food? (WORRIED); (2) Were you unable to eat healthy and nutritious food or food that you preferred? (HEALTHY); (3) Did you eat only a few kinds of foods? (FEWFOOD); (4) Did you skip a meal because there was not enough food? (SKIPPED); (5) Did you eat less than you thought you should eat? (ATELLES); (6) Did your household run out of food? (RUNOUT); (7) Did you go hungry because you could not afford enough food? (HUNGRY); and (8) Did you go without eating for a whole day? (WHLDAY). All questions were dichotomous with Yes or No response options. For item 2, the assigned value of the response was inverted. However, this item was excluded from the FIES scale because it obtained a value greater than 1.5 in the infit statistic in the Rasch model (19). For our analysis a "Yes" response to a question was considered as 1, and "No" as 0. Subsequently, items 1, 3, 4, 5, 6, 7, and 8 were summed to obtain a

variable that classified households with a score ≥ 4 as having moderate to severe FI, and those with a score of 0 to 3 as having no or low FI. It was not considered necessary to change the cut-off points or categories because the Food and Agriculture Organization (FAO) documents do not indicate this procedure of adjusting the cut-off points when removing an item from the scale and because other studies (17, 18), which also eliminated items due to high infit values, applied the cut-off points of the FAO protocol without modification.

2.2.2. Explanatory variables

Based on a review of the literature and the availability of variables from the ENPOVE 2022 (10, 14, 16), the following independent variables were selected: gender (male, female), age group of the household head in years (15 to 29, 30 to 39, 40 to 49, 50 or more), higher education of the household head (yes, no), physical or psychological limitations of the household head (yes, no), whether the household head worked in the last week (yes, no), holding of a migratory permit by the household head (yes, no), time of arrival in Peru (6 or more years, less than or equal to 5 years), household members with health insurance (yes, no), rented housing (yes, no), wealth tercile (low, middle, high), presence of children under 5 years old in the household (no, yes), presence of elderly adults in the household (no, yes), household size (single-person, 2 to 5, 6 or more), and city of residence (Metropolitan Lima, Arequipa, Chiclayo, Chimbote, Ica, Piura, Trujillo, Tumbes).

We created the wealth tercile which took into consideration housing characteristics and household goods or services (20). Each characteristic (walls, roofs, floors, water, drainage and lighting, internet, television, stove, blender, iron, computer, cell phone, landline, radio, refrigerator and washing machine) was recategorized as a dichotomous variable (yes, no) assigning it a score generated through principal components analysis (PCA) and each household was assigned a score for each characteristic, and the scores for each household were summed (20). All results included the sample weights and households were classified according to the total score of the household and three equal categories (terciles) were created: "low," "middle" and "high."

2.3. Statistical analysis

Stata 17.0 (StataCorp, College Station, TX, United States) was used to clean, recode, and analyze the data. All analyses included the complex sampling characteristics and household sampling weights of the ENPOVE 2022 survey. The R programming language in the RStudio environment (R Core Team 2020) was used to evaluate the Rasch fit statistics (infit and outfit) and overall model fit for the FIES using the RM.weight package, and the results are presented for both the 8-item and 7-item (excluding item 2) versions of the FIES.

Summary statistics and cross-tabulations were used to describe the study sample. Chi-square tests with Rao-Scott correction were performed to determine differences between the proportions of the variables included in the study. The 95% confidence intervals (CIs) were estimated using the Taylor series linearization method. Poisson log generalized linear regression models were fitted to evaluate the association between independent variables and food insecurity, reporting prevalence ratios (PR) and 95% CIs as measures of association. The adjusted analysis included all independent variables with a value of p less than 0.20 obtained in the bivariate analysis. Multicollinearity of the independent variables was evaluated by the variance inflation factor (no multicollinearity was found). We also conducted sensitivity analyses to verify whether the results of the associated factors changed when the 8 FIES items were included. The sensitivity analyses are presented in the Supplementary Material. Finally, a value of p of less than 0.05 was considered statistically significant.

2.4. Ethical considerations

The ENPOVE 2022 databases do not contain information that would allow respondents to be identified. Since our study was based on the secondary data analysis of the ENPOVE 2022, which databases are freely and publicly available in the INEI microdata repository,[1] ethical approval was not required.

3. Results

3.1. Characteristics of the study population

A total of 3,491 households in which Venezuelan migrants and refugees resided were included in the analysis. Regarding household heads, it was found that the majority were males [64.9% vs. females (35.1%)] and belonged to the age group of 30–39 years (38.9%). Further details of the sociodemographic, economic, and migratory characteristics of the population included are presented in Table 1.

3.2. Proportion and rasch model of the FIES

Figure 1A shows the proportion of affirmative responses to each of the 8 FIES items, where the lowest proportion was found in the WHLDAY category (10.5%), while the highest proportion was found in the WORRIED item (61.8%). Also, Figure 1B shows that the proportions of mild, moderate and severe food insecurity using the 8-item FIES were 35.9, 31.3, and 11.3%, respectively; while the 7-item FIES, which was used in this study, reported that mild, moderate and severe food insecurity were 33.5, 33.8, and 5.3%, respectively (Figure 1C).

All infit statistics for the 7 items included were within the widely acceptable range or in the range that can still be used for measurement (0.7–1.5), implying that they measured the same latent trait. Furthermore, the reliability of the Rasch model was 0.71, suggesting adequate consistency of the instrument (Table 2).

3.3. Prevalence of moderate–severe food insecurity according to household characteristics

The prevalence of moderate–severe food insecurity (MSFI) was 39.0% (95% CI: 36.7–41.4%). The highest proportions of MSFI were

1 https://proyectos.inei.gob.pe/microdatos/

TABLE 1 Characteristics of the households included in this study, ENPOVE 2022.

Characteristic	Absolute frequency (n =3,491)	%*
Gender of household head		
Male	2,229	64.9
Female	1,262	35.1
Age group (years) of household head		
15–29	1,207	32.9
30–39	1,300	38.9
40–49	621	17.6
50 or more	363	10.6
Higher education of household head		
Yes	1,584	47.9
No	1907	52.1
Physical or psychological limitation of household head		
Yes	60	2.0
No	3,431	98.0
Household head worked in the last week		
Yes	3,001	86.6
No	490	13.4
Holding of a migratory permit by the household head		
Yes	2,364	75.1
No	1,127	24.9
Arrival in Peru of household head		
6 or more years	339	10.9
Less than or equal to 5 years	3,152	89.1
Household members with health insurance		
Yes	309	10.7
No	3,182	89.3
Rented house		
Yes	3,317	95.6
No	174	4.4
Wealth tercile		
Lowest	1,272	33.4
Middle	1,199	35
Highest	1,020	31.6
Presence of children under 5 years of age		
No	2,428	71.3
Yes	1,063	28.7
Presence of an older adult (60 and over)		
No	3,237	93.0
Yes	254	7.0
Household size		
Unipersonal	611	17.7
2–5	2,572	74.5
6 or more	308	7.8
City of household		
Lima Metropolitana	1922	83.8
Arequipa	204	3.6
Chiclayo	192	1.5
Chimbote	234	1.4
Ica	189	2.5
Piura	188	1.9
Trujillo	368	4.5
Tumbes	194	0.8

*The weighting factor and sample specifications of ENPOVE were included. ENPOVE, Encuesta Población Venezolana.

observed in households in which the household head was female (46.7%), did not have a higher education (43.7%), had a physical or psychological limitation (53.4%), did not work in the last week (54.1%), did not have a migratory permit to reside in the city of residence (49.3%), and had arrived in Peru in the last 5 years (39.8%). Regarding household characteristics, the highest MSFI figures were found in households with at least one child under 5 years of age (42.8%), household members had health insurance (30.0%), it was a rented dwelling (39.5%), belonged to the lowest wealth index (52.7%), and were located in Tumbes (60.9%) and Chiclayo (52.7%) (Table 3).

3.4. Determinants of moderate–severe food insecurity

In the adjusted analysis, it was observed that the female sex of the household head (adjusted PR [aPR]: 1.24; 95% CI: 1.11–1.39; $p<0.001$), not having higher education (aPR: 1.12; 95% CI: 1.01–1.25; $p=0.041$), not having worked in the last week (aPR: 1.27; 95% CI: 1.12–1.45; $p=0.001$), household size consisting of 2 to 5 (aPR: 1.17; 95% CI: 1.01–1.37; $p=0.042$), and 6 or more members (aPR: 1.38; 95% CI: 1.10–1.72; $p=0.005$), and the household being located in Chiclayo (aPR: 1.24; 95% CI: 1.06–1.46; $p=0.008$) and Tumbes (aPR: 1.21; 95% CI: 1.05–1.40; $p=0.008$) increased the probability of experiencing MSFI in the household, while belonging to the middle (aPR: 0.74; 95% CI: 0.66–0.84; $p<0.001$) and high wealth tertile (aPR: 0.50; 95% CI: 0.42–0.58; $p<0.001$), and home located in Ica (aPR: 0.69; 95% CI: 0.53–0.90; $p=0.007$) decreased the probability of this outcome (Table 4).

3.5. Sensitivity analysis

When including the 8 FIES items in the calculation of the FI, the results of the associated factors found in the main analysis and the sensitivity analysis were largely consistent (see Supplementary Material). We only found not having higher education which was significant in the main analysis became non-significant in the sensitivity analysis, and the city of Arequipa which was not significant in the main analysis became significant in the sensitivity analysis. On the other hand, the prevalence of moderate–severe FI with 7 items went from 39.0% (95% CI: 36.7–41.4%) to 42.6% (95% CI: 40.2–45.1%) with the 8 items.

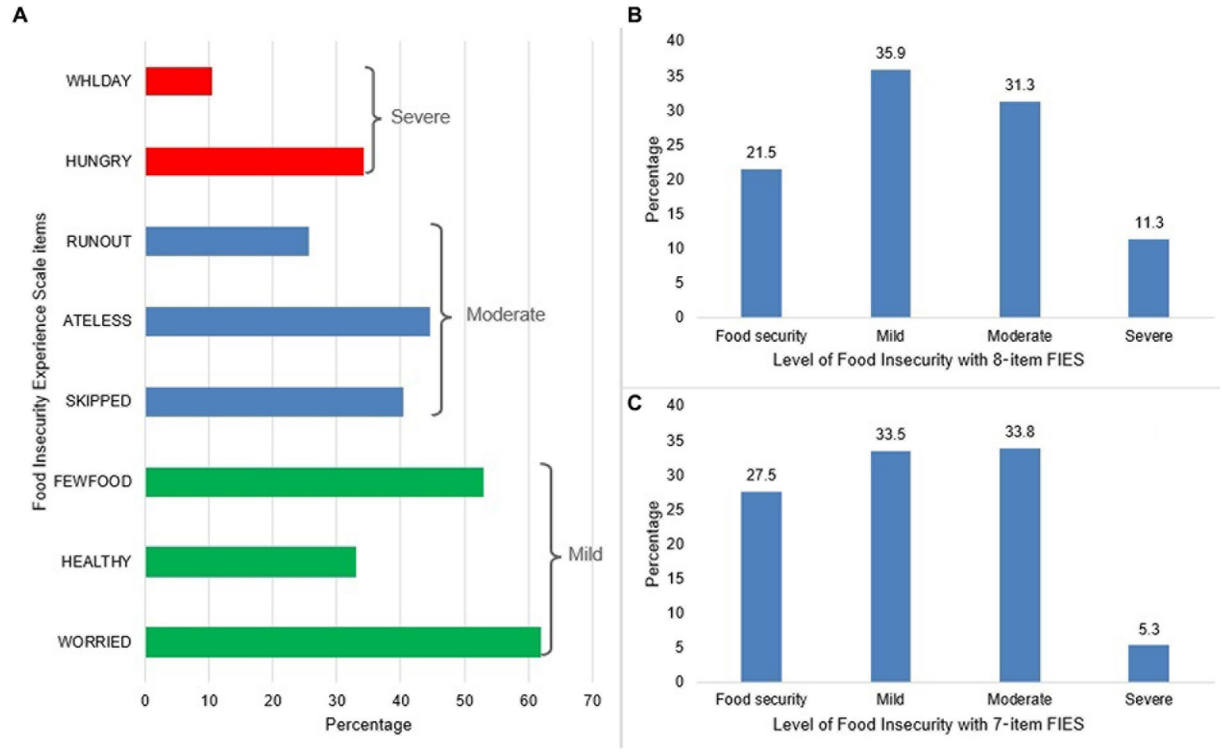

FIGURE 1
(A) Raw score of responses to Food Insecurity Experience Scale items and **(B)** and **(C)** level of food insecurity according to the 8- or 7-item Food Insecurity Experience Scale.

TABLE 2 Evaluation of the assumptions of the rash model of the Food Insecurity Experience Scale.

Item	Item severity	Standard error	Infit	Outfit
8 Items*				
WORRIED	−1.8689310	0.05363209	0.8903619	0.9094915
HEALTHY	0.3255702	0.05038797	1.7750747	2.7845104
FEWFOOD	−1.1897263	0.05076805	1.1033882	1.3289784
SKIPPED	−0.2541140	0.04969296	0.7857971	0.6801665
ATELESS	−0.5618956	0.04978105	0.7247948	0.6695117
RUNOUT	0.8991941	0.05258210	0.8873609	0.7962524
HUNGRY	0.2214051	0.05016552	0.6867110	0.5311893
WHLDAY	2.4381822	0.07043999	0.9700901	1.2260546
7 Items**				
WORRIED	−2.1755354	0.0628402	1.0398901	1.6554289
FEWFOOD	−1.3275513	0.05671906	1.3632707	2.1725721
SKIPPED	−0.2222556	0.05474767	0.8691253	0.8310948
ATELESS	−0.5834282	0.05491153	0.8115017	0.8314149
RUNOUT	1.1206663	0.05844651	0.9775228	0.9665989
HUNGRY	0.3338467	0.05535234	0.7125410	0.5675720
WHLDAY	2.8571335	0.08129745	1.0470332	2.2401959

*Rasch reliability: 0.73; Rasch reliability (flat): 0.72. **Rasch reliability: 0.72; Rasch reliability (flat): 0.71.

TABLE 3 Frequency of moderate–severe food insecurity among Venezuelan households by background characteristics, ENPOVE 2022.

Characteristics	Moderate–severe food insecurity		
	No (*n*=1,915) %* (95% CI)	Yes (*n*=1,576) %* (95% CI)	*p*-value**
Overall	61.0 (58.6–63.3)	39.0 (36.7–41.4)	
Gender of household head			
Male	65.1 (62.2–67.9)	34.9 (32.1–37.8)	<0.001
Female	53.3 (49.5–57.1)	46.7 (42.9–50.5)	
Age group (years) of household head			
15–29	61.4 (57.5–65.2)	38.6 (34.8–42.5)	0.975
30–39	61.1 (57.5–64.6)	38.9 (35.4–42.5)	
40–49	60.7 (55.7–65.5)	39.3 (34.5–44.3)	
50 or more	59.7 (52.9–66.1)	40.3 (33.9–47.1)	
Higher education of household head			
Yes	66.1 (62.9–69.2)	33.9 (30.8–37.1)	<0.001
No	56.3 (53.0–59.4)	43.7 (40.6–47.0)	
Physical or psychological limitation of household head			
Yes	46.6 (31.0–62.8)	53.4 (37.2–69.0)	0.075
No	61.3 (58.8–63.6)	38.7 (36.4–41.2)	
Household head worked in the last week			
Yes	63.3 (60.7–65.8)	36.7 (34.2–39.3)	<0.001
No	45.9 (40.0–51.8)	54.1 (48.2–60.0)	
Holding of a migratory permit by the household head			
Yes	64.4 (61.6–67.0)	35.6 (33.0–38.4)	<0.001
No	50.7 (46.6–54.9)	49.3 (45.1–53.4)	
Arrival in Peru of household head			
6 or more years	67.4 (61.0–73.3)	32.6 (26.7–39.0)	0.035
Less than or equal to 5 years	60.2 (57.6–62.7)	39.8 (37.3–42.4)	
Household members with health insurance			
Yes	70.0 (62.9–76.3)	30.0 (23.7–37.1)	0.008
No	59.9 (57.4–62.4)	40.1 (37.6–42.6)	
Rented house			
Yes	60.5 (58.0–62.9)	39.5 (37.1–42.0)	0.029
No	71.9 (61.8–80.2)	28.1 (19.8–38.2)	
Wealth tercile			
Lowest	47.3 (43.4–51.2)	52.7 (48.8–56.6)	<0.001
Middle	61.7 (57.7–65.5)	38.3 (34.5–42.3)	
Highest	74.7 (71.0–78.0)	25.3 (22.0–29.0)	
Presence of children under 5 years of age			
No	62.5 (59.8–65.1)	37.5 (34.9–40.2)	0.024
Yes	57.2 (53.0–61.3)	42.8 (38.7–47.0)	
Presence of an older adult (60 and over)			
No	60.9 (58.4–63.4)	39.1 (36.6–41.6)	0.886
Yes	61.5 (53.9–68.6)	38.5 (31.4–46.1)	
Household size			
Unipersonal	64.5 (59.4–69.3)	35.5 (30.7–40.6)	0.115
2–5	60.7 (58.0–63.4)	39.3 (36.6–42.0)	
6 or more	55.1 (47.2–62.7)	44.9 (37.3–52.8)	

(Continued)

TABLE 3 (Continued)

Characteristics	Moderate–severe food insecurity		
	No (*n*=1,915) %* (95% CI)	Yes (*n*=1,576) %* (95% CI)	*p*-value**
City of household			
Lima Metropolitana	61.5 (58.7–64.2)	38.5 (35.8–41.3)	<0.001
Arequipa	59.0 (50.6–67.0)	41.0 (33.0–49.4)	
Chiclayo	47.3 (39.2–55.6)	52.7 (44.4–60.8)	
Chimbote	56.5 (48.0–64.5)	43.5 (35.5–52.0)	
Ica	72.8 (64.6–79.7)	27.2 (20.3–35.4)	
Piura	56.3 (48.2–64.1)	43.7 (35.9–51.8)	
Trujillo	58.3 (51.9–64.4)	41.7 (35.6–48.1)	
Tumbes	39.1 (30.4–48.5)	60.9 (51.5–69.6)	

Data are displayed as weighted % of the row unless otherwise indicated. * The weighting factor and sample specifications of ENPOVE were included. ** Estimated *p*-value using the Chi-square test with Rao-Scott adjustment. ENPOVE, Encuesta Población Venezolana; CI, Confidence Interval.

TABLE 4 Factors associated with moderate–severe food insecurity among Venezuelan households, ENPOVE 2022.

Variable	Crude		Adjusted*	
	PR (95% CI)	*p*-value	aPR (95% CI)	*p*-value
Gender of household head				
Male	Reference		Reference	
Female	1.34 (1.20–1.50)	<0.001	1.24 (1.11–1.39)	<0.001
Age group (years) of household head				
15–29	Reference		Not included	
30–39	1.01 (0.89–1.15)	0.902		
40–49	1.02 (0.87–1.19)	0.830		
50 or more	1.04 (0.86–1.26)	0.662		
Higher education of household head				
Yes	Reference		Reference	
No	1.29 (1.15–1.44)	<0.001	1.12 (1.01–1.25)	0.041
Physical or psychological limitation of household head				
Yes	Reference		Reference	
No	0.72 (0.53–0.99)	0.043	0.79 (0.57–1.10)	0.170
Household head worked in the last week				
Yes	Reference		Reference	
No	1.48 (1.30–1.68)	<0.001	1.27 (1.12–1.45)	<0.001
Holding of a migratory permit by the household head				
Yes	Reference		Reference	
No	1.38 (1.24–1.54)	<0.001	1.09 (0.97–1.22)	0.161
Arrival in Peru of household head				
6 or more years	Reference		Reference	
Less than or equal to 5 years	1.22 (1.01–1.49)	0.045	1.02 (0.85–1.24)	0.817
Household members with health insurance				
Yes	Reference		Reference	
No	1.34 (1.06–1.68)	0.013	1.05 (0.83–1.32)	0.700
Rented house				
Yes	Reference		Reference	

(Continued)

TABLE 4 (Continued)

Variable	Crude		Adjusted*	
	PR (95% CI)	*p*-value	aPR (95% CI)	*p*-value
No	0.71 (0.51–0.99)	0.045	0.78 (0.57–1.08)	0.140
Wealth tercile				
Lowest	Reference		Reference	
Middle	0.73 (0.65–0.82)	<0.001	0.74 (0.66–0.84)	<0.001
Highest	0.48 (0.41–0.56)	<0.001	0.50 (0.42–0.58)	<0.001
Presence of children under 5 years of age				
No	Reference		Reference	
Yes	1.14 (1.02–1.28)	0.021	1.05 (0.94–1.19)	0.372
Presence of an older adult (60 and over)				
No	Reference		Not included	
Yes	0.99 (0.81–1.21)	0.886		
Household size				
Unipersonal	Reference		Reference	
2–5	1.11 (0.95–1.29)	0.186	1.17 (1.01–1.37)	0.042
6 or more	1.27 (1.01–1.58)	0.038	1.38 (1.10–1.72)	0.005
City of household				
Lima Metropolitana	Reference		Reference	
Arequipa	1.06 (0.86–1.32)	0.573	1.21 (0.98–1.49)	0.082
Chiclayo	1.37 (1.15–1.63)	<0.001	1.24 (1.06–1.46)	0.008
Chimbote	1.13 (0.92–1.39)	0.239	0.96 (0.78–1.17)	0.661
Ica	0.71 (0.53–0.94)	0.018	0.69 (0.53–0.90)	0.007
Piura	1.13 (0.93–1.38)	0.211	1.05 (0.88–1.25)	0.607
Trujillo	1.08 (0.92–1.28)	0.344	1.04 (0.89–1.22)	0.598
Tumbes	1.58 (1.34–1.87)	<0.001	1.21 (1.05–1.40)	0.008

Weighting factors and sample specifications of ENPOVE were included for all analysis. ENPOVE, Encuesta Población Venezolana; PR, Prevalence Ratio; aPR, Adjusted Prevalence Ratio; CI, Confidence Interval.

4. Discussion

This study sought to determine the prevalence and determinants of MSFI in the households of Venezuelan migrants and refugees in Peru. In addition, the reliability of the FIES as a tool to measure FI in the target population was determined. The findings of the present study showed that four out of ten households in which Venezuelan migrants and refugees resided experienced MSFI. The determinants associated with this outcome were related to socio-demographic characteristics of the household head and economic and geographic characteristics of the household. Regarding the FIES, our study showed that this tool had adequate internal consistency, and that its items assessed the same latent range. Additionally, the proportion of positive responses on the FIES items ranged from 10.5% for the WHLDAY item to 61.8% for the WORRIED item.

We found that approximately 40% of households in which Venezuelan migrants and refugees reside experienced MSFI. This finding is lower than that reported in studies of Venezuelan migrants and refugees residing in Trinidad and Tobago (86.61%) (16), in migrants and refugees from the Middle East and North Africa residing in the United States (40–71%) (21), in migrants from Haiti residing in Chile (78%) (22), and in undocumented migrant households in the United Kingdom (94.6%) (23), while it was higher than that reported in studies conducted in Libyan migrant families in Australia (13.7%) (11) and in migrants residing in Portugal (24). The differences between the prevalence of FI reported in our study and studies conducted in various regions of the world could be due to the use of the instruments (Latin American and Caribbean Food Security Scale [ELCA], United States Department of Agriculture Household Food Security Survey Module [USDA HFSSM], and Ten-item Radimer/Cornell Hunger Scale) that differ from the FIES and the unit of analysis, since the studies conducted in Trinidad and Tobago, the United States, Chile and Portugal assessed FI at the individual level. Only the study conducted in Trinidad and Tobago used the FIES as a tool to measure FI (16). However, the temporality (during the COVID-19 pandemic) used in this study was different from ours, which would generate a higher proportion of FI. Although the differences found between the studies could generate dissimilar proportions of FI, these figures expose a global problem in vulnerable populations (such as migrants and refugees). Specifically, in Peru, our

result is lower than that reported in Venezuelan migrant and refugee households during the COVID-19 pandemic (76.3%) (9). However, this difference could be influenced by the timing of the study (conducted during the COVID-19 pandemic) (9), during which there were higher unmet basic needs in health and food due to the social isolation during the pandemic and the prioritization of economic resources in health strategies. In addition, the report from Peru used the database of a non-governmental organization as a sampling frame and included beneficiaries of an intervention in districts of Metropolitan Lima with low socio-economic status, while the present study represented migrants in urban areas at the national level. Thus, our finding could expose situations of vulnerability that have developed as a consequence of the preventive measures put in place, the constant food shortages and prioritization of resources during the pandemic (25), which may have aggravated the nutritional and FI status of the households in which migrants reside.

Regarding the determinants associated with MSFI, it was found that socio-demographic determinants of the head of household such as being female, not having a higher education and not having worked in the last week increased the probability of MSFI. In addition to these determinants, economic and geographic characteristics of the household such as household size of 2 or more members and being located in Chiclayo and Tumbes were reported to increase the probability of this outcome, while a medium and high wealth index, and the household being located in Ica decreased the probability of this outcome. Our findings are consistent with those reported in studies of Venezuelan migrants and refugees in Trinidad and Tobago (16), Libyan migrant families in Australia (11) and migrant and refugee households in Colombia (26). With respect to the sex of the household head, female-headed households have greater economic challenges and disadvantages related to lower incomes, higher levels of informal work (housecleaning or street vending) and a greater dedication to household chores, which may impact FI (26). Household heads with lower levels of education have a higher prevalence of FI because education is associated with lower employment rates and, consequently, lower income, which hinders access to food with high nutritional value (27, 28). In addition, households with two or more members experience FI due to higher food costs that result in higher living expenses to ensure adequate nutrition in large households (29). Similarly, households located in Chiclayo and Tumbes experience higher levels of MSFI, which could be attributed to the large number of migrants located in these cities (30). Tumbes is a border region where the highest numbers of Venezuelan migrants enter, while Chiclayo is characterized by better job opportunities compared to other regions, which could be one of the reasons for the high migration of Venezuelans to this region (30). However, the migrant population in these cities lives in conditions of poverty, discrimination and unsatisfied basic needs.

On the other hand, the socio-economic level of households is a determining factor for experiencing FI. According to the biomedical literature, the economic income of migrants influences their food choices and dietary diversity, since lower purchasing power is associated with the consumption of high-calorie, low-cost foods, as well as lower dietary diversity (10, 31), which would have an impact on an inadequate diet and a higher prevalence of FI. It is worth mentioning that many Venezuelan migrants and refugees have experienced FI prior to their emigration due to lower income (8). Thus, our findings suggest that in Peru, these figures may have increased due to the unfavorable conditions experienced by migrants. Also, households located in Ica presented lower MSFI figures, which could be attributed to the fact that Ica has one of the fastest growing economies at the national level and would provide employment opportunities for migrants in the manufacturing and agricultural sectors, among others (32). These characteristics of the labor market have an impact on household incomes and increase access to food with a high nutritional content.

To determine the FI in our target population, we used the FIES, a widely used tool that was developed and validated internationally by the FAO (19, 33). According to our findings, this tool was found to have adequate infit statistics and internal consistency after excluding the HEALTHY item for having a value greater than 1.5. In addition, the proportions of positive responses to the FIES were: 61.8% (WORRIED), 52.9% (FEWFOOD), 40.5% (SKIPPED), 44.6% (ATELESS), 25.7% (RUNOUT), 34.3% (HUNGRY), and 10.5% (WHLDAY). The figures for items 1 to 5 are higher than those obtained for RUNOUT, HUNGRY and WHLDAY, which would indicate an adequate order of severity, and items 6 to 8 obtained the lowest proportions, as reported in previous studies recommending their use as global anchors (33). These results highlight their usefulness for estimating FI in Venezuelan migrant and refugee households.

Our findings have implications for the design and implementation of health policies. First, governmental and non-governmental institutions should consider the main determinants that increase the likelihood of FIMS as starting points for strategy or policy formulation. Second, non-governmental institutions (such as the United Nations Refugee Agency) that provide humanitarian support to Venezuelan migrants and refugees should prioritize resources to serve the population currently suffering from FI or at increased risk of experiencing IF and living in unfavorable conditions. Finally, government institutions should redouble efforts to improve the living and nutritional conditions of migrants through the granting of migration permits, improvements in working conditions, nutrition education campaigns, and improvements in access to and availability of foods with high nutritional value to achieve dietary diversity and adequate nutritional indicators. These changes could impact the fulfilment of SDG 2.1, which seeks to ensure access to food for all populations, including the most vulnerable (34).

The main strength of our study is the use of a database with complex sampling, representative at the Peruvian level and including many Venezuelan migrants and refugees residing in the main cities of Peru, which provides a current socio-demographic, economic and nutritional overview of one of the populations experiencing the greatest situations of vulnerability. In addition, the determination of FI was carried out using the FIES scale, which is a tool developed and validated internationally by the FAO, and which has been used for the study of FI worldwide during the pandemic period (9, 19). However, the present study is not without limitations. First, the lack of temporality in the measurement of the variables prevents causality from being established. Second, the interpretation of the FIES items may not have been correctly understood by respondents due to the negative or positive orientation of the items. Third, there is a possible recall bias, because some variables were based on events that occurred at specific points in the past, although the study period was shortened to the last 30 days to reduce this bias. Finally, some variables, such as the receipt of humanitarian support, economic bonuses or

income by main or secondary occupation, which have not been included in this study due to their unavailability in the database.

In conclusion, four out of ten Venezuelan migrant and refugee households experienced MSFI. The determinants that increase the prevalence of MSFI are related to the socio-demographic characteristics of the head of household and economic and geographic characteristics of the household. In this sense, the institutions in charge of ensuring adequate quality and quantity of food should carry out public health strategies focused on the main determinants that influence the appearance of FI in Venezuelan migrants and refugees, especially when this population experiences poorer conditions of access to health, education, food and employment. Furthermore, this study is a starting point for epidemiological studies to assess dietary quality, nutritional indicators and dietary diversity in one of the most vulnerable populations in Peru.

Data availability statement

Publicly available datasets were analyzed in this study. The datasets analyzed for this study can be found on the website of the Instituto Nacional de Estadística e Informática (http://iinei.inei.gob.pe/microdatos/).

Author contributions

AH-V: conceptualization, data curation, formal analysis, investigation, methodology, software, supervision, validation, and writing – original draft. AH-V, JA, and RV-F: project administration. AH-V, RV-F, FV-L, and JA: visualization. AH-V, RV-F, and FV-L: writing – review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2023.1187221/full#supplementary-material

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Undernutrition and associated factors among adult prisoners in Fiche town, central Ethiopia: a facility-based cross-sectional study

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Background: Undernutrition is a major public health problem worldwide, particularly in developing countries like Ethiopia. However, nutritional problems are frequently overlooked in low-income countries, especially among vulnerable populations such as imprisoned people. The scientific data on the rate of undernutrition among imprisoned people in Ethiopia is limited. Hence, this study aimed to assess the magnitude and associated factors of undernutrition among adult prisoners in Fiche town, central Ethiopia.

Methods: A facility-based cross-sectional study was conducted from August 15 to September 15, 2020. A systematic random sampling technique was used to select participants. All prisoners whose age was 18years and above who have been in prison for at least 6months were included. Data were collected using interviewer-administered pretested semi-structured questionnaires and standard anthropometric measurements. A cut-off point of body mass index <18.5 kg/m^2 was used to measure undernutrition. Data were coded, entered into Epi-data version 3.1, and analyzed using Statistical Package for Social Sciences version 20.0. A binary logistic regression analysis was conducted to identify factors associated with undernutrition. The adjusted odds ratio (AOR) with a 95% confidence interval (CI) was calculated to measure the strength of the association and a *p*-value of less than 0.05 was considered statistically significant.

Results: The overall magnitude of undernutrition among adult prisoners was 20% (95% CI: 16.5–23.6). Duration of imprisonment, incarcerated for 25 to 59months (AOR=3.07; 95% CI: 1.33, 7.04) and for greater than 59months (AOR=4.56; 95% CI: 2.0, 10.45), mild and moderate depression (AOR=1.9; 95% CI: 1.05, 3.45), and moderately severe and severe depression (AOR=2.78; 95% CI: 1.17, 6.60) were significantly associated with increased odds of undernutrition. However, being female (AOR=0.51; 95% CI: 0.26, 0.98), having financial support (AOR=0.36; 95% CI: 0.15, 0.87), engaging in income-generating work within the prison (AOR=0.27; 95% CI: 0.15, 0.47), having medium dietary diversity (AOR=0.35; 95% CI: 0.15, 0.80), and having good dietary diversity (AOR=0.23; 95% CI: 0.08, 0.61) significantly decreased the odds of undernutrition.

Conclusion: The magnitude of undernutrition among adult prisoners was high, with one in five prisoners in Fiche town prison having undernutrition. Sex,

financial support, duration of imprisonment, income-generating work in the prison, dietary diversity, and depression were predictors of undernutrition. Hence, access to healthy food and diversified diets should be ensured for prisoners, and implementing early screening and treatment of depression, as well as encouraging prisoners to engage in income-generating work within the prison is recommended to reduce the burden of undernutrition.

KEYWORDS

undernutrition, associated factors, prisoners, Fiche, Ethiopia

Introduction

Malnutrition refers to either inadequate intake of nutrients or intake of nutrients over body requirements (1, 2). The rate of malnutrition is high in developing countries, ranging from 6% to 48% among older adults in sub-Saharan Africa (2). In Ethiopia, malnutrition is a common health problem affecting 21.9% of the population in 2014 (3). Factors such as inadequate food consumption, increased nutrient loss, inadequate nutrient absorption, loss of appetite, inability to chew and swallow, and rising prescription drug use are identified as being associated with malnutrition (4–6). The health consequences of malnutrition are significant, ranging from delayed recovery to increased mortality (7, 8). Insulin resistance, poor immune function, reduced muscle strength, difficulty keeping warm, dyslipidemia and diminished capacity for hard labor are possible physiologic consequences of malnutrition (9–11).

Globally, nearly 11 million people are confined in prisons, with the largest number held in Africa (12). Marginalized and poor people make up a large percentage of the world's prisoners (13). There are approximately 100,000 to 120,000 inmates in Ethiopia (14). Nowadays, due to the increasing number of imprisoned people, the provision of adequate food remains an ongoing problem, putting prisoners at risk of malnutrition (15). Prisoners are subjected to a variety of harmful and deterrent health conditions, including nutritional-related problems (16, 17).

Access to adequate nutrition is a basic human right and prisoners should be provided with healthy food choices and diversified diets to optimize health (18, 19). Prisoners are exposed to a number of unfavorable health and health-deterring factors including higher risks of mortality and injuries (15–17, 20, 21). The literature indicates that prisoners face different nutritional problems ranging from several micronutrient deficiencies and re-emerging related diseases to delayed recovery, mental illness, sexual health problems, infectious diseases, and increased risk of mortality (22–24).

Prisoners are particularly vulnerable to suffering from undernutrition compared to the general population (7, 25). Several factors have been identified for undernutrition among prisoners, including lack of adequate food, poor dietary diversity, infections, prolonged duration of imprisonment, absence of financial support and family visits, and overcrowding living conditions (26–28). In addition, behavioral factors such as smoking, khat chewing and alcohol use are identified risk factors of undernutrition (29).

In Africa, there is limited evidence on the various health problems of prisoners despite the relevance of such evidence to the health of the prisoners and the community (29). Prisoners incarcerated in developing countries are especially vulnerable to dietary deficiencies, with the highest rate in the prisons of low-income countries (8). For instance, 38.4% of the female detainees in Antanmora prison, Madagascar were undernourished (28). The evidence from two studies in Ethiopia indicated that about 18.6% and 23.2% of adult prisoners were undernourished (30, 31).

In low-income countries, nutrition-related issues are often neglected; particularly among vulnerable groups such as imprisoned people (32). The foods served in many prisons are not sufficient in terms of quantity and quality (33). In many developing countries, including Ethiopia, the incarcerated people primarily obtain their food from the prison, which is insufficient to meet their nutritional needs (7). In Ethiopia, the prison health system is not well integrated with the national health system, and the health problems of prisoners are mostly marginalized by researchers (29). Hence, the scientific data on the rate of undernutrition among prisoners in Ethiopia is limited. Therefore, this study aimed to determine the magnitude and predictors of undernutrition among adult prisoners in Fiche town, central Ethiopia.

Methods and materials

Study setting and period

The study was conducted in Fiche town prison, North Shewa, central Ethiopia from August 15 to September 15, 2020. Fiche town is located 152 km from Addis Ababa, the capital city of Ethiopia, to the north. The town is the administrative center for the North Shewa Zone of Oromia Regional State. Fiche Town Prison serves as a central destination for inmates coming from surrounding smaller prisons or police stations. There were 2,100 prisoners in Fiche town prison during the study period, of whom 1,200 (749 males and 451 females) were adults 18 years of age and older.

Study design and population

A facility-based cross-sectional study was conducted to determine the magnitude of undernutrition and associated factors among adult

Abbreviations: AOR, Adjusted Odds Ratio; CI, Confidence Interval; COR, Crude Odds Ratio; DDS, Dietary Diversity Score; TB, Tuberculosis; WHO, World Health Organization.

prisoners in Fiche town prison, central Ethiopia. All randomly selected prisoners whose age was 18 years and above who have been in prison for at least 6 months and were available during the data collection period were included in the study. Whereas, pregnant and lactating mothers as well as prisoners with physical deformities who were unable to assume an erect position during anthropometric measurements were excluded.

Sample size determination

The sample size required for the study was determined using a single population proportion formula with the assumptions of a 25.2% prevalence of undernutrition among adult prisoners taken from a previous study conducted in Northern Ethiopia (29), a 95% CI, and a 4% margin of error. Hence, the final sample size required for this study after adding a 10% for non-response rate was **497**.

Sampling techniques and procedures

A stratified random sampling technique was employed to form the strata by the sex of eligible prisoners. A sampling frame was created using lists of eligible prisoners obtained from the prison administration office. Then, after stratifying the sampling frame by the sex of prisoners, the estimated sample size was proportionally allocated to the size of each stratum. The study sample was selected using prisoners' identification (ID) numbers. The first participant was selected by lottery method from each stratum. Finally, the study participants were selected from each stratum using systematic random sampling techniques.

Data collection tools and techniques

An interviewer-administered pretested and validated semi-structured questionnaire adapted from available literature (29, 31, 34) and modified to the study variables was used to collect the data. The questionnaire was initially developed in English, translated to the local languages (Afan Oromo and Amharic), and then re-translated into English by language experts to check for consistency. The questionnaire consisted of socioeconomic and demographic characteristics, nutritional status, behavioral characteristics, history of previous detentions, duration of imprisonment, clinical conditions and service-related variables, and anthropometric measurements. The data regarding socio-demographic characteristics and related variables were collected by trained data collectors and supervisors using interviewer-administered pretested questionnaires. Behavioral characteristics such as smoking cigarettes were gathered using "Yes/No" questions. Prisoners were classified as smokers if they smoked one or more cigarettes per day (35). Similarly, Yes/No questions were used to assess the presence of acute or chronic diseases such as tuberculosis (TB).

Measurement of variables

Undernutrition

Undernutrition was considered in the adult prisoners whose body mass index (BMI) was less than 18.5 kg/m^2 (36, 37).

Anthropometric measurements

The weight and height of the participants were measured using a digital standing weight scale and stadiometer (Detecto, United Kingdom) which measures weight and height together. The weight scale was calibrated to zero before measuring each participant and the accuracy of the instrument was checked by measuring the weight of a known object. The accuracy of the stadiometer was also checked by measuring the height of an object with a known height. The weight and height measurements were taken while wearing only light clothing, bare feet, and no headwear. The height was measured while respondents were standing erect against the stadiometer with the shoulder, buttock, calf and heels touching the stadiometer and eyes looking straight ahead (Frankfurt plane) so that the line of sight was perpendicular to the body. Both weight and height were recorded to the nearest 0.1 kg and 0.1 cm, respectively (30, 31, 37). The BMI was calculated by a person's weight in kilograms divided by the square of height in meters.

Dietary diversity score

Individual dietary diversity score (IDDS) was measured after dietary intake data were collected using a 24 h dietary recall method. Any type of food that was consumed by participants within 24 h before the time of data collection was recorded. A set of 10 food groups were used to guide the scoring per the food items consumed. Participants received a "1" point if they consumed a minimum of one food within each sub-group, and a "0" if they did not (38). The scores were summed up to get the total IDDS. Finally, prisoners with a score of 5 and above were categorized as having a diversified diet and those with a score of less than 5 were classified as having a non-diversified diet (39).

Depression

Depression was assessed using the Patient Health Questionnaire-nine (PHQ-9) with a five-point severity scale. The tool has strong psychometric properties as evidenced by its validity and reliability, and a score of 10 or more on this scale is reported to have a sensitivity of 88% and a specificity of 88% for major depressive disorder (40). The total score was computed by adding the scores of all nine items on the scale. The depressive symptoms on PHQ-9 were rated on a scale ranging from "0" (not at all) to "3" (nearly every day). The total score ranges from 0–27. The scores represent 0–4 considered as none/minimal, 5–9 as mild, 10–14 as moderate, 15–19 as moderately severe, and 20–27 as severe depression (41). The participants were considered in a state of depression if they scored five and above.

Khat chewing

Khat chewing was measured considering both lifetime chewing duration (in years) and time spent in a single chewing session (in hours). Participants who used khat for more than five years and chewed for more than four hours in a single chewing session before they were incarcerated were considered khat chewers (31).

Data quality management

A pretested and validated semi-structured data collection tool was adapted to ensure data quality. Two days training were given to data collectors and supervisors on the objectives of the study, the contents

of data collection tools, the anthropometric measurements, and how to collect and record data appropriately. A pretest was conducted on 5% of the sample size in a similar study population before the actual data collection period to check for the reliability and validity of data collection tools. The questionnaires were reviewed and checked for completeness and consistency, and necessary amendments were made based on the results of the pretest. The collected data were carefully checked for completeness, accuracy and consistency by supervisors and the principal investigator on daily basis. Double data entry was done by two individuals to minimize errors.

Data processing and analysis

The collected data were cleaned, coded and entered into Epi-Data version 3.1 and analyzed using Statistical Package for Social Sciences (SPSS) version 20.0 software. Texts, tables and figures were used to display descriptive and summary statistics. The binary logistic regression analysis was conducted to identify the determinants of undernutrition. Initially, the bivariate logistic analysis was conducted to determine the candidate variables for the multivariate logistic analysis. All variables with a *p*-value of less than 0.25 in the bivariate logistic analysis were fitted into the multivariate logistic analysis to identify factors significantly associated with undernutrition. The variance inflation factor (VIF) was used to check the existence of multicollinearity among variables. All variables were observed with VIF <2, showing the non-existence of multicollinearity. The logistic regression goodness of fit of the model was checked using the Hosmer and Lemeshow statistical test and indicated a good fit for the model at a *p*-value of 0.793. Both crude and adjusted odds ratios with a 95% CI were calculated to show the strength of the association, and a *p*-value <0.05 was used to declare statistical significance.

TABLE 1 Socio-demographic characteristics of the study participants in Fiche town prison, central Ethiopia, 2020 (*n*=479).

Variables	Category	Frequency (*N*)	Percentage (%)
Sex	Male	298	62.20
	Female	181	37.80
Age (in years)	18–29	119	24.84
	30–39	133	27.76
	40–49	113	23.60
	>49	114	23.80
Religion	Orthodox	322	67.22
	Protestant	90	18.79
	Muslim	55	11.48
	Others	12	2.51
Marital status	Never married	308	35.70
	Ever married	171	64.30
Educational status	No formal education	301	62.84
	Primary education	76	15.87
	Secondary education	67	13.99
	Tertiary education	35	7.30
Previous occupation	Farmer	232	48.43
	Merchant	113	23.59
	Government employee	53	11.06
	Daily laborer	33	6.89
	Jobless	48	10.03
Previous residence	Rural	261	54.50
	Urban	218	45.50

Results

Socio-demographic characteristics of study participants

A total of 479 adult prisoners were enrolled in the study, giving a response rate of 96.4%. The mean (SD) age of the study participants was 39.64 (±12.21) years. Among the prisoners, more than one-fourth (27.76%) were in the age group of 30–39 years. The majority (62.2%) of the prisoners were males. In this study, nearly two-thirds (64.3%) of the prisoners were ever married and 62.84% had never received any level of formal education. More than half (54.5%) of the prisoners were rural residents and 48.43% were farmers before imprisonment (Table 1).

Detention conditions of prisoners

Among the prisoners, 46.35% were held in prison for 25 months and above. The majority (86.85%) had no history of previous detentions. Almost all (98.75%) prisoners were sleeping in a group. The majority (78.5%) of the prisoners were involved in income-generating activities in the prison. More than two-thirds (72.23%) of the prisoners were not visited by their families and more than three-quarters (80.17%) did not receive any financial support from their families or significant others (Table 2).

Behavioral, nutritional and health-related characteristics

The majority (86.22%) of the prisoners were nonsmokers. Less than one-third (29.85%) of the prisoners had a good dietary diversity score (DDS), and three-fourths of prisoners ate three times a day. More than three-fourths (77.45%) of the prisoners had food sources other than the prison. Regarding health-related characteristics, 13.99 and 3.76% of the prisoners had a self-reported current illness and a history of TB treatment in the last 12 months, respectively. In the current study, 5.43% and 1.46% of the prisoners had moderately severe and severe depression during the survey, respectively and were linked to nearby health facilities for further evaluation and management (Table 3).

Magnitude of undernutrition

The overall magnitude of undernutrition among adult prisoners in this study was found to be 20% (95% CI: 16.5–23.6) (Figure 1). Among undernourished prisoners, 6.7% were moderately undernourished.

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TABLE 2 Detention conditions of the prisoners in Fiche town prison, central Ethiopia, 2020 (*n*=479).

Variables	Category	Frequency (*N*)	Percentage (%)
Duration of detention (in months)	6–12	115	24.01
	13–24	142	29.64
	25–59	114	23.80
	>59	108	22.55
History of previous detention	Yes	63	13.15
	No	416	86.85
Sleeping condition	Individual	6	1.25
	In a group	473	98.75
Engaged in income-generating work in the prison	No	103	21.50
	Yes	376	78.50
Family visits	No	346	72.23
	Yes	133	27.77
Financial support	No	384	80.17
	Yes	95	19.83

About 23.15% of the male prisoners were undernourished in the study (Figure 2).

Factors associated with undernutrition

In the bivariable binary logistic analysis, sex, financial support, duration of imprisonment, income-generating work in the prison, dietary diversity, and depression were significantly associated with undernutrition. The odds of undernutrition among female prisoners were reduced by 49% (AOR = 0.51; 95% CI: 0.26, 0.98). The odds of undernutrition among prisoners with financial support were reduced by 64% (AOR = 0.36; 95% CI: 0.15, 0.87). Prisoners who were incarcerated for 25 to 59 months (AOR = 3.07; 95% CI: 1.33, 7.04) and for greater than 59 months (AOR = 4.56; 95% CI: 2.00, 10.45) were more likely to be undernourished compared to prisoners who were detained for 6 to 12 months. The odds of undernutrition among prisoners engaged in income-generating work were reduced by 73% (AOR = 0.27; 95% CI: 0.15, 0.47). Similarly, the risk of developing undernutrition among prisoners with medium dietary diversity (AOR = 0.35; 95% CI: 0.15, 0.80) and good dietary diversity (AOR = 0.23; 95% CI: 0.08, 0.61) was reduced by 65 and 77%, respectively. Moreover, the odds of undernutrition among prisoners with mild and moderate depression and moderately severe and severe depression were (AOR = 1.9; 95% CI: 1.05, 3.45) and (AOR = 2.78; 95% CI: 1.17, 6.60), respectively (Table 4).

Discussion

This study was conducted to determine the magnitude of undernutrition and associated factors among adult prisoners in Fiche town prison, central Ethiopia. Sex, financial support, duration of imprisonment, income-generating work in the prison, dietary

TABLE 3 Behavioral, nutritional and health-related characteristics of the study participants in Fiche town prison, central Ethiopia, 2020 (*n*=479).

Variables	Category	Frequency (*N*)	Percentage (%)
Smoking	No	413	86.22
	Yes	66	13.78
Alcohol use	No	396	82.67
	Yes	83	17.33
Chew khat	No	463	96.66
	Yes	16	3.34
Meal frequency (per day)	Once	6	1.25
	Twice	56	11.70
	Three times	345	72.03
	Four or more times	72	15.02
Food sources other than the prison	No	108	22.55
	Yes	371	77.45
Dietary diversity (DD)	Low	43	8.98
	Medium	293	61.17
	Good	144	29.85
Self-reported current illness	No	412	86.01
	Yes	67	13.99
History of TB treatment in the last 12 months	No	461	96.24
	Yes	18	3.76
History of medical treatment for the last 2 weeks	No	460	96.03
	Yes	19	3.97
Depression	None/minimal	317	66.18
	Mild	92	19.21
	Moderate	37	7.72
	Moderately severe	26	5.43
	Severe	7	1.46

TB, Tuberculosis.

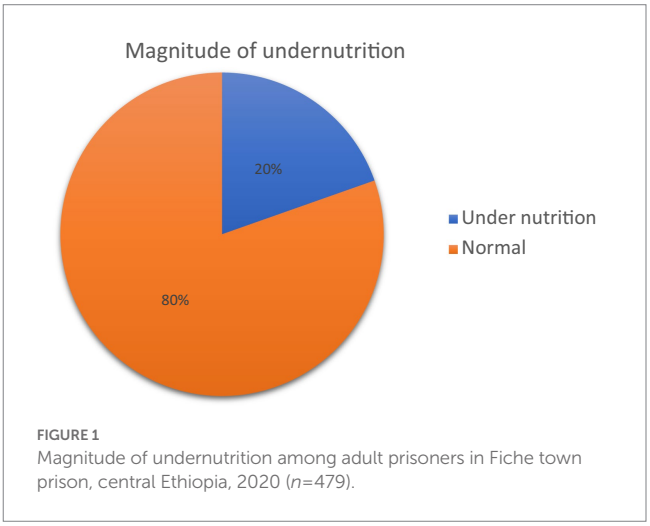

FIGURE 1
Magnitude of undernutrition among adult prisoners in Fiche town prison, central Ethiopia, 2020 (*n*=479).

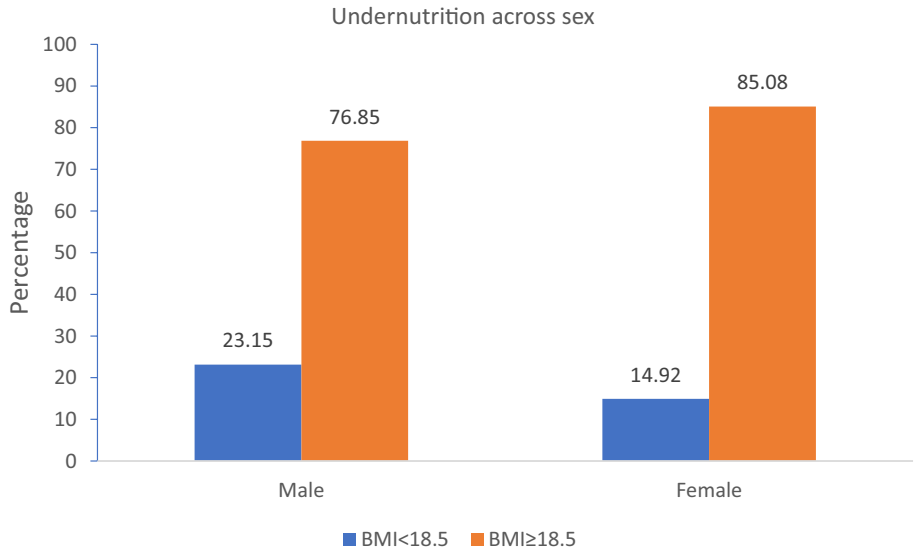

FIGURE 2
Magnitude of undernutrition across sex among adult prisoners in Fiche town prison, central Ethiopia, 2020 (*n*=479).

diversity, and depression were predictors of undernutrition among adult prisoners in Fiche town prison.

In the current study, the overall magnitude of undernutrition among adult prisoners was found to be 20%. This finding is consistent with the studies conducted in Ethiopian prisons: Mizan (18.6%) (31) and Butajira (23.2%) (30). However, this finding is lower than the findings of the studies conducted in Tigray prison, Ethiopia (25.2%) (29), Kality prison, Addis Ababa, Ethiopia (43%) (42) and Antanimora prison, Madagascar (38.4%) (28). This disparity might be because of the difference in characteristics of the study participants. The current study was conducted among all prisoners, but the study conducted in Kality prison was among prisoners living with HIV/AIDS; increasing body demand for nutrients, diminishing body stores, reducing food intake, and adversely affecting nutrient absorption and metabolism (27), whereas a study from Antanimora prison was among female prisoners. In disparity, this finding is higher than the studies from New Guinea (5%) (23) and Nigeria (4%) (43). This discrepancy might be, due to the difference in the study setting, the number of prisoners in the study area and the socioeconomic characteristics of study participants.

In this study, female prisoners were less likely to be undernourished compared to male prisoners. This might be due to the coordinated effort to improve the situation by the female prisoner's administrative office that put female prisoners in a relatively better state of health and nutrition than male prisoners in the study. In addition, women can consume more energy than they expend and accumulate fat more effectively, making them more efficient at energy conservation (44). An additional explanation could be that the federal government has coordinated efforts to ameliorate the situation of female inmates, resulting in better health and nutrition than male inmates (42, 45).

Prisoners who had financial support were less likely to be at risk of developing undernutrition compared to their counterparts. This finding is supported by the studies conducted in Tigray, Butajira and Mizan prisons in Ethiopia which showed prisoners with financial support were less likely to be undernourished (29–31). This could be because prisoners who have financial support can afford to buy meals from outside the prison and thus have better access to adequate and diverse food. Similarly, prisoners who were engaged in income-generating work in the prison were less likely to be undernourished compared to prisoners who were not. This could be because the foods in many prisons are insufficient to provide the body with the essential energy (28), and prisoners who are engaged in income-generating work can afford to buy meals from outside the prison for their caloric needs.

In the present study, the duration of imprisonment was significantly associated with undernutrition. Prisoners who had been imprisoned for a longer time were more likely to be undernourished compared to prisoners who had been imprisoned for a shorter time. This finding is in line with the studies conducted in Tigray, Butajira and Mizan prisons in Ethiopia (29–31). Moreover, this finding is also supported by the study conducted among female prisoners in Antanimora prison, Madagascar (28). The evidence from the study has shown that prison foods are frequently nutritionally deficient, and prisoners who have been detained for a long time are exposed to these nutritionally deficient foods regularly, potentially leading to undernutrition (33).

The finding of this study revealed that prisoners with medium and good dietary diversity were less likely to be undernourished compared to prisoners with lower dietary diversity. Previous literature showed a strong association between dietary diversity and nutritional status (46–48). This is because dietary diversity is associated with food availability and nutrient intake and is an important factor in nutritional outcomes (49).

The finding of the current study further revealed that depression was significantly associated with undernutrition. The prisoners who had depression were more likely to be undernourished compared to their counterparts. The finding

TABLE 4 Factors associated with undernutrition among adult prisoners in Fiche town prison, central Ethiopia, 2020 (n=479).

Variables	Under nutrition		COR (95% CI)	p-value	AOR (95% CI)	p-value
	Yes (n =96) N (%)	No (n =383) N (%)				
Sex						
Male	69 (23.15)	229 (76.85)	1		1	
Female	27 (14.92)	154 (85.08)	1.01 (0.64–1.61)	0.07	0.51(0.26–0.98)[a]	**0.04**
Age category (in years)						
18–29	24 (20.17)	95 (79.83)	1		1	
30–39	21 (15.79)	112 (84.21)	0.78 (0.39–1.41)	0.19	0.63 (0.28–1.40)	0.26
40–49	20 (17.70)	93 (82.30)	0.85 (0.44–1.64)	0.24	0.84 (0.31–2.03)	0.70
>49	31 (27.19)	83 (72.81)	1.47 (0.80–2.72)	0.10	0.98 (0.39–2.42)	0.97
Marital status						
Never married	65 (21.10)	243 (78.90)	1		1	
Ever married	31 (18.13)	140 (81.87)	0.82 (0.51–1.33)	0.21	1.06 (0.60–1.88)	1.06
Financial support						
No	86 (22.39)	298 (77.61)	1		1	
Yes	10 (10.53)	85 (89.47)	0.41 (0.20–0.82)	0.23	0.36 (0.15–0.87)[a]	**0.02**
Food sources other than the prison						
No	24 (22.22)	84 (77.78)	1		1	
Yes	72 (19.41)	299 (80.59)	0.84 (0.50–1.42)	0.63	0.82 (0.39–1.68)	0.58
Duration of imprisonment (in months)						
6–12	12 (10.43)	103 (89.57)	1		1	
13–24	17 (11.97)	125 (88.03)	1.16 (0.53–2.55)	0.68	1.28 (0.55–3.02)	0.56
25–59	(27 23.68)	87 (76.32)	2.66 (1.27–5.57)	0.20	3.07 (1.33–7.04)[a]	**0.00**
>59	40 (37.04)	68 (62.96)	5.05 (2.47–10.31)	0.00	4.56 (2.00–10.45)[a]	**0.00**
Family visits						
No	69 (19.94)	277 (80.06)	1		1	
Yes	27 (20.30)	106 (79.70)	1.02 (0.62–1.68)	0.29	0.66 (0.41–1.20)	0.36
Income-generating work in the prison						
No	41 (39.81)	62 (60.19)	1		1	
Yes	55 (14.63)	321 (85.37)	0.26 (0.16–0.42)	0.02	0.27 (0.15–0.47)[a]	**0.00**
Dietary diversity (DD)						
Low	23 (53.49)	20 (46.51)	1		1	
Medium	241 (82.25)	52 (17.75)	0.24 (0.12–0.47)	0.14	0.35 (0.15–0.80)[a]	**0.01**
Good	120 (83.33)	24 (16.67)	0.22 (0.10–0.46)	0.21	0.23 (0.08–0.61)[a]	**0.00**
Self-reported current illness						
No	57 (13.83)	355 (86.17)	1	0.24	1	
Yes	28 (41.79)	39 (58.21)	4.47(2.55–7.83)		5.20 (2.69–10.07)	0.07
Depression						
No/minimal	49 (15.46)	268 (84.54)	1		1	
Mild & moderate	37 (28.68)	92 (71.32)	2.05 (1.24–3.39)	0.03	1.90 (1.05–3.45)[a]	**0.01**
Moderately severe & severe	10 (30.30)	23 (69.70)	2.83 (1.39–5.79)	0.02	2.78 (1.17–6.60)[a]	**0.00**

[a]Significantly associated variables at a p-value <0.05. The bold values are to indicate/show significantly associated variables that had p-value <0.05.

of this study is in line with the study conducted in Mizan Prison Institute, Ethiopia (31). This could be, due to depression, which can affect people's appetite and lead to a reduction in food intake, resulting in significant weight loss and undernutrition (41, 50). The evidence from the studies also showed that malnutrition increases the risk of depression (51).

Strengths and limitations

The primary data were gathered from the study participants and used in this study to determine the magnitude of undernutrition. The calibrated and standardized anthropometric instruments were used to minimize measurement error. The study provides research-based relevant data on the magnitude of undernutrition and identifies its determinant factors which could help health policymakers in designing evidence-based preventive measures. Despite these important merits, the study had the following limitations. Primarily, due to the nature of the cross-sectional study design, it was difficult to establish the cause-effect relationship between the variables. Secondly, the BMI used to measure undernutrition was one of the limitations since it is not sensitive enough to recognize small clinically significant weight loss. The self-reported questionnaires were prone to social desirability bias. Moreover, recall bias was another limitation since some questions were asked about the events that occurred 24 h back. This was minimized by probing the respondents about the events.

Conclusion

The magnitude of undernutrition among adult prisoners was found to be high. One in five prisoners was undernourished in Fiche town prison, alarming the need for urgent and appropriate interventions. Sex, financial support, duration of imprisonment, income-generating work in the prison, dietary diversity, and depression were predictors of undernutrition. Therefore, the prison authorities should ensure that prisoners have access to healthy food options and diversified diets, as well as implementing early screening and treatment of depression are crucial in reducing the burden of undernutrition and related health conditions. In addition, encouraging prisoners to participate in income-generating activities within the prison is recommended in the study setting. Moreover, prisoners who lack social support and have been incarcerated for a prolonged period of time should be given special attention.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Haramaya University, College of Health and Medical Sciences' Institutional Health Research and Ethics Review Committee (IHRERC). The patients/participants provided their written informed consent to participate in this study.

Author contributions

MW, AS, and BA conceived, designed, acquired data, analyzed, and interpreted the findings. IK, AG, SH, AM, and BA revised and provided critical intellectual feedback. IK and SH drafted the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Undernutrition among rural school-age children: a major public health challenge for an aspirational district in Karnataka, India

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Background: For school-age children, a healthy transition from childhood to adolescence and adulthood depends on proper nutrition. Globally, most nutritional surveys focus on preschool and adolescents, neglecting school-age children. Recent studies have shown the prevalence of thinness among adolescents to be 26.5% in Karnataka. Similarly, among children aged < 5 years in the Raichur district, the prevalence of stunting, wasting, and being underweight was 39.8, 23.2, and 40.7%, respectively. The present study aimed to bridge the data gap between < 5 years of children and adolescents through a nutritional survey of school-going children in Raichur, one of the aspirational districts of India.

Materials and methods: A cross-sectional survey was conducted from January to March 2020 among rural school-age children ($n = 2700$) in 30 villages of the Raichur district of Karnataka, India. The school children were selected through a multi-stage cluster sampling technique. The WHO Anthro-plus software was used for calculating the age and sex-specific Z-scores for weight-for-age (WAZ), height-for-age (HAZ), and BMI-for-age (BAZ).

Results: Of the 2,700 school-age children surveyed, the mean weight and height were 22.2 kg (±5.8) and 124.9 cm (±11.6), respectively. The prevalence of children having weight-for-age Z-scores < −2 SD (Underweight) was 45.3% (95% CI: 42.7%–47.8%). The magnitude of stunting and severe stunting was 19.5% (95% CI: 18.0%–21.0%) and 7.6% (95% CI: 6.6%–8.6%), respectively. The proportion of children with BMI for age Z-scores < −2SD (thinness) was 43% (95% CI: 41.1%–44.9%), with sub-district Sindhanur having a dual burden of malnutrition.

Conclusion: Despite many flagship programs, the prevalence of undernutrition in school-age children remains a considerable public health problem in the aspirational district of Raichur, India. Furthermore, exploratory studies are recommended to identify the factors associated with undernutrition among school-age children and strategize evidence-based intervention.

KEYWORDS

anthropometry, undernutrition, school-age children, stunting, thinness, BMI

Introduction/background

Undernutrition is still a significant health challenge globally, especially in low- and middle-income countries (1). Undernutrition comprises four forms: stunting (low height-for-age), wasting (low weight for height), underweight (low weight-for-age), and micronutrient deficiencies. Globally in 2020, 149 million children were stunted, 45 million were estimated to be wasted, and approximately 45% of deaths among children below the age of 5 years were associated with undernutrition (2). A recently conducted National Family Health Survey-5 in India during 2019–2020 estimated that 35%, 19.3%, and 32.1% of children younger than 5 years were stunted, wasted, and underweight, respectively (3). Despite several large-scale flagship programs such as the Mid-Day Meal Scheme, Integrated Child Development Services (ICDS), and Prime Minister's Overarching Scheme for Holistic Nutrition (POSHAN), the persistence of undernutrition in India is impeding the efforts to achieve the targets set by the National Nutrition Mission in which the aim is to reduce the stunting in children (0–6 years of age) from 38.4% to 25% by 2022 (Mission 25 by 2022) in India (4, 5).

Undernourished children have a high risk of infection due to immune dysfunction (6, 7), growth flattering (8), neurocognitive impairment, decreased physical capacity, poor academic performance, increased absenteeism, and early school dropout (7, 9–11). While monitoring the nutritional indicators among children younger than 5 years has always been key in the Millennium Development Goals, the Sustainable Development Goals, and the NFHS-5 survey in India (3, 12, 13), it has inadvertently led to overlooking nutritional status among school-age children. Older children and adolescents are mainly at risk of undernutrition because they experience a growth spurt, requiring all essential macronutrients and micronutrients to supplement the body's increased demand for attaining puberty and development. Many studies have also documented that undernutrition is associated with delayed sexual maturation, which is required to achieve an adult's developmental potential (14, 15).

Globally, most nutritional surveys primarily focus on children of < 5 years and adolescents (11–15), neglecting school-going children, which have been highlighted in a few studies conducted in India and African countries (7, 10, 16). A nutritional survey of school-going children is essential in understanding their transition from childhood to adolescence and adulthood (14–17). The preschool years are the first crucial time for intervention when a child's overall growth is compromised. However, some studies have shown evidence of catch-up growth beyond the preschool age. With the right nutritional interventions, school-going children who are undernourished have a significantly high chance of catching up during the pubertal period (the second crucial time) (15, 18, 19). The World Health Organization (WHO) added growth standards for children aged 5 to 19 years in 2007 by using the prevalence of stunting, underweight, and thinness as undernutrition indicators rather than wasting in recognition of the importance of the age group and to close the gap (20). Despite that, nutritional data on school-aged children are globally scarce, including in India (21, 22).

India is a large nation with a diverse geography, climatic conditions, socioeconomic distribution, religion, culture, and food habits. Thus, the prevalence of undernutrition differs substantially between the states and districts. NITI Aayog of the Government of India introduced the Aspirational Districts Programme in 2018 to catalyze development in the 112 most backward districts of the country (23, 24). In Karnataka, Raichur and Yadgir are the only two districts in the Aspirational Districts Programme. The program aims to rapidly and sustainably transform the backward districts to catch up with the rest of the country in terms of key development indicators. The Aspirational Districts Programme is a holistic effort to address all aspects of development, including health and nutrition. The introduction of the Aspirational Districts Programme recognizes that despite decades of action, there are still significant disparities in the development across India. The program will go a long way in ensuring that the fruits of development reach all sections of society, especially the most vulnerable and marginalized (24). Raichur district has a low literacy rate of 59.56%, indicating limited educational attainment (25). The NITI Aayog report highlights that 32.19% of the population in Raichur experiences multidimensional poverty, emphasizing the prevalence of socioeconomic challenges in the region (26).

The prevalence of stunting, wasting, and being underweight among children aged < 5 years was 39.8, 23.2, and 40.7%, respectively, in the Raichur district (27). The prevalence of thinness among adolescents was 26.5% in the state of Karnataka (28). There is a need to bridge the data gap regarding the growth and nutritional status between children of age < 5 years and adolescents. Hence, the present study was designed to evaluate the nutritional status among school-age children in one of the aspirational districts of India.

Materials and methods

Study design

The present cross-sectional study was conducted on rural school-going children (6–12 years), which was chosen using a multi-stage cluster sampling method. It was a part of the Iodine Deficiency Disorder survey conducted in the rural areas of the Raichur district from January to March 2020. The survey was solicited by the Deputy Director of Nutrition, Directorate of Health and Family Welfare Services, Government of Karnataka.

Study setting and participants

Five clusters/sub-districts covering 30 villages in the Raichur district, Karnataka, were included in the study. The number of villages covered in each sub-district/taluka was; Devadurga 5, Lingasugur 7, Manvi 7, Raichur 6, and Sindhanur 5 villages. The children of age group 6–12 years studying in the government primary schools of the selected villages were included in the study.

Sample size and sampling techniques

This study was a part of the Iodine Deficiency Disorders (IDD) survey conducted under the National Iodine Deficiency Disorders

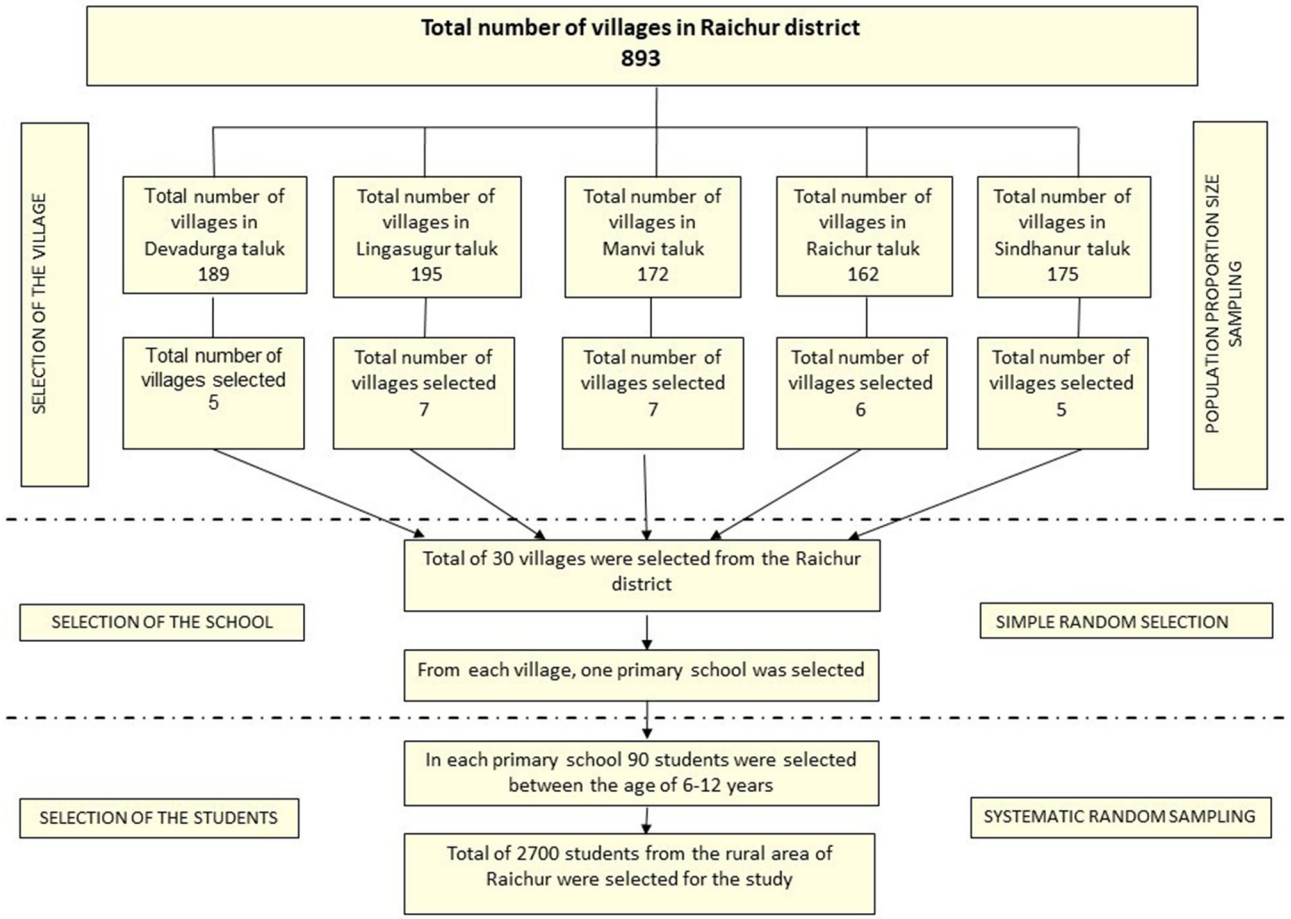

FIGURE 1
Flowchart summarizing the sampling process adopted during the study.

Control Programme (NIDDCP). Thus, followed the sample size and sampling method as per Revised NIDDCP guidelines (29). No formal sample size estimation was carried out for the study. The samples were selected using a multi-stage cluster sampling method with probability proportional to size. The survey involved a sample size of 2,700 students, comprising 90 children from each village. Figure 1 describes the flow of sampling conducted during the study.

Selection of the villages using the PPS method

A total of 30 villages from the five sub-districts/talukas of the Raichur district were selected using the PPS systematic sampling method. Initially, the complete list of villages and the population were obtained from the Zilla Panchayat Office, Raichur. Later, the villages were selected after calculating sampling intervals, and the first village was chosen randomly. The following steps were involved during the selection process of the villages.

1. Number of villages = 30
2. Calculation of sampling interval

$$= \frac{\text{Total population of the district}}{30} = \text{“k”}$$

3. Selection of random start between 1 to k, say “n”
4. Selected random numbers were n, n+k, n+2k,..... n+29k.

Finally, five villages from Devadurga, seven from Lingasugur, seven from Manvi, six from Raichur, and five from Sindhanur were included.

Selection of the school in the village by simple random sampling

Many of the chosen villages had one primary school; in the villages with more than one primary school, the school was selected randomly by the balloting method.

Selection of the students from schools by systematic random sampling

On the day of the visit, the list of students (6–12 years) present was obtained from the attendance register of the school. The students in each school were stratified by their grades and gender. Both male and female children were included proportionately in a 1:1 ratio. Later, 90 students allocated to the school were distributed to six participating grades, proportionately based on the student population in the class. Finally, students were selected in each stratum using a systematic random sampling technique.

Ethical consideration

The study documents were reviewed and approved by the Institutional Ethics Committee of Raichur Institute of Medical Sciences (RIMS), with approval number RIMS/IEC/Approval/02/22–23. During the survey, written consent from the parents/guardians of the students was obtained. Verbal assent was taken from the children between the age of 6 and 12 years. Before starting the survey, permission was sought from the concerned government officials.

Anthropometric data collection

The data were collected by the qualified and trained doctors of RIMS and a medical scientist from the Model Rural Health Research Unit (Indian Council of Medical Research—National Institute of Traditional Medicine) using a pretested, structured questionnaire and a checklist to record anthropometric measurements. Before the survey, the data collecting team was trained at RIMS, Raichur, regarding data collection, anthropometric measurements, and clinical assessment. Weights in kilograms were recorded to the nearest 100 g (0.1 kg) using SECA®813 digital flat scale. Similarly, height was measured in centimeters to the nearest 1 mm (0.1 cm) using SECA portable stadiometer model 213. To minimize error, the height and weight of each child were measured thrice, and the average was considered. Using a standard 10 kg weight, the weighing scale was checked for accuracy and consistency each day before commencing the survey. While measuring the height, the children were asked to stand on the stadiometer in such a way that their heels, buttocks, and heads touched the vertical stand of the stadiometer. The heads of the students were positioned at the Frankfurt Horizontal Line/Eye Ear line to ensure uniformity. Later, the anonymized data were entered into Microsoft Excel for further analysis.

TABLE 1 Characteristics of the school children surveyed in the rural areas of the Raichur district.

Characteristics	Number (%)
Age (n = 2,700)	
6 years	373 (13.8%)
7 years	381 (14.1%)
8 years	398 (14.7%)
9 years	392 (14.5%)
10 years	386 (14.3%)
11 years	379 (14.0%)
12 years	391 (14.5%)
Gender (n = 2,700)	
Male	1,349 (49.9)
Female	1,351 (50.1)
Height (cm) (Mean ±SD)	124.9 ± 11.6
Weight (kg) (Mean ±SD)	22.2 ± 5.8
Cluster/Taluka (n = 2,700)	
Manvi	630 (23.3%)
Devadurga	450 (16.7%)
Lingasur	630 (23.3%)
Raichur	540 (20.0%)
Sindhanur	450 (16.7%)
Weight for Age (Underweight) (n = 1,540)	
Normal	843 (54.7%)
Moderate underweight	423 (27.5%)
Severe underweight	274 (17.8%)
Height for Age (Stunting) (n = 2,688)	
Normal	1,958 (72.8%)
Moderate stunting	525 (19.5%)
Severe stunting	205 (7.6%)
BMI for Age (Thinness) (n = 2,602)	
Severe Thinness	556 (21.4%)
Thinness	563 (21.6%)
Normal BMI	1,371 (52.7%)
Overweight	65 (2.5%)
Obese	26 (1%)
Severely Obese	21 (0.8%)

Data analysis

The data were imported into SPSS software (IBM SPSS Statistics for Windows, version 25) and were analyzed for descriptive statistics. Two-sample Z-test of proportions was performed to determine any significant difference in age and gender characteristics. Z-scores were computed using the WHO Anthro-plus software for weight-for-age (WAZ), height-for-age (HAZ), and BMI for age (BAZ). Underweight, stunting, and thinness were assessed using WAZ, HAZ, and BAZ, respectively, based on the WHO growth reference 2007 criteria for measuring malnutrition in school-age children (20). Z-score values below−2SD were considered underweight, thin, and stunted. Z-scores between−2SD

and−3SD were considered moderate, whereas < −3SD was considered severe. BAZ greater than +1SD and less than +2SD was referred to as overweight, +2SD to +3SD as obese, and > +3SD was defined as severely obese. The WAZ was calculated up to the age of 9 years (119 months), as it is insufficient for growth monitoring beyond 10 years due to its inability to differentiate between relative height and body mass. The distribution plots of Z-scores based on age, sex, and cluster (taluka) compared with WHO child growth standards were also generated using WHO Anthro-plus software.

Results

The study included 2,700 rural school students from 30 different schools in the Raichur district of Karnataka. After data cleaning, measurements for weight and height were available for 2,602 (96.4%) and 2,688 (99.5%) students, respectively. The age of children ranged from 72 to 155 months. There was an even distribution of male (1,349; 49.9%) and female (1,351; 50.1%) school children for the study. The mean weight and height of the study sample were 22.2 kg (±5.8) and 124.9 cm (±11.6), respectively (Table 1). Figure 2 illustrates the prevalence of underweight, stunting, and thinness categorized by age and gender. The kernel density plots for WAZ, HAZ, and BAZ portrayed skewness toward the left side when compared with the WHO growth standard graph (Figure 3).

Weight-for-age

Of the 1,540 total samples, 698 (45.3% (95% CI: 42.7%−47.8%) children had a WAZ score below−2 SD (underweight). The prevalence of severe underweight among the children was 17.8% (95% CI: 15.8%−19.7%). Male children were more likely to be underweight at 47.4% (95% CI: 43.7%, 51%) compared with female children at 43.2% (95% CI: 39.7%−46.8%); however, the difference was not statistically significant (p-value = 0.098). In male children, the prevalence of underweight was high in the age group of 96–107 months 60.9% (95% CI: 53.8–68%); whereas in female children, it was high in 108–119 months, 51.5% (95% CI: 44.3–58.7%); of age (Figure 2; Table 2).

Height-for-age

Among 2,688 school children, stunting (HAZ score below−2 SD) was found in 27.2% (95% CI: 25.5%−28.9%), and the proportion of severe stunting was 7.6% (95% CI: 6.6%−8.6%). Female children were marginally more stunted as compared with male school children (28.6% (95% CI: 26.1%−31%) vs. (25.7% (95% CI: 23.4%−28.1%) but not statistically significant (p-value = 0.0841). Within the age group, stunting was high in the age group of 144–155 months in both male (34.0%) and female (43.7%) school children, and the difference between the genders was significant with a p-value of < 0.001 (Table 3). The graph generated from the WHO AnthroPlus has also shown the distribution of the HAZ scores among the school children shifted toward the left compared with the WHO growth standard graph (Figure 3).

BMI-for-age

The prevalence of severe thinness, thinness, overweight, obesity, and severe obesity in school-age children was shown by the distribution of BAZ scores in the study samples to be 21.4% (95% CI: 19.8%−23%), 21.6% (95% CI: 20.1%−23.2%), 2.5% (95% CI: 1.9%−3.1%), 1% (95% CI: 0.6%−1.4%), and 0.8% (95% CI: 0.5%−1.2%), respectively. In male and female children combined, the prevalence of thinness [(46.2%) (41%−51.3%)] was high in the age group of 144–155 months. The study's findings depicted a statistically significant (p-value = 0.0001) higher prevalence of thinness in male children [(46.8%) (95% CI: 44.1%−49.6%)] than in female children [(39.3%) (95% CI: 36.6%−41.9%)]. In male children of the age group of 96–107 months, the prevalence of thinness was much higher [(54.4% (95% CI: 46.9%−61.9%)] compared with the other age groups. Similarly, in female children, the prevalence of thinness [(41.7%) (95% CI: 34.4%−49%]) was high in the age group of 84–95 months (Figure 2; Table 4).

Geographical/cluster distribution

The geographical distribution of WAZ score <-2SD was high in Lingasugur taluka at 48.9% (95% CI: 43.8%−54.0%), followed by Devadurga at 46.5% (95% CI: 40.5%−52.6%), Manvi at 45.1% (95% CI: 40.0%−50.3%), Raichur at 43.5% (95% CI: 37.9%−49.1%), and Sindhanur at 40.9% (95% CI: 34.8–46.9). The distribution of HAZ score <-2SD was more in Devadurga taluka at 34.6% (95% CI: 30.1%−39.1%), and it was the least in Manvi at 20.0% (95% CI: 16.8%−23.2%). Among all the districts, the prevalence of thinness BMI-Z scores <-2SD was high in Manvi taluka at 49.4% (95% CI: 45.3%−53.4%) followed by Lingasugur taluka at 46.5% (95% CI: 42.4%−50.6%) and other talukas of Raichur district. Severe thinness (< −3SD) was found highly prevalent in Lingasugur, 27.5% (95% CI: 23.8%−31.2%), compared with Manvi taluka, 22.9% (95% CI: 19.5%−26.3%). One of the interesting findings in Sindhanur taluka was the very high prevalence of overweight [(7.2%) (95% CI: 4.6%−9.8%)] and obesity [(3.7%) (1.8%−5.6%)] compared with the rest of the talukas in the district (Table 5).

Discussion

The NFHS-5 (2019–2020) findings from the Raichur district have highlighted a high prevalence of stunting (39.8%), wasting (23.2%), and underweight (40.7%) in the under-5 age group (28). The lack of nutritional data in school-age children from one of the most backward districts of Karnataka stressed the immediate need to bridge the gap. Thus, the current study aimed at generating evidence to devise holistic interventions in future. The results of the present study illustrated the perpetuation of undernutrition in school-going children.

The present study found an overall high prevalence of underweight (45.3%), with 17.8% of the children being severely

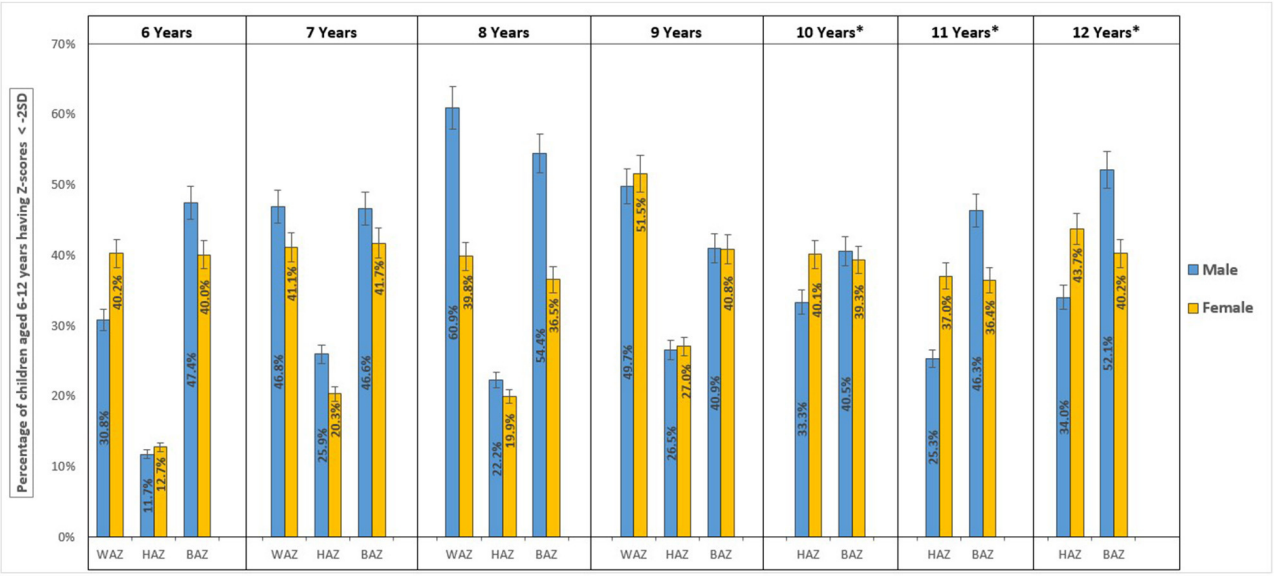

FIGURE 2
Prevalence of undernutrition, stunting, and thinness among school age children (6–12 years) categorized by age and gender.

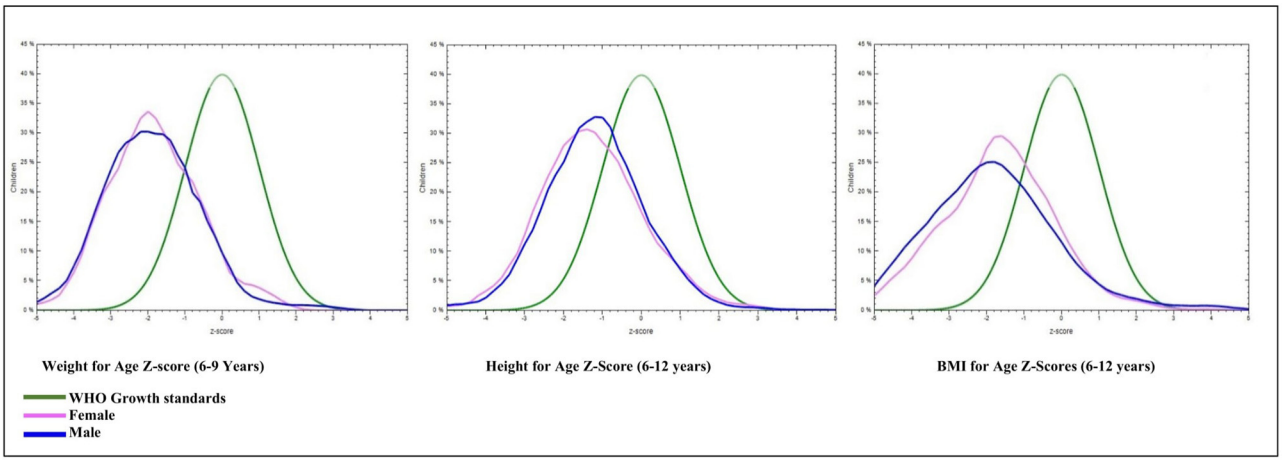

FIGURE 3
Kernel density plots displaying *Z*-score distribution of Weight-for-Age, Height-for-Age, and BMI- for-Age by gender compared with WHO reference 2007 (61 months to 19 years) normal distribution curve.

underweight, with no significant difference between the genders. The findings of this study suggest that the prevalence of underweight in the study area was higher compared with the overall prevalence of Karnataka reported in the Comprehensive National Nutritional Survey (CNNS) 2019. According to CNNS data for the age group of 5–9 years, the distribution of WAZ less than−2SD was 35.2% and 39.5% in India and Karnataka, respectively, whereas this study showed that in the Raichur district, it was 45.3%. Similarly, the percentage below−3SD was 10.0% at the national level, 11.3% at the state level (27), and 17.8% at the study district. One of the studies conducted in the Mandya district of Karnataka reported the underweight to be 30.3%, which was significantly less compared with this study's results (30). A study conducted in Telangana, a neighboring state of Karnataka, had reported 30.85% underweight (31), and a study conducted in Punjab found that 58.8% of children (5–9 years) were severely underweight (10). This study showed a higher prevalence of underweight than studies conducted in Sri Lanka, Nigeria, and Nepal (7, 32, 33) and a lower prevalence than a study conducted in Ethiopia, where the prevalence was 59.7% (34). The underweight results of this study mirror the results of the study in Ghana, where the prevalence was 45.8% (35). The studies conducted by Isanaka et al. (36) in Colombia and Ieiri et al. (37) in the Philippines have established a relationship between the underweight and food insecurity, utilizing underweight as a nutritional indicator to assess recent weight loss or taking into consideration people who are unable to gain weight because of a

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TABLE 2 Distribution of weight-for-age among the school children of age 6–9 years in the rural areas of Raichur district, Karnataka, India.

Age groups			Weight-for-age** (%)					
Years	Months	N	% < −3SD	(95% CI)	% < −2SD[1]	(95% CI)	Mean	SD
Male								
6	(72–83)	182	14.3	(8.9%, 19.6%)	30.8	(23.8%, 37.7%)	−1.47	1.41
7	(84–95)	188	17.6	(11.8%, 23.3%)	46.8	(39.4%, 54.2%)	−1.96	1.25
8	(96–107)	197	30.5	(23.8%, 37.1%)	60.9	(53.8%, 68%)	−2.24	1.25
9	(108–119)	191	15.2	(9.8%, 20.5%)	49.7	(42.4%, 57.1%)	−1.92	1.21
Total (6–9)	(72–119)	758	19.5	(16.6%, 22.4%)	47.4	(43.7%, 51%)	−1.91	1.31
Female								
6	(72–83)	189	6.9	(3%, 10.8%)	40.2	(33%, 47.5%)	−1.49	1.15
7	(84–95)	192	10.9	(6.3%, 15.6%)	41.1	(33.9%, 48.4%)	−1.77	1.19
8	(96–107)	201	19.4	(13.7%, 25.1%)	39.8	(32.8%, 46.8%)	−1.74	1.2
9	(108–119)	200	26.5	(20.1%, 32.9%)	51.5	(44.3%, 58.7%)	−2	1.35
Total (6–9)	(72–119)	782	16.1	(13.5%, 18.8%)	43.2	(39.7%, 46.8%)	−1.75	1.24
Both Sexes Combined								
6	(72–83)	371	10.5	(7.3%, 13.8%)	35.6	(30.6%, 40.6%)	−1.48	1.28
7	(84–95)	380	14.2	(10.6%, 17.9%)	43.9	(38.8%, 49.1%)	−1.86	1.22
8	(96–107)	398	24.9	(20.5%, 29.2%)	50.3	(45.2%, 55.3%)	−1.99	1.25
9	(108–119)	391	21	(16.8%, 25.1%)	50.6	(45.6%, 55.7%)	−1.96	1.28
Total (6–9)	(72–119)	1540	17.8	(15.8%, 19.7%)	45.3	(42.7%, 47.8%)	−1.83	1.27

[1]Includes children who are below−3 SD from the WHO Child Growth Standards. **Weight-for-age reference data are not available beyond 10 years because this indicator does not distinguish between height and body mass in an age period where many children are experiencing the pubertal growth spurt and may appear as having excess weight (by weight-for-age) when in fact they are just tall.

lack of food supply or intake due to episodes of disease (38, 39). The findings of this study make way to explore the challenges associated with food insecurity in the Raichur district, where most of the children mainly depend on mid-day meals to cover most of their daily calorie requirements. The Mid-Day Meal Scheme is a government-sponsored program in India that aims to improve the nutritional status among primary and upper primary school children by providing free mid-day meals, meeting the minimum nutritional standard of 450–700 kCal and 12–20 g of protein (40).

Another notable finding of this study was the left-side skewness of the HAZ kernel density plots compared with the WHO growth standard graph, indicating the high prevalence of stunting. The distribution of stunting in the study area was more when compared with that of Karnataka (27). The study results align with the findings of the studies conducted in the south Indian districts of Mandya and Karimnagar (30, 31); however, higher compared with the study in Sri Lanka (32) and Nigeria (7) and much lower compared with the study undertaken in Ethiopia by Herrador et al. (41). According to the report of NFHS-5 data and the Raichur district nutrition profile carried out in 2020 by the International Food Policy Research Institute (IFPRI), the prevalence of stunting was approximately 40% among < 5-year-old children (28, 42), indicating that the interventions to address undernutrition have not yielded the expected results in the aspiration district. In this study, the distribution of stunting was found more in female children compared with male children; a similar trend was observed in the study conducted by Nowsin et al. (43) in Bangladesh; in contrast, the study in Srilanka by Naotunna et al. (32) found a higher distribution of stunting in male children than female children. Another study from Abakaliki metropolis of Nigeria found no difference in the stunting proportion between the genders (7). Stunting was most prevalent in the age group of 144–155 months, with a significantly high occurrence among female children compared with male children. The study conducted by Bongale Y T et al. observed that children aged 10–12 years had a 70% higher likelihood of experiencing stunting compared with children aged 6–7 years. One of the reasons could be prolonged exposure to chronic food shortages (44). The finding of higher prevalence among female children could be linked to the factors such as household dynamics, gender bias, and parental preferences, favoring male children (45). Several studies have found that mothers' educational status, poor dietary diversity, household income, and size were significantly associated with stunting (5, 46, 47). Since Raichur is one of the most socioeconomically underdeveloped districts, it is important to identify the causes of stunting, especially in female children because the effects of stunting tend to be passed down from generation to generation and have an impact on pregnancy outcomes such as small for gestational age and preterm birth (48).

The high prevalence of thinness indicates acute undernutrition, perhaps due to an acute shortage in the supply or intake of food (7). This study found a significantly higher prevalence of thinness (43%)

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TABLE 3 Distribution of height-for-age among the school children of age 6–12 years in the rural areas of Raichur district, Karnataka, India.

Age groups			Height-for-age (%)					
Years	Months	N	% < −3SD	(95% CI)	% < −2SD[1]	(95% CI)	Mean	SD
Male								
6	(72–83)	180	2.2	(0%, 4.7%)	11.7	(6.7%, 16.6%)	−0.49	1.41
7	(84–95)	189	7.4	(3.4%, 11.4%)	25.9	(19.4%, 32.4%)	−0.99	1.53
8	(96–107)	194	5.7	(2.2%, 9.2%)	22.2	(16.1%, 28.3%)	−1.1	1.34
9	(108–119)	189	6.3	(2.6%, 10.1%)	26.5	(19.9%, 33%)	−1.25	1.15
10	(120–131)	198	7.1	(3.2%, 10.9%)	33.3	(26.5%, 40.2%)	−1.32	1.25
11	(132–143)	190	3.7	(0.7%, 6.6%)	25.3	(18.8%, 31.7%)	−1.41	1.15
12	(144–155)	200	13.5	(8.5%, 18.5%)	34	(27.2%, 40.8%)	−1.79	1.09
Total (6–12)	(72–155)	1340	6.6	(5.3%, 8%)	25.7	(23.4%, 28.1%)	−1.21	1.33
Female								
6	(72–83)	189	3.7	(0.7%, 6.7%)	12.7	(7.7%, 17.7%)	−0.66	1.33
7	(84–95)	192	4.7	(1.4%, 7.9%)	20.3	(14.4%, 26.3%)	−0.85	1.37
8	(96–107)	201	6.5	(2.8%, 10.1%)	19.9	(14.1%, 25.7%)	−0.99	1.45
9	(108–119)	200	4	(1%, 7%)	27	(20.6%, 33.4%)	−1.19	1.14
10	(120–131)	187	12.3	(7.3%, 17.3%)	40.1	(32.8%, 47.4%)	−1.7	1.25
11	(132–143)	189	12.2	(7.2%, 17.1%)	37	(29.9%, 44.2%)	−1.6	1.28
12	(144–155)	190	17.4	(11.7%, 23%)	43.7	(36.4%, 51%)	−1.92	1.17
Total (6–12)	(72–155)	1348	8.6	(7.1%, 10.1%)	28.6	(26.1%, 31%)	−1.27	1.36
Both Sexes Combined								
6	(72–83)	369	3	(1.1%, 4.9%)	12.2	(8.7%, 15.7%)	−0.58	1.37
7	(84–95)	381	6	(3.5%, 8.6%)	23.1	(18.7%, 27.5%)	−0.92	1.45
8	(96–107)	395	6.1	(3.6%, 8.6%)	21	(16.9%, 25.2%)	−1.04	1.4
9	(108–119)	389	5.1	(2.8%, 7.5%)	26.7	(22.2%, 31.3%)	−1.22	1.14
10	(120–131)	385	9.6	(6.5%, 12.7%)	36.6	(31.7%, 41.6%)	−1.51	1.26
11	(132–143)	379	7.9	(5.1%, 10.8%)	31.1	(26.3%, 35.9%)	−1.51	1.22
12	(144–155)	390	15.4	(11.7%, 19.1%)	38.7	(33.8%, 43.7%)	−1.85	1.13
Total (6–12)	(72–155)	2688	7.6	(6.6%, 8.6%)	27.2	(25.5%, 28.9%)	−1.24	1.34

[1]Includes children who are below−3 SD from the WHO Child Growth Standards.

than the overall prevalence in India (23.0%) and Karnataka (28.2%) (27). The distribution of thinness was more in male children when compared with female children. One reason could be gender disparities in physical activity levels, contributing to differences in energy expenditure between male and female children. According to a longitudinal study, male children demonstrated a daily increase in local energy expenditure from the age of 5 to 10 years. In contrast, female children experienced a significant 50% decline in physical activity between the age of 6 and 9 years (49, 50). There may be various sociocultural and psychosocial factors that influence the socialization of girls toward physical activity, necessitating further exploration. Similar findings were observed in the study conducted in Sudan, Nigeria, Sri Lanka, and Myanmar (7, 32, 51, 52). One of the interesting findings of the study was the geographical variation in the distribution of BMI for age Z-scores, particularly with the Sindhanur sub-district/taluka, where the prevalence of > +1SD and > +2SD was high compared with that of other talukas in the district as well as that of Karnataka state (27). Sindhanur as a major taluka with thriving commercial and industrial activities (53) may have better socioeconomic conditions, explaining the variation compared with other talukas. This finding implies that the interventions should be segmented and much more comprehensive to tackle both thinness and overweight in the target talukas facing the double burden of malnutrition.

Considering this study among some of the limited studies conducted in India regarding malnutrition in school-age children, the authors acknowledge some limitations in this study. The study results should be interpreted after careful contemplation of the methodology. As the study mainly focused on the children of rural areas, the study's findings are valid, particularly for rural settings. Even though adequately trained doctors from RIMS did the anthropometric measurements, some anthropometric

TABLE 4 Distribution of BMI-for-age among the school children of age 6–12 years in the rural areas of Raichur district, Karnataka, India.

Age groups			BMI-for-age (%)											
Years	Months	N	% < −3SD	(95% CI)	% < −2SD[1]	(95% CI)	% > +1SD	(95% CI)	% > +2SD	(95% CI)	% > +3SD	(95% CI)	Mean	SD
Male														
6	(72–83)	171	25.1	(18.4%, 31.9%)	47.4	(39.6%, 55.1%)	7	(2.9%, 11.1%)	5.8	(2%, 9.7%)	3.5	(0.5%, 6.6%)	−1.72	1.85
7	(84–95)	176	25	(18.3%, 31.7%)	46.6	(38.9%, 54.2%)	3.4	(0.4%, 6.4%)	1.7	(0%, 3.9%)	1.1	(0%, 3%)	−1.9	1.66
8	(96–107)	182	30.8	(23.8%, 37.7%)	54.4	(46.9%, 61.9%)	3.8	(0.8%, 6.9%)	1.6	(0%, 3.8%)	0.5	(0%, 1.9%)	−2.12	1.64
9	(108–119)	181	19.3	(13.3%, 25.4%)	40.9	(33.4%, 48.3%)	6.6	(2.7%, 10.5%)	3.3	(0.4%, 6.2%)	2.8	(0.1%, 5.4%)	−1.56	1.75
10	(120–131)	195	21	(15%, 27%)	40.5	(33.4%, 47.7%)	7.2	(3.3%, 11.1%)	3.1	(0.4%, 5.8%)	1	(0%, 2.7%)	−1.57	1.73
11	(132–143)	188	21.3	(15.2%, 27.4%)	46.3	(38.9%, 53.7%)	4.8	(1.5%, 8.1%)	1.6	(0%, 3.7%)	1.1	(0%, 2.8%)	−1.8	1.55
12	(144–155)	190	26.8	(20.3%, 33.4%)	52.1	(44.7%, 59.5%)	3.7	(0.7%, 6.6%)	0.5	(0%, 1.8%)	0	(0%, 0.3%)	−1.97	1.5
Total (6–12)	(72–155)	1283	24.2	(21.8%, 26.5%)	46.8	(44.1%, 49.6%)	5.2	(4%, 6.5%)	2.5	(1.6%, 3.4%)	1.4	(0.7%, 2.1%)	−1.81	1.68
Female														
6	(72–83)	185	18.9	(13%, 24.8%)	40	(32.7%, 47.3%)	5.9	(2.3%, 9.6%)	3.2	(0.4%, 6.1%)	1.1	(0%, 2.8%)	−1.57	1.61
7	(84–95)	187	20.3	(14.3%, 26.4%)	41.7	(34.4%, 49%)	2.1	(0%, 4.5%)	0	(0%, 0.3%)	0	(0%, 0.3%)	−1.78	1.36
8	(96–107)	197	17.8	(12.2%, 23.4%)	36.5	(29.6%, 43.5%)	3	(0.4%, 5.7%)	1.5	(0%, 3.5%)	0	(0%, 0.3%)	−1.63	1.43
9	(108–119)	191	20.9	(14.9%, 27%)	40.8	(33.6%, 48.1%)	4.7	(1.4%, 8%)	1	(0%, 2.8%)	0	(0%, 0.3%)	−1.73	1.6
10	(120–131)	183	16.9	(11.2%, 22.6%)	39.3	(32%, 46.7%)	1.6	(0%, 3.8%)	0.5	(0%, 1.9%)	0	(0%, 0.3%)	−1.63	1.4
11	(132–143)	187	17.6	(11.9%, 23.4%)	36.4	(29.2%, 43.5%)	2.7	(0.1%, 5.3%)	0.5	(0%, 1.8%)	0	(0%, 0.3%)	−1.6	1.38
12	(144–155)	189	18	(12.2%, 23.7%)	40.2	(33%, 47.5%)	3.2	(0.4%, 5.9%)	1.1	(0%, 2.8%)	0.5	(0%, 1.8%)	−1.72	1.39
Total (6–12)	(72–155)	1319	18.7	(16.5%, 20.8%)	39.3	(36.6%, 41.9%)	3.3	(2.3%, 4.3%)	1.1	(0.5%, 1.7%)	0.2	(0%, 0.5%)	−1.66	1.45
Both Sexes combined														
6	(72–83)	356	21.9	(17.5%, 26.3%)	43.5	(38.2%, 48.8%)	6.5	(3.8%, 9.2%)	4.5	(2.2%, 6.8%)	2.2	(0.6%, 3.9%)	−1.64	1.73
7	(84–95)	363	22.6	(18.1%, 27%)	44.1	(38.8%, 49.3%)	2.8	(0.9%, 4.6%)	0.8	(0%, 1.9%)	0.6	(0%, 1.5%)	−1.84	1.51
8	(96–107)	379	24	(19.6%, 28.4%)	45.1	(40%, 50.3%)	3.4	(1.5%, 5.4%)	1.6	(0.2%, 3%)	0.3	(0%, 0.9%)	−1.86	1.55
9	(108–119)	372	20.2	(15.9%, 24.4%)	40.9	(35.7%, 46%)	5.6	(3.2%, 8.1%)	2.2	(0.5%, 3.8%)	1.3	(0%, 2.6%)	−1.65	1.67
10	(120–131)	378	19	(15%, 23.1%)	39.9	(34.9%, 45%)	4.5	(2.3%, 6.7%)	1.9	(0.4%, 3.3%)	0.5	(0%, 1.4%)	−1.6	1.58
11	(132–143)	375	19.5	(15.3%, 23.6%)	41.3	(36.2%, 46.5%)	3.7	(1.7%, 5.8%)	1.1	(0%, 2.2%)	0.5	(0%, 1.4%)	−1.7	1.47
12	(144–155)	379	22.4	(18.1%, 26.8%)	46.2	(41%, 51.3%)	3.4	(1.5%, 5.4%)	0.8	(0%, 1.8%)	0.3	(0%, 0.9%)	−1.84	1.45
Total (6–12)	(72–155)	2602	21.4	(19.8%, 23%)	43	(41.1%, 44.9%)	4.3	(3.5%, 5.1%)	1.8	(1.3%, 2.3%)	0.8	(0.4%, 1.2%)	−1.73	1.57

[1]Includes children who are below −3SD from the WHO Child Growth Standards.

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TABLE 5 Cluster-wise distribution of weight-for-age, height-for-age, and BMI-for-age among the school children of age 6–12 years in the rural areas of Raichur district, Karnataka, India.

Cluster		Weight–for–age** (%)											
	N	% < −3SD	(95% CI)	% < −2SD[1]	(95% CI)	Mean	SD						
Manvi	359	15.6	(11.9,19.4)	45.1	(40.0, 50.3)	−1.76	1.18						
Devadurga	260	19.2	(14.4, 24.0)	46.5	(40.5, 52.6)	−1.9	1.21						
Lingasur	368	21.5	(17.3, 25.7)	48.9	(43.8, 54.0)	−1.94	1.37						
Raichur	301	15.9	(11.8, 20.1)	43.5	(37.9, 49.1)	−1.82	1.17						
Sindhanur	252	16.3	(11.7, 20.1)	40.9	(34.8, 46.9)	−1.7	1.36						
Total	1540	17.8	(15.8%, 19.7%)	45.3	(42.7%, 47.8%)	−1.83	1.27						
Height–for–age (%)													
		% < −3SD	(95% CI)	% < −2SD[1]	(95% CI)	Mean	SD						
Manvi	630	5.2	(3.4%, 7.1%)	20	(16.8%, 23.2%)	−0.99	1.3						
Devadurga	448	10.3	(7.3%, 13.2%)	34.6	(30.1%, 39.1%)	−1.43	1.42						
Lingasur	629	5.6	(3.7%, 7.4%)	26.4	(22.9%, 29.9%)	−1.13	1.34						
Raichur	540	5.4	(3.4%, 7.4%)	28	(24.1%, 31.8%)	−1.31	1.16						
Sindhanur	441	14.1	(10.7%, 17.4%)	29.9	(25.5%, 34.3%)	−1.45	1.47						
Total	2688	7.6	(6.6%, 8.6%)	27.2	(25.5%, 28.9%)	−1.24	1.34						
BMI–for–age (%)													
		% < −3SD	(95% CI)	% < −2SD[1]	(95% CI)	% > +1SD	(95% CI)	% > +2SD	(95% CI)	% > +3SD	(95% CI)	Mean	SD
Manvi	620	22.9	(19.5%, 26.3%)	49.4	(45.3%, 53.4%)	1.8	(0.7%, 2.9%)	0.3	(0%, 0.8%)	0	(0%, 0.1%)	−1.95	1.36
Devadurga	431	15.8	(12.2%, 19.3%)	39.2	(34.5%, 43.9%)	4.4	(2.4%, 6.5%)	0.7	(0%, 1.6%)	0	(0%, 0.1%)	−1.61	1.45
Lingasur	593	27.5	(23.8%, 31.2%)	46.5	(42.4%, 50.6%)	3.5	(2%, 5.1%)	1.2	(0.2%, 2.1%)	0.7	(0%, 1.4%)	−1.91	1.62
Raichur	528	20.1	(16.6%, 23.6%)	41.3	(37%, 45.6%)	3	(1.5%, 4.6%)	0.8	(0%, 1.6%)	0.2	(0%, 0.7%)	−1.71	1.47
Sindhanur	430	17.9	(14.2%, 21.6%)	34.9	(30.3%, 39.5%)	10.2	(7.3%, 13.2%)	7.2	(4.6%, 9.8%)	3.7	(1.8%, 5.6%)	−1.32	1.89
Total	2602	21.4	(19.8%, 23%)	43	(41.1%, 44.9%)	4.3	(3.5%, 5.1%)	1.8	(1.3%, 2.3%)	0.8	(0.4%, 1.2%)	−1.73	1.57

[1]Includes children who are below −3SD from the WHO Child Growth Standards, ** Weight-for-age reference data are not available beyond 10 years because this indicator does not distinguish between height and body mass in an age period where many children are experiencing the pubertal growth spurt and may appear as having excess weight (by weight-for-age) when in fact they are just tall.

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measurement errors attributed to inter-observer and intra-observer bias cannot be denied in the study.

Conclusion

In conclusion, the Raichur district, which is working to catch up with the rest of the country in terms of key development indicators, has a serious problem with undernutrition among school-going children (6–12 years). Additionally, exploratory studies are advised in this age group to break the intergenerational cycle of undernutrition and plan an evidence-based intervention by identifying the factors linked to undernutrition.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Ethics Committee of Raichur Institute of Medical Sciences (RIMS), with approval number RIMS/IEC/Approval/02/22-23. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

PV: project implementation, management, data collection, anthropometry, BMI analysis, and the first draft of the manuscript. SN: project implementation, management, data collection, and the first draft of the manuscript. UP: project implementation, management, data collection, anthropometry, data entry, and the first draft of the manuscript. RK: project implementation, fieldwork management, and finalization of the draft. NC and MB: data review, analysis, drafting, and finalizing the manuscript. SH and SS: project implementation, fieldwork management, and finalization of the draft. SR: conceptualization, overall project management, drafting, and finalization of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Analysis of the nutritional status in the Palestinian territory: a review study

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Background: Food insecurity, occupation, and poverty contribute to the poor nutritional status of Palestine. This review study aimed to analyze the nutritional status in the Palestinian Territory by analyzing published data from 2011 to 2023.

Method: Searching for relevant publications yielded 67 studies. Based on reviewing these studies, five major themes were identified: low birth weight, breastfeeding, obesity and overweight, protein-energy malnutrition, and micronutrient deficiency.

Results: Based on the review of these studies, five major themes were identified, namely, low birth weight, breastfeeding, obesity and overweight, protein-energy malnutrition, and micronutrient deficiency. Based on the literature, the prevalence rate of exclusive breastfeeding was 24.4% in the Gaza Strip, compared to a national rate of 39.9% in 2020. Smoking, anemia in mothers, diet during pregnancy, and indoor pollution were associated with low birth weight. One-fifth of the boys and girls were stunted by 2 years of age in the Gaza Strip, and girls were more stunted than boys. The prevalence rates of underweight, overweight, and obesity among school children in the West Bank were 7.3%, 14.5%, and 15.7%, respectively. Age, gender, and living area were significant predictors of being overweight among school children. The prevalence rates of overweight and obesity among adults in Palestine were 57.8% and 26.8%, respectively. Obesity is associated with a family history, chronic diseases, and low physical activity among adults. Exclusive breastfeeding was below the WHO recommendations, while significant rates of obesity and overweight were found among children and adults. Iron-deficiency anemia (IDA) among pregnant women and children remains a challenging public health issue, while other micronutrient deficiencies are high among children.

Conclusion: This review emphasizes the need for multi-sectoral interventions to address malnutrition and nutritional shifts. It identifies gaps and addresses nutrition-related issues in the Palestinian Territory, which can serve as a basis for guiding United Nations agencies and governments in formulating evidence-based policies and strategies for prioritizing nutritional interventions to meet sustainable development goals.

KEYWORDS

Palestine, nutritional status, obesity, exclusive breastfeeding, stunting, wasting, anemia, vitamin D deficiency

1. Introduction

Palestine (Palestinian territories) is considered one of the Eastern Mediterranean regions (EMR) that suffer from the burden of malnutrition, especially among children, involving deficiencies in micronutrients coupled with elevated rates of non-communicable diseases (NCDs), overweight, and obesity (1–3). Over the past few decades, it has been determined that unhealthy eating habits are the chief risk factor for the global burden of NCDs (3). Based on the Global Burden of Disease (2017 report), high sodium intake and insufficient dietary fibers were the two primary components responsible for 6 million deaths worldwide (4), along with an increase in the prevalence of obesity by 5.9% (5). Lifestyle change is one of the leading reasons for this increase in NCDs over the past several decades (6), leading to nutritional changes such as shifting to high-energy, saturated fat-rich, and sugar-dense meals, and decreasing consumption of complex carbohydrates and fibers (7, 8).

Malnutrition in children, particularly in the early stages of life, is considered high risk for impaired cognitive and physical growth and can increase susceptibility to infectious diseases (9–12). On the other hand, obesity among children has adverse health effects, including metabolic complications and psychological and physiological effects, in addition to long-term complications that may include premature death, NCD later in life, and disability (9, 12–14). Micronutrient deficiency, especially iron deficiency, anemia, vitamin A deficiency, and iodine deficiency, might be considered a silent emergency in many developing and low-income countries, particularly for children, which puts two billion people at risk of experiencing anemia, night blindness, and various other NCDs (15).

Palestine (the West Bank and the Gaza Strip) faces the challenges of military occupation, sieges and curfews, parental unemployment, limited food availability, poverty, and food insecurity, which have all contributed to the deterioration of the nutritional status of the Palestinian population, especially among the more vulnerable groups such as children and women (16). Combating nutrition shifts and malnutrition requires multi-sectoral and multifactorial strategies and interventions (17), particularly in Palestine. These interventions need a comprehensive review of the current nutritional status in Palestine, which would be essential in informing evidence-based prioritization of interventions, the development of national nutritional policies, and monitoring purposes. Therefore, the main objective of this review is to provide a comprehensive overview of the nutritional status in Palestine by reviewing the existing literature and research on specific nutrition indicators, including low birth weight (LBW), malnutrition, stunting, and underweight among children under 5 years of age, as well as breastfeeding practices, overweight and obesity among both children and adults and related behaviors. Additionally, the review focuses on micronutrient deficiencies, including iron deficiency anemia trends among women of reproductive age and children, as well as deficiencies in vitamin A, vitamin D, and iodine-based on the available data and studies. This study's recommendation can aid in the development of policies and strategies that can serve as a guide and tool for donor organizations and government entities to prioritize interventions and formulate nutritional strategic plans. Moreover, this study will shed light on critical data gaps and emphasize the need for political support and interest from United Nations agencies. Furthermore, it aims to address the recommendations of the International Conference on Nutrition (ICN)-2, tackle NCDs, work toward global targets for nutrition, and contribute to the achievement of Sustainable Development Goals.

2. Materials and methods

2.1. Palestinian background information

The estimated population of Palestinian territory (West Bank and Gaza Strip) is 5.35 million (3.18 million in the West Bank, including east Jerusalem, and 2.17 million in the Gaza Strip) (18), and 44% of the population are children (19). Palestine is a densely populated country, with 781 inh/km^2 (the Gaza Strip is 5,138 inh/km^2, and the West Bank is 500 inh/km^2) (20). The estimated life expectancy in 2020 was 74.1 years (West Bank: 74.4 years, Gaza Strip: 73.7 years) (women: 75.3; years, men: 73.3 years) (21). The mortality rate for those under 5 years was 14 per 1,000 (boys: 16 per 1,000, girls: 12 per 1,000) (22). In 2020, NCDs accounted for more than two-thirds of Palestinian deaths (23). Concerning food insecurity, the report from 2020 indicated that 40% of households in the West Bank and 60% in the Gaza Strip are moderately to severely food insecure (24). Moreover, the poverty rate in the Gaza Strip was 53%, compared to 13.9% in the West Bank and 29.2% at the national level (25).

2.2. Study review methodology

To analyze the nutritional status in the Palestinian Territory, a search was carried out between November 2022 and March 2023 to identify relevant studies published in the English language, utilizing various scientific databases, such as PubMed, Science Direct, Scopus, Google Scholar, the ResearchGate website, the Palestinian Ministry of Health website, the Global School-Based Student Health Survey (26), the Palestinian Central Bureau of Statistics (PCBS), and the World Health Organization Seventy-Fifth World Health Assembly A75/26 Provisional Agenda Item 20 (27). Additionally, data from WHO databases, such as the WHO/UNICEF Joint Child Malnutrition Estimate 2021 (28), the WHO/Nutrition Country Profile (29), and the STEP-wise Approach to NCD Risk Factor Surveillance (STEPS) 2021, were also accessed and reviewed (30).

This review presents the prevalence and trends of various nutritional indicators, focusing on the periods when national data are available over the years. Moreover, specific national indicators were evaluated based on the WHO target goals for 2025 (31). The search terms used in combination included; "malnutrition" OR "obesity" OR "stunting" OR "under-nutrition" OR "micronutrient deficiency" OR "nutrition status" OR "diet-related risk factors" OR "national nutrition strategy" OR "nutrition government policy" OR "nutrition health policy" AND "Palestinian Territory" Or "West Bank" OR "Gaza Strip" OR "State of Palestine." The search was limited to articles published from January 2011 to January 2023. Selected sources included journals, books, master's and PhD theses, book chapters, and government data sets. Magazine and newspaper

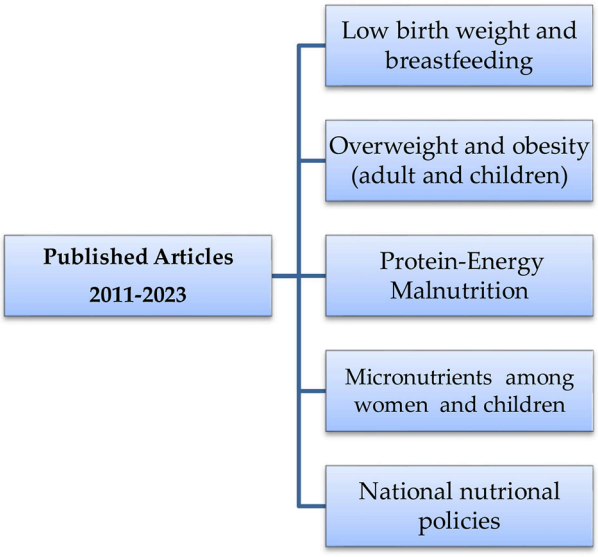

FIGURE 1
Literature review's main themes.

articles were not used as sources for this analysis. A total of 67 studies were extracted using the above filters and keywords.

After reviewing all relevant literature, the following five main themes were created according to the co-author's recommendations (Figure 1):

1. Low birth weight, exclusive breastfeeding, and complementary feeding.
2. Obesity and overweight by age groups.
3. Protein and energy malnutrition (stunting, wasting, and underweight).
4. Micronutrient deficiencies.
5. National nutritional policies in Palestine.

3. Results

3.1. Low birth weight, exclusive breastfeeding, and complementary feeding

3.1.1. Low birth weight

Overall, nine studies were conducted (five were conducted in the Gaza Strip, two in the West Bank, and two were national studies) (32–40). The prevalence of low birth weight, as reported by the Palestinian Central Bureau of Statistics, was 10.7 nationally (11.8 West Bank, 9.1 Gaza Strip) between 2019 and 2020 (41). A study indicated that exposure to war and occupation in Gaza is associated with an increased prevalence of LBW (40). Another factor is exposure to indoor pollution from tobacco smoke and wood fuel smoke (33). The prevalence rate of LBW reported by Al Natour and her colleagues was 15.1% in a northern city of the West Bank (32), while smoking, anemia in mothers, parity, and diet during pregnancy were found to be associated with LBW. Diet was also discussed in another study in Gaza, as specific diets for pregnant women (an Asian-like pattern) that consist mainly of vegetables, beans, and a less fatty diet were more protective against LBW (34). The trend of LBW shows a decline in the percentage between 2012 and 2021 from 8.5% to 6.7% (Figure 2).

3.1.2. Exclusive breastfeeding

Nine studies discussed breastfeeding in Palestine: four in the Gaza Strip, five in the West Bank, and one national (53–61). The reported prevalence rate of exclusive breastfeeding in the Gaza Strip was 24.4% (56), whereas the reported national EBF (52) in 2020 was 39.9%. However, data from the Palestinian Central Peru of Statistics (PCPS) for the year 2019–2020 indicate that the total EBF was 43.3% (41.9% West Bank, 44.8% Gaza Strip) (62). However, it was addressed in the studies conducted in the West Bank and Jerusalem that employed mothers were less likely to practice exclusive breastfeeding than unemployed mothers. The perception that breast milk is insufficient to meet the infant's needs, along with factors such as the mother's age and the number of children, serve as determinants for exclusive breastfeeding (53, 54, 60). Figure 3 shows the trend of the national EBF (0–5 months) from 2010 to 2020, demonstrating that the EBF increased from 28.7 to 38.9.

3.1.3. Complementary feeding

Only two studies were found related to complementary feeding without specifying the type and frequency of complementary feeding; one study in Gaza found that more than half (55%) of women imitated commentary feeding between 4 and 5 months (63). Another study in Gaza investigating weaning practices among infants younger than 2 years found that the majority of women initiate complementary feeding at <6 months (64). One report from UNICEF regarding the nutritional status of children reported that among Palestinian children, only 42 % receive a minimum diversity diet (this includes receiving food from at least four of the seven nutritional groups: (1) legumes and nuts; (2) grains or roots; (3) milk products; (4) Flesh food like meat, liver, and fish; (5) eggs; (6) vegetables rich in vitamin A; and (7) other vegetables and fruits.

3.2. Protein energy malnutrition (stunting, wasting, and underweight) among children under 5 years

No studies were conducted in the West Bank; however, seven studies were conducted in the Gaza Strip (16, 65–70). Tsigga and Grammatikopoulou (70) found in their review study that the trend of the prevalence of underweight and wasted children in the Gaza Strip slightly declined after 2004. Al Balbesi and his colleagues (65) found that stunting was observed in one-fifth of boys and girls by 2 years of age, and girls were more stunted than boys. According to a study by El-kishawi et al., short maternal stature and parental consanguinity were factors associated with stunting in the Gaza Strip (67). Other risk factors found by Al-Najar et al. (69) were poor awareness of healthy diets, poverty, poor socioeconomic situations, urbanization, and lifestyle among communities. Moreover, the

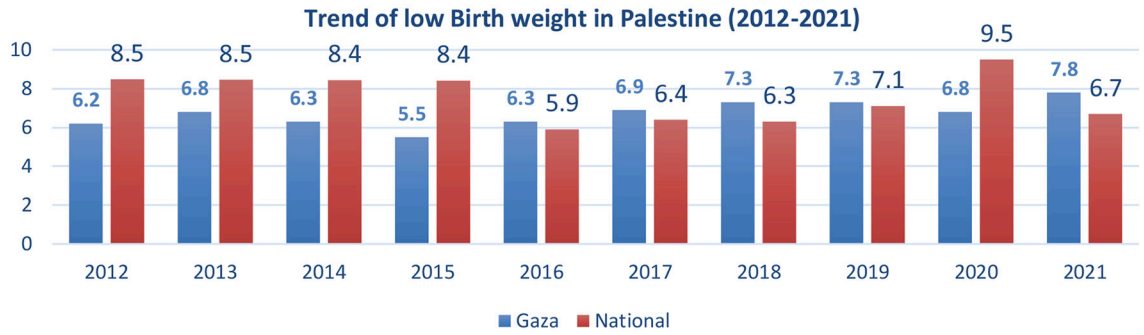

FIGURE 2
Trends of low birth weight (Infant Weight <2,500 gm) in the Gaza strip and the national Palestinian data between 2012 and 2021. Sources: UNICEF/WHO: data.unicif.org, who.int/nutgrowthdb/LBW estimates, State of Palestine, Ministry of Health yearly report of 2016, 2017, 2018, 2019, 2020, and 2021. Health Information Center, Palestinian Ministry of Health/Gaza Strip Indicators Report 2016–2020, Health Indicators for Gaza Strip 2020–2021 (41–51).

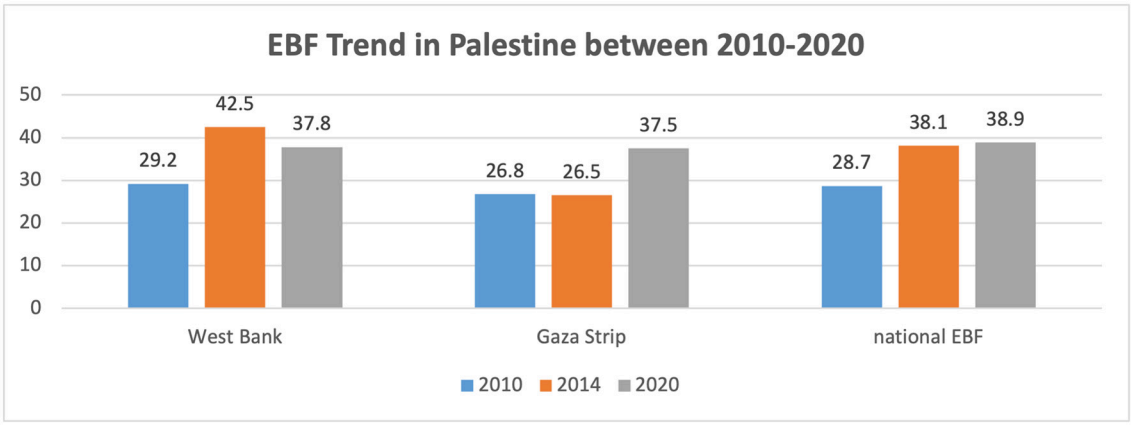

FIGURE 3
Trends of exclusive breastfeeding in Palestine between 2010 and 2020. Source: UNICEF, UNICEF Data: Monitoring the Situation of Children and Women (52) note: not all regions were included in the West Bank or the Gaza Strip based on the available data.

political situation and the blockade in the Gaza Strip are associated with all the previously mentioned risk factors.

The household study found an interesting result related to food security and nutrition knowledge and attitudes, as more than half of food-insecure households have inadequate nutrition-related knowledge and negative nutrition-related attitudes (77.6%), and close to all of the studied sample (95.2%) did not achieve a minimum dietary diversity score (68). The reported prevalence of growth indicators at 12 months of age at primary health care centers in 2021, based on the annual health report from the Ministry of Health, was as follows: 0.4% stunting, 0.3% underweight, and 0.2% wasting (50). The WHO presented trends in waste prevalence for children under 5 years old in Palestine from the year 2000 to 2020 to show that it decreased from 2 to 1.3% (Figure 4). However, the trend shows a slight decrease in stunting prevalence from 2000 to 2020, which is less than the global prevalence (Figure 5).

In relation to the prevalence of underweight in Palestine, Figure 6 shows the trend of underweight in the West Bank and Gaza Strip between 2014 and 2021, where it shows a decline in both areas (West Bank: 1.5–0.1, Gaza Strip: 1.3–0.9). One study by El Kishawi and her colleagues discussed the dual form of malnutrition in three areas in the Gaza Strip, which was conducted as a household study measuring the Body Mass Index (BMI) for mothers of underweighted classified children to determine that the dual form of malnutrition was 15.7% in the Gaza Strip. However, low monthly income, low level of father education, low level of maternal nutrition knowledge, and birth order were all found to be risk factors (74).

3.3. Obesity and overweight by age groups

3.3.1. Overweight and obesity and underweight among children

There were 13 studies found in both the West Bank and the Gaza Strip (75–87). In the West Bank, one study was conducted in the northern region among school children. The study revealed that the prevalence of overweight and obesity among children was 14.5% and 15.7%, respectively. The main predictors for being overweight

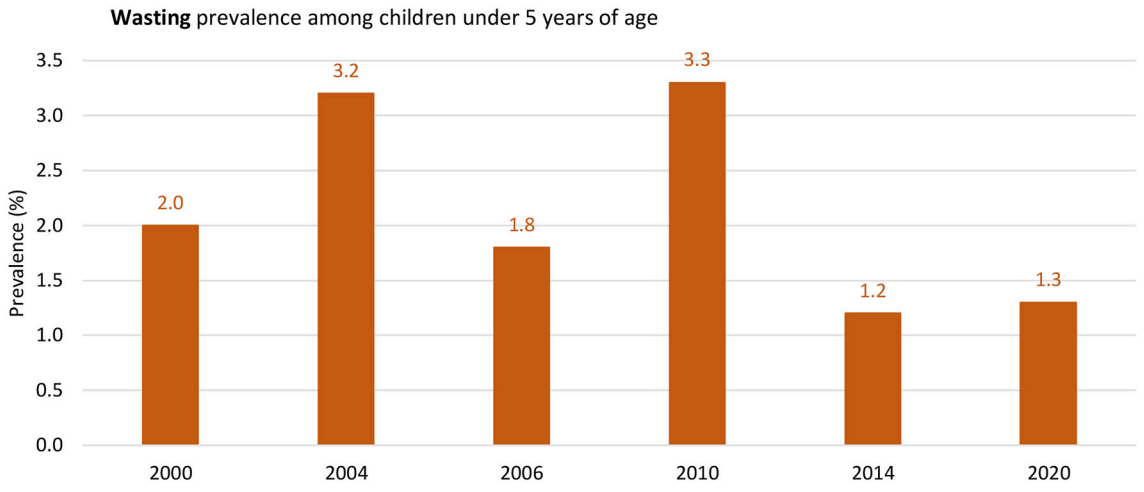

FIGURE 4
The trend of Wasting among Children Under 5 years old in Palestine between the year 2000 to 2020. Source: WHO Global Health Observatory, The UNICEF/WHO/WB joint child malnutrition estimates for stunting and overweight (71).

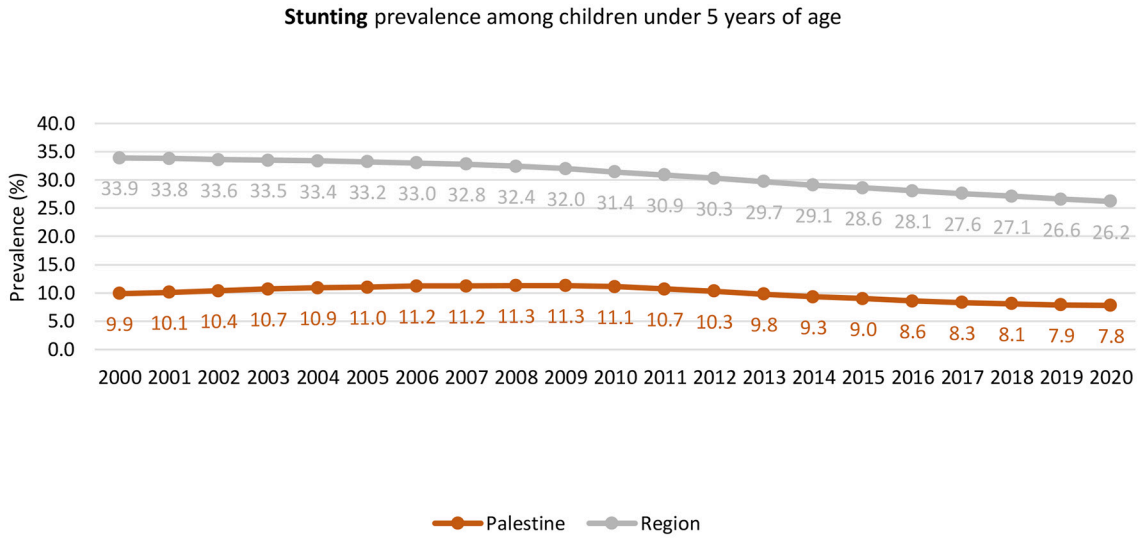

FIGURE 5
Trend of stunting among children under 5 years old in Palestine between the years 2000. Source: WHO Global Health Observatory, The UNICEF/WHO/WB joint child malnutrition estimates for stunting and overweight (69).

were age, gender, and living area (75). Another study conducted by Ghrayeb et al. (76) in the southern area of the West Bank among school children found that the prevalence of overweight was 18.6% and obesity was 9.2%. Interestingly, a study conducted in the West Bank in 20 marginalized schools found that the overall prevalence of underweight, overweight/obese students was 6% and 34%, respectively. However, the prevalence of overweight and obesity differed between 6th-grade and 9th-grade students. In 6th grade, the prevalence was 43% for boys and 24% for girls, whereas, for 9th-grade students, it was 20% for boys and 42% for girls. Factors that were found to be significant contributors to this difference included 9^{th-}grade students consuming fewer milk products, engaging in less physical activity, consuming more sugar in their diet, and consuming more carbonated soft and energy drinks (78, 79). A study conducted by Massad and his colleagues (80) in 22 UNRWA schools in the West Bank found that the prevalence of overweight was 12% and obesity was 6%. Factors associated with being underweight were male sex, unemployed mothers, and households not having enough food for at least the last 2 days, whereas older age, long time spent watching TV, and low physical activity were found to be associated with being overweight. A study in the West Bank found that those who were not exposed to any form of violence and had good health literacy were less likely to be obese (83).

Concerning underweight studies among children more than 5 years old, only two studies were found; the first one conducted in

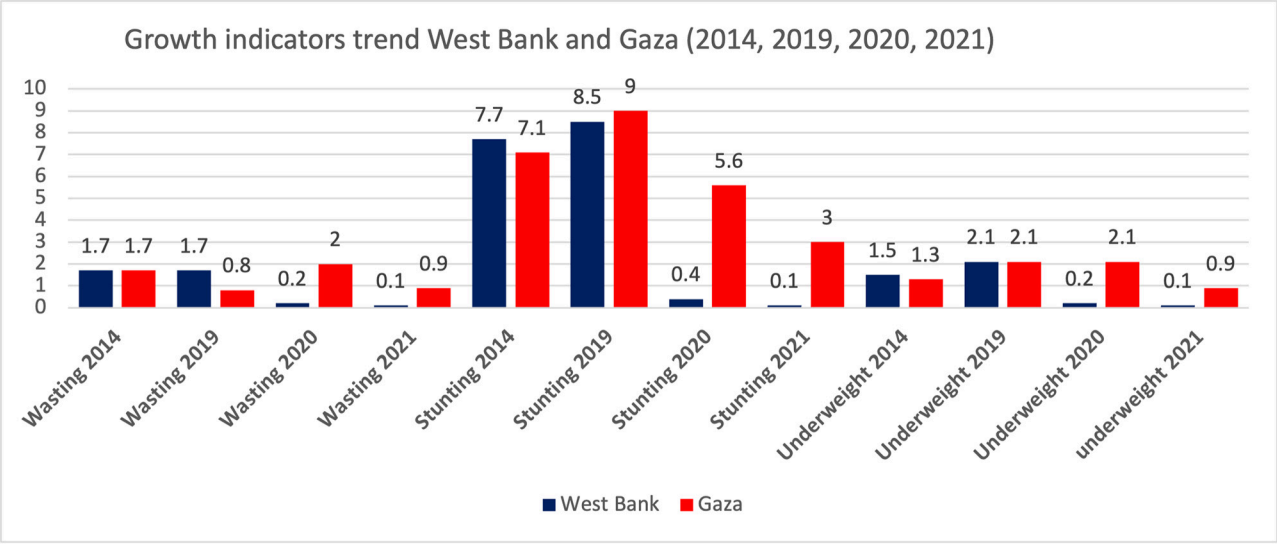

FIGURE 6
The trend of wasting, stunting, and underweight among children under 5 in the West Bank and Gaza strip in years 2014, 2019, 2020, and 2021. Sources: PCPS, Palestinian Multiple Indicator Cluster Survey 2019-2020, Survey Findings Report, Palestinian Multiple Indicator Cluster Survey 2015, Survey Findings Report, Ministry of Health Yearly Report 2021, Ministry of Health/Gaza Strip, Health Indictors, 2021 (41, 49, 50, 72, 73).

Nablus city (73), the Northern region of the West Bank, found that the prevalence rate was 7.3%, and the second one was in Jerusalem among school-age children, as it found that 4.8% were underweight and/or anemic (23.3%) (84).

Studies that correlate obesity among children in Palestine with hypertensive disorders, diabetes mellitus, leptin, and lipid profiles have found a strong relationship between being overweight and obese (77, 82, 86). In one household study involving children under 5 years, the prevalence of overweight/obesity in both the West Bank and the Gaza Strip was 8.8% (7.3% overweight and 1.5% obese) and 1.4% underweight. The prevalence was higher in the West Bank than in the Gaza Strip among the wealthiest households and boys (81). However, the prevalence of overweight reported by the Ministry of Health (MOH) in the West Bank among children under 12 months old in 2021 was 0.8% (50). The trends based on the MOH annual health report show a decrease from 1.4 to 0.8% in 2021 (Figure 7).

The trend of adolescent overweight shows an increase from 2000 to 2020 (from 20.4% to 34% in boys and 24.6% to 32.9% in girls). In addition, obesity shows an increase in both girls and boys (from 6.8% to 13.8% and 7.3 to 15.3, respectively) based on the Country Nutrition Profile report (Figure 8) (88). One study conducted in Hebron city in the West Bank discussed the prevalence and psychosocial impact of obesity among adolescents, finding that the prevalence of obesity was 3.3% and overweight was 13.8%, and finding a high significance between obesity and low student self-satisfaction (87).

3.3.2. Obesity among adults

Overall, 16 studies were found to be related to obesity among adults within the studied time frame (8 studies in the West Bank, two studies in the Gaza Strip, and five national studies) (89–104). Abdeen and his colleagues found that the prevalence of overweight in the West Bank was 35.5% among women and 40.3% among men, while obesity was 31.5% in women and 17.5% in men (89). Two studies involving mothers in the Gaza Strip found that the prevalence of overweight and obesity was 64.1%, and among urban and refugee populations, it was 67.5%. In addition, there were significant associations with age, medium and high education, high household income, nutritional education, and non-working women (90, 91). One study was conducted among university students in the West Bank to find the prevalence of overweight and obesity at 25% (31.1% men, 15.6% women) and 7.2% (9.4% men, 4% women), respectively. Moreover, it was associated with a family history of obesity and low physical activity. The study also found that 27.1% of the participants were pre-hypertensive (93). Another study among female university students in the West Bank found the prevalence of overweight and obesity at 12.4% and 1.7%, respectively (102). The available national data based on the STEPS Survey conducted in Palestine between 2010 and 2011 showed that the prevalence of overweight among adults was 57.8%, while obesity was 26.8% (105).

Studies have found that obesity among adults in Palestine and hypertensive disorders, diabetes mellitus, and cholesterol levels were highly correlated (92–96, 98, 103). In one study, waterpipe smoking was also strongly associated with increased BMI (99). The impact of COVID-19 was also studied in terms of decreasing physical activity, increasing dietary intake, and smoking, which is significantly associated with increasing BMI among Palestinians (97, 100, 104). One study discussing the effect of obesity during pregnancy and its consequences found that among pregnant women with class III obesity, 5% suffered from hypertensive disorders, and 13.9% delivered large babies (101). The prevalence of obesity during pregnancy was reported by the Ministry of Health/Gaza Strip health indicators in 2020 and 2021 as 18.9% and 25%, respectively (43, 44).

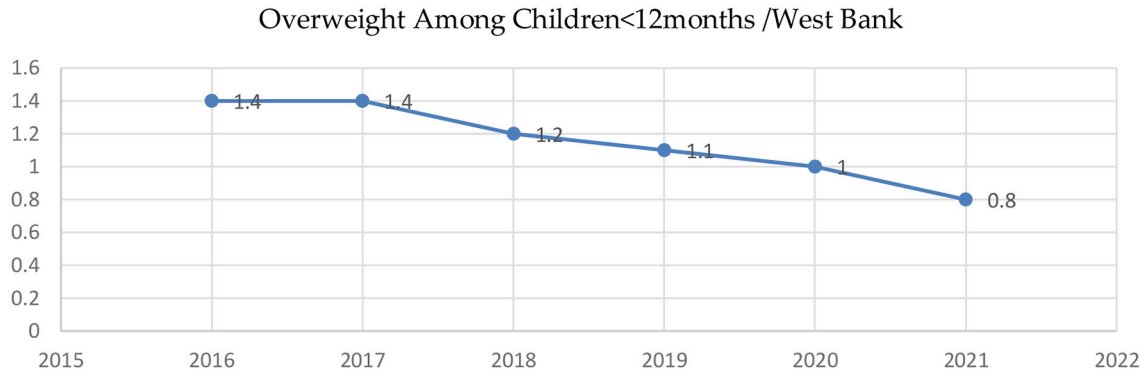

FIGURE 7
Trends of overweight among Children <12 months in the West Bank, Palestine. Sources: State of Palestine, Ministry of Health MOH, health annual reports (2016-2022) (45–50).

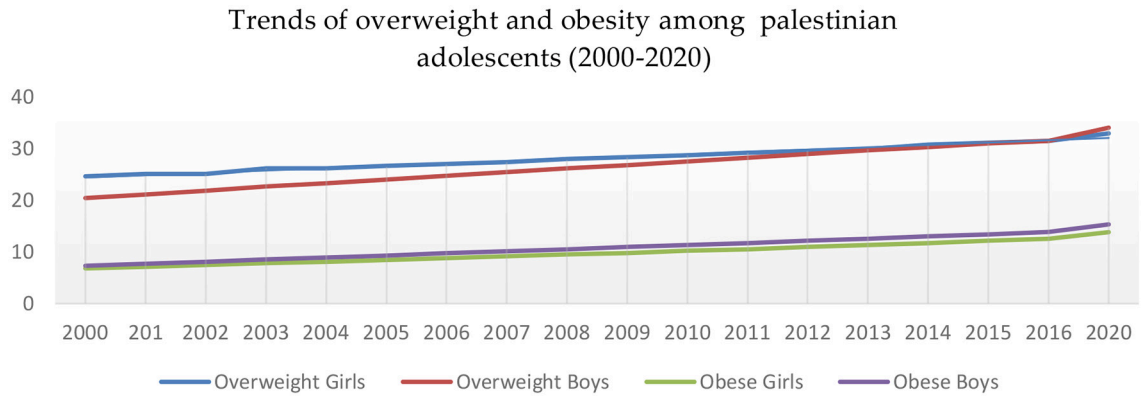

FIGURE 8
Trends of Palestinian adolescents overweight and obesity between 2000 and 2020. Source: Global Nutrition Report, Country Profile of the State of Palestine (88).

3.4. Micronutrient deficiency

3.4.1. Iron deficiency anemia

3.4.1.1. Iron deficiency Anemia among women

According to a study conducted in the Gaza Strip, the prevalence of anemia was 20.7% in the first trimester and 42.8% in the second and third trimesters. Serum ferritin levels were 23.6 in the first trimester and 38.6 in the second and third trimesters (106). A study conducted in Hebron, West Bank, found that the prevalence of IDA was 25.7% and about half of them (52%) had depleted iron stores and experienced serious pregnancy consequences for those women, including low birth weight and the frequency of preterm labor (107).

In the Gaza Strip, the prevalence of anemia among secondary female students older than 15 years was 33.5%. The main risk factors for anemia were skipping breakfast, eating 1–2 meals daily, the father's job status, the average monthly expenditure, a sedentary lifestyle, and the duration of menstruation (more than 7 days). Anemia was also strongly correlated with poor academic performance (108). The reported anemia among women of reproductive age decreased from 36.7 in 2000 to 31 in 2019 (based on the WHO Global Health Observatory, Figure 9) (109). Figure 10 shows the prevalence of anemia among pregnant women in the Gaza Strip between 2016 and 2021 (based on the Ministry of Health's national health indicators 2016–2021) (43, 73), which looks relatively stable but high.

3.4.1.2. Iron deficiency anemia among children

A study in the Gaza Strip conducted to assess the level of anemia among preschool children found that the prevalence was 59.7% (46.5% mild and 13.5% moderate). Factors found to be significant were the area of living, boys being more susceptible, poor households, and being underweight (110). A kindergarten study in Gaza found a prevalence of 33.9% iron deficiency anemia, and the main associated factors were the area of living and a low level of parental education (111). Jalambo and his colleagues [111] found the prevalence of anemia, stunting, and parasite infection in Gaza among 5–6-year-old children at 40.7%, 9.1%, and 17.1%, respectively. A study in the Gaza Strip among adolescent female students found that the prevalence of anemia was 35.8%, iron deficiency was 40.3%, and skipping breakfast, the amount of junk food intake, low consumption of fruits and vegetables, and mothers' education were all found to be associated factors (112). A KAP study

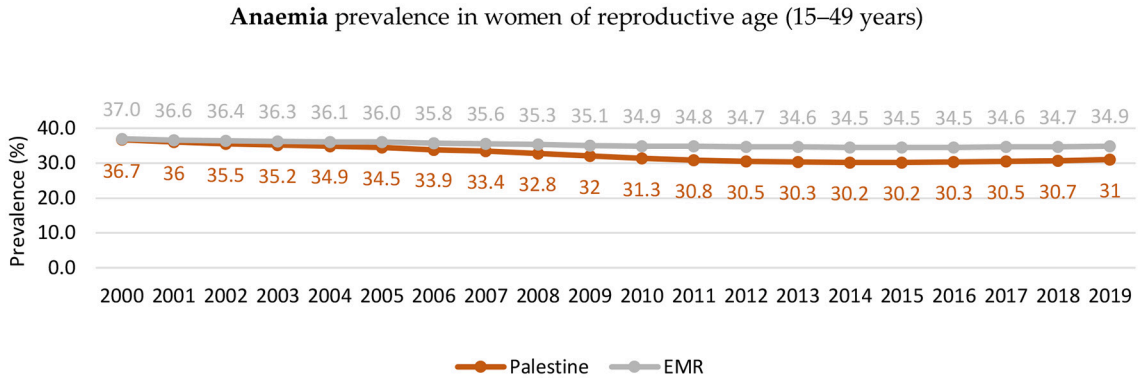

FIGURE 9
Trends in anemia among women in reproductive age in palestine compared to the global prevalence (2000–2019). Source: WHO Global Health Observatory (109).

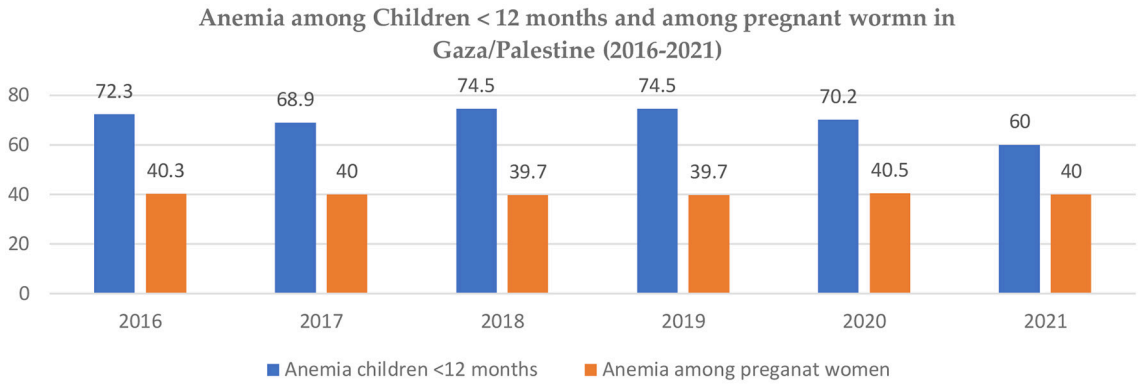

FIGURE 10
The prevalence of anemia among children less than 12 months and anemia among pregnant women in the Gaza Strip (2016–2021). Source: Ministry of Health/Gaza Strip, National Health Indicators (2016–2021) (44, 73).

among adolescents in Gaza found that 81.3% were not aware of the consequences of IDA among pregnant women, 89% were not aware of iron-rich foods, 74.8% were not aware of foods that reduce iron absorption, 81.7% usually consumed tea or coffee, and more than half consumed them daily. In addition, two-thirds were unsure or did not consider IDA a significant condition (113).

Qasrawi et al. (114) found in their study in the West Bank that both boys' and girls' school achievements were highly associated with the adequacy of fruits and vegetables and a low intake of soft drinks and energy drinks. Figure 10 shows the prevalence of anemia among children younger than 12 months between 2016 and 2021, which indicates a decrease from 72.3% to 60% based on the Ministry of Health's Gaza Strip health indicators (44, 73).

3.4.2. Other micronutrients

The 2013 Palestinian Micronutrient Survey reported the prevalence of the following deficiencies among pregnant women in the first trimester in the West Bank and Gaza Strip: 21.3% and 23.6% for iron, 49.6% and 67.9% for zinc, 8.8% and 11.4% for vitamin A, 66.7% and 78.6% for vitamin D, 19.1% and 27.9% for vitamin B12, and 13.2% and 17.5% for vitamin E, respectively, and those rates show higher for the second and third trimesters (115).

One study was conducted in the West Bank by UNRWA and governmental schools to assess the level of micronutrients post-national interventions at grades six and nine for female and male students and found that the prevalence of micronutrients was low: iron; 9.6%, MCV; 18.8%, folate; 2.4%, zinc; 31.3%, B12; 22%, thyroxine; 8.2%, and thyroid stimulating hormone; 3.6%. The study also found that gender differences were more prevalent among girls with iron deficiency anemia, area of living, and type of school (UNRWA schools had a higher prevalence compared to governmental schools) (116).

Horino et al.(106), in their study on micronutrient deficiencies in the Gaza Strip among pregnant women, reported the following findings:

- Zinc deficiency was observed in 67.9% of pregnant women during the first trimester, while it increased to 84.7% during the second and third trimesters.

- Folate deficiency was found in 2% of pregnant women during the first trimester, which rose to 10% during the second and third trimesters.
- Vitamin A deficiency was identified in 11.4% of pregnant women during the first trimester and increased to 18.6% during the second and third trimesters.
- Vitamin B12 deficiency was observed in 27.9% of pregnant women during the first trimester, and it rose to 51% during the second and third trimesters.
- Vitamin D deficiency was prevalent in 78.6% of pregnant women during the first trimester, while it decreased to 69% during the second and third trimesters.

Another study on micronutrient deficiencies among lactating women found that 2.7% in the West Bank and 19.7% in the Gaza Strip had iron deficiency anemia, 88.8% in the West Bank and 92.7% in the Gaza Strip had Zinc deficiency, 36% in the West Bank and 24% in the Gaza Strip had vitamin D deficiency, and 33.1% in the West Bank and 92.7% in the Gaza Strip had vitamin A deficiency. A significant association was found between those who consume chocolate and the type of community (117).

A study regarding nutrient intake and adequacy among preschool children in the Gaza Strip found that 75% consume less than the recommended dietary allowance. The highest level of deficiencies was found in energy (89.8%), followed by calcium (73.3%), iron (47.2%), carbohydrates (20%), and Zinc (17%) (118). A study assessing the risk factors for vitamin A and D in the West Bank and Gaza found that the overall national prevalence was 73.1% and 60.7%, respectively. The main risk factors highlighted were that children in Gaza had a higher prevalence of 1.34 and 1.96 times than in the West Bank, older children were more susceptible, and female children were more susceptible (119). Concerning iodine deficiency, a study conducted in Jenin, West Bank, among pregnant and lactating women and newborns tested the levels of iodine in breastmilk, pregnant women's urine, and infant blood samples, to find out that the levels were below the WHO epidemiologic criteria and optimal level of iodine, considering that newborn iodine levels will be affected by the mother's breast milk. This was explained in the study by the low intake of iodine (120). However, iodine intake is considered sufficient based on the WHO observatory and trends in iodine levels in the Eastern Mediterranean Region (121).

3.5. Palestinian national nutrition policies

Policies and strategic plans in Palestine have been reviewed and summarized in Table 1.

TABLE 1 List of national policies and strategic plans available in Palestine.

Policy/program/strategic plan	Year of implementation	Status
Policy on salt iodization	2005	Active
Wheat flour fortification	2006	Active
Child growth monitoring	2010	Active
Code of marketing of breast milk substitutes	2012	Active
Strategy or plan of action on infant and young child feeding	2017–2022	Achieved
Development of a national nutrition strategy or action plan	2017–2022	Done
Plan of action for obesity prevention	2017	Active
Policy to reduce salt/sodium consumption	2019–2020	Active
Policy to limit trans-fatty acids intake	2021	Active

Source: Policies in Palestine: In Global Database on the Implementation of Nutrition Action (122).

4. Discussion

4.1. Low birth weight and exclusive breastfeeding

4.1.1. Low birth weight

Our review showed a decrease in the trend of low birth weight in Palestine, which had decreased between 2012 and 2021 (8.5%−6.7%). However, in the Gaza Strip, the percentage is still relatively high (9.7%). While the study in the West Bank has a different prevalence (13.7%), this rate was below the global level (14.6%) (123), not far from Western Asia (10.9%) (124) but not less than that in the UAE (11.8%) (125), and Jordan (16.7%) (126). Factors discussed in the studies were smoking, anemia, a high number of parities, and diet during pregnancy. This was consistent with other studies in Nepal, Ethiopia, and Brazil, with comorbidity and low iron intake during pregnancy (127–129). Another study in the UAE by Taha and her colleagues found other factors included cesarean section delivery, preterm birth, and first-child orders (130).

4.1.2. Exclusive breastfeeding

Several studies discussed the prevalence rate of exclusive breastfeeding in both the West Bank and the Gaza Strip. The prevalence in overall Palestine (43.3%) was below the WHO target prevalence and other regional countries, such as the reported prevalence in the UAE (59.7%) (131) but higher than those in Jordan (25.4%) (126) and Lebanon (27%) (132). Factors associated with low exclusive breastfeeding found in both the West Bank and the Gaza Strip include the perception that breast milk is not sufficient to meet an infant's needs, a younger maternal age, and the number of children. These factors were mainly addressed in studies conducted in the West Bank and Jerusalem, particularly among employed mothers. These findings are consistent with global trends and with observations from various other studies (133–135). Previous studies have shown that early nutrition and breastfeeding might play a significant role in maintaining immunity, preventing non-communicable diseases, and promoting cognitive and physical growth (136, 137). However, several barriers discussed in global studies that minimized breastfeeding rates and facilitated mixed feeding were the lack of designated breastfeeding facilities in working places, shopping malls, and airport communities, as well as the perceived community attitudes toward breastfeeding and formula feeding that were enhanced by milk companies and the market (137–140).

4.2. Protein energy malnutrition (stunting, wasting, and underweight) among children under 5 years

This research area was studied extensively in the Gaza Strip but not in the West Bank; it could be related to the fact that many NGOs and humanitarian organizations, together with UNRWA, are working in the Gaza Strip more to assess the nutritional status under the blockade of the political changes. Children's nutritional status and rights are crucial since they could be affected. Therefore, monitoring the malnutrition status in the Gaza Strip was more than in the West Bank. Based on the national data, wasting, stunting, and being underweight have dramatically decreased since 2014. However, the review showed differences between the West Bank and the Gaza Strip. In Gaza, the percentage is still high compared to the West Bank. Wasting in Palestine was reported to be 1.3%, which was below the global (6.7%) and regional (5.1%) levels (141) and the prevalence reported in Jordan (2.4%) (126). The prevalence rate of the national data was also below the regional level (71). Factors identified in Gaza studies were parental consanguinity, short maternal stature, gender, poor awareness of healthy diets, poverty, poor socioeconomic situations, urbanization, and lifestyle, in addition to the political blockade in Gaza. Similar to what was found in African studies and Afghani refugees (14, 142), other studies found short paternal height, socioeconomic factors, and parental educational level (143).

Among the interesting studies was the study by El Kishawi and her colleagues, which found a strong relationship between dual malnutrition of the mother and her child, as the percentage of malnutrition was 15.7% in Gaza, where low-income and parental education together with birth order were found to be associated factors. Considering that poverty affects both the mother's and the child's health, this alarming situation may be a strong indicator of poverty in the Gaza Strip. Therefore, breastfeeding and other nutritional strategies must consider the parent's educational level and poverty status. Dual malnutrition was found in other studies, particularly in Africa, where the factors listed were much more similar (144).

4.3. Obesity and overweight

4.3.1. Children obesity

There are a greater number of studies discussing childhood obesity in the West Bank compared to the Gaza Strip. These studies have revealed that the prevalence of childhood obesity varies depending on factors such as geographical area, type of school, family wealth, and gender. The prevalence of overweight and obesity in 2020 data was higher among boys than girls (34%, 32%), (15.3%, 13.8%). The overall obesity level exceeded the global prevalence of (5.7%) in 2020 (145) and in Jordan, (6.5%) (126), and was very close to the UAE as one of the developed gold countries in both overweight and obesity prevalence of 35.8% and 17.3%, respectively (125). Childhood obesity is a key predictor of future health and the development of chronic diseases.

Three studies collating the BMI among children with metabolic disorders and hypertension found interesting results, similar to the study findings by Aburawi et al. (146), where they found that children with excess fat had increased risks of developing dyslipidemia, systemic inflammation, cholestasis, endothelial dysfunction, and diabetes. Obesity among children is considered one of the most alarming public health risks and problems since it may lead to various psychological and physical complications (147). Therefore, it is crucial to focus on more studies on the Gaza Strip children's problems, owing to the fact that poor nutritional habits, particularly high-fat and high-carbohydrate diets, might lead to overweight and obesity, which can be accompanied by malnutrition from both carbohydrates and fats used previously to build a dietary weight loss regime (148). Factors that were found to be associated with childhood obesity in Palestine and were consistent with those in other studies included consuming fast food and sugar-sweetened beverages (149, 150), low physical inactivity (151), age, as more obesity was found in adolescence rather than younger age (152), and time spent on TV (153, 154), and boys were more prone to being obese in comparison to girls (152). COVID-19 lockdown was also found to affect children's eating habits, as what was found in Rome has a negative influence on children in terms of eating habits and sedentary life with increased childhood obesity (155).

4.3.2. Adult obesity

The prevalence of obesity among adults in Palestine, either in the West Bank or Gaza Strip, found a high prevalence of overweight (more than half of the participants) and obesity (about one-third of the participants), which is considered a real problem that requires attention and the formulation of health policies and strategies. Factors mentioned as being associated with overweight and obesity among adults in Palestinian studies were the following: lifestyle changes such as decreased intake of fruits and vegetables, consumption of caloric beverages, snacking, a lack of physical activity, and smoking were all consistent with studies in different countries regionally and globally (150, 156–159). Obesity was more prevalent among women than men in Palestine due to cultural constraints, lifestyle, and low physical activity, which was similar to what had been found in different studies compared to men (160). Interestingly, several studies have examined the connections between obesity and hypertension, diabetes, and cardiac diseases among adults. These studies have shed light on the impact of obesity on a person's overall quality of life (161–163). One study in the West Bank examined the prevalence of obesity among pregnant women and pregnancy outcomes. Their results were highly consistent with those of other studies that found a strong relationship between induced pregnancy hypertension and delivering large babies (164, 165).

4.4. Micronutrients

4.4.1. Iron deficiency anemia

Iron deficiency anemia (IDA) is a public health problem and was ranked number nine among the modifiable risk factors for death (166). Several studies were reviewed regarding IDA among women of reproductive age in both the West Bank and the Gaza Strip; the prevalence based on the WHO (30%) was

found to be close to the regional level (34.9%) (167). However, data from the Ministry of Health/Gaza indicators was 40% higher than the regional prevalence (44). In Palestine, the prevalence of iron-deficiency anemia (IDA) among pregnant women remains a challenging public health issue, with a rate higher than that of the UAE (24.3%) (125) but lower than that of Jordan (43%) (126). One study identified IDA among non-pregnant women, with risk factors including skipping breakfast, consuming only 1–2 meals per day, father's job status, average monthly expenditure, personal monthly expenses, sedentary lifestyle, and prolonged menstruation (more than 7 days). Furthermore, the study found that anemia was highly associated with poor academic performance, a trend observed in other studies (168, 169).

Although the trend of anemia among children <12 months in the Gaza Strip has shown a decline, it remains unacceptably high. Further attention is required to identify the underlying causes and associated factors to enable the planning of more effective actions (170). The prevalence of iron-deficiency anemia (IDA) in Palestine is considerably higher than that of Saudi Arabia (51%) (171) and the UAE (29.9%) (125). Literature has demonstrated that IDA has a detrimental effect on the physiological and psychological wellbeing of school-age children and their academic achievement. These findings are consistent with those of other studies (172, 173). Skipping breakfast, consuming excessive amounts of junk food, having a low intake of fruits and vegetables, and mothers' low levels of education are found to be associated with iron-deficiency anemia (IDA) among kindergarten and school-age children. These risk factors are similar to those in the UAE and Saudi Arabia (125, 171). Given these findings, there is a need for targeted programs that educate children and families on the importance of a healthy diet and proper nutrition to reduce the prevalence of IDA among children.

4.4.2. Other micronutrients

Micronutrient deficiency is prevalent in national and local studies in the West Bank and the Gaza Strip, including zinc, vitamin D, and vitamin A, in pregnant women and children. Zinc deficiency was among the highest in both women and lactating mothers. In a population study, the percentage of pregnant women with zinc deficiency in South Asia ranges from 15 to 74% (174). A study in Ethiopia found that the associated factors were increased coffee intake, low animal-source diets, and a lack of diet diversity (175). Another study in Jordan found a significant association between zinc deficiency among pregnant women and pre-eclampsia (176). In Palestine, further studies are recommended to address more than micronutrient deficiency among children and pregnant women.

5. Conclusions and recommendations

In conclusion, low birth weight (LBW) remains a problem in Palestine, with rates ranging from 8.5% to 6.7% from 2012 to 2021. Exposure to war and occupation, indoor pollution, smoking, anemia in mothers, and a poor diet during pregnancy are risk factors associated with LBW. Exclusive breastfeeding rates in Palestine have improved in recent years, with national rates reaching 43.3%, but employment, perceived insufficient breast milk, and the number of children remain significant barriers to exclusive breastfeeding. Complementary feeding practices are not well documented, with only two studies found. The prevalence of stunting, wasting, and being underweight remains high among children under 5 years in the Gaza Strip, with risk factors including poor awareness of healthy diets, poverty, poor socioeconomic situations, urbanization, and lifestyle among communities, in addition to the political situation and the blockade. To address these issues, it is recommended to increase public awareness campaigns to promote healthy eating habits, provide training for healthcare providers on appropriate infant and young child feeding practices, improve maternal health, and address the underlying socioeconomic and political issues. It is also recommended to conduct more research on complementary feeding practices and monitor progress toward achieving the World Health Organization's nutrition goals.

The prevalence of overweight and obesity is high among children and adults in Palestine. Age, gender, living area, low physical activity, consumption of carbonated soft drinks and energy drinks, less consumption of milk products, and mothers' low education levels are significant predictors of overweight and obesity among children. Moreover, underweight children were found to be associated with households not having enough food for at least the last 2 days. Studies found a strong relationship between overweight and obesity and hypertensive disorders, diabetes mellitus, and lipid profiles. Overweight and obesity are also prevalent among adults, particularly women. The national data highlights the need for comprehensive interventions to control overweight and obesity, particularly among vulnerable populations. Such interventions should focus on encouraging healthy eating habits and physical activity and improving mothers' education levels. Furthermore, these programs should address the root causes of undernutrition to achieve sustainable development goals. Future research should focus on developing culturally appropriate interventions to address this public health problem in Palestine.

Author contributions

Conceptualization: HAS, EA, and AA-J. Methodology, writing—original draft preparation, and visualization: EA and HAS. Review and editing: HAS. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Association between dietary consumption patterns and the development of adolescent overnutrition in eastern Ethiopia: new perspectives

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Background: Overnutrition among adolescents is becoming a major public health concern, with all the adverse consequences associated with unhealthy eating behaviors. Hence, clear evidence linking dietary consumption with the risk of overnutrition is crucial for targeted dietary recommendations using a robust statistical approach. This study assessed the link between dietary consumption patterns and the risks of overnutrition among adolescents in Ethiopia.

Method: A community-based survey was conducted on a random sample of 510 adolescents selected using a stratified random sampling *via* proportional allocation. Dietary consumption was captured using a validated and contextualized 80-item food frequency questionnaire over the past month through a face-to-face interview. Weight and height were measured under a standard procedure. Body Mass Index for Age Z-score (BAZ) was calculated, and BAZ above +1 was considered overnutrition. The frequency measures were standardized into daily equivalents, and dietary patterns were derived using exploratory factor analysis after checking for assumptions. A bivariable and multivariable binary logistic regression model was fitted with an odds ratio and 95% confidence intervals.

Results: A total of 510 participants were enrolled. Four major dietary patterns ("cereals, energy, and discretionary calory," "fat, oil, and milk groups," "proteins and vegetables," and "fruits"), explaining 66.6% of the total variation, were identified. The overall prevalence of overnutrition was 29.0% (27–31%), where 22.5 and 6.5% were overweight and obese, respectively. Physical inactivity (AOR = 6.27; 95% CI: 2.75–14.3), maternal literacy (AOR = 111.3; 95% CI: 50.0–247.8), habit of snacking (AOR = 1.80; 95% CI: 0.69–4.67), skipping meals (AOR = 2.05; 955 CI: 0.84–5.04), cereals and discretionary food dietary pattern (AOR = 2.28; 95 CI: 0.94–5.55), and protein–rich and vegetable dietary pattern (AOR = 2.30; 95% CI: 0.97–5.46) were important factors associated with odds of overnutrition.

Conclusion: Overnutrition is a public health concern affecting one-third of adolescents, and it is closely linked with dietary consumption patterns, eating behaviors, wealth status, literacy, and level of physical activity. Therefore, public health interventions targeting unhealthy eating and lifestyles are urgently needed to curb the increasing burden of overnutrition among adolescents and its future complications.

KEYWORDS

adolescents, dietary pattern, overnutrition, principal component analysis, Ethiopia

1. Introduction

Adolescents account for 16% of the global population (12 billion), of which more than 85% reside in developing countries (1). Adolescence is one of the critical life stages determining the healthy transition to adulthood, with distinct nutritional requirements and dietary habits attributable to the physiological and cognitive changes (2, 3). These huge pools of adolescents are facing an unprecedented change in food environments where processed, high-calorie, and low-nutrient foods are readily accessible and preferred (4, 5). Eating behavior, insufficient physical activity, and sedentary life during adolescence can lead to an increasing burden of overnutrition and diet-related chronic diseases (6, 7).

Overnutrition is characterized by excessive accumulation of fat as a result of excessive energy intake or decreased daily energy expenditure. The World Health Organization (WHO) defines adolescent overnutrition as body mass index (BMI) for age Z-score (BAZ) above +1, including overweight (BAZ between +1 and +2) and obesity (BAZ above +2) (8). Due to the nutritional transition and effects of globalization, overnutrition is becoming a major public health problem, especially among adolescents (9, 10). Overnutrition among adolescents tends to persist to adulthood, and they are more likely to develop chronic diseases like diabetes mellitus, hypertension, and coronary artery disease (11, 12). Adolescents' overweight and obesity are rising alarmingly, approaching epidemic levels in many developed countries, and have become a double burden for low- and middle-income countries (13).

The global prevalence of overweight and obesity is rising among adolescents by 14% over the past decades, affecting over 340 million adolescents, and the rate of increase is alarming in developing countries (30%) (11). Similarly, the Lancet report indicated that the number of obese girls increased from 5 million in 1979 to 50 million in 2016 and from 6 to 76 million among boys, emphasizing a huge burden. Moreover, an estimated 213 million children and adolescents are overweight (13), and the burden reaches 10.6 and 2.5% in Sub-Saharan Africa (14). In Ethiopia, the pooled prevalence of overnutrition was 11.3% (15), and different studies reported a prevalence of 9 to 26% (9, 15–18), suggesting a huge public health concern among adolescents.

Studies conducted so far have mainly focused on the effects of individual food consumption and some aspects of diet on overnutrition. However, diet could be better characterized using a robust statistical approach called "dietary pattern analysis." It is a better approach to characterize habitual consumption and overall dietary consumption (19–23). Dietary patterns better predict the risks of overnutrition than individual food or nutrient consumption estimates. Hence, such evidence would give a more practical policy recommendation on what foods should be recommended for optimal nutrition in this context (21). Despite all its advantages, no study has been conducted in Ethiopia linking dietary patterns with adolescent overnutrition. Thus, this study was aimed at characterizing the major dietary consumption patterns and their association with overnutrition among adolescents in eastern Ethiopia.

2. Materials and methods

2.1. Study setting

This study was conducted in Dire Dawa, which is located at a latitude of 9° 35′ 35″ N, a longitude of 41° 51′ 57″ E, and 1,204 m above sea level in eastern Ethiopia. According to the Dire Dawa health bureau, the region has a total population of 535,685, and the majority of the population lives in urban areas (72%). An estimated 59,871 adolescents reside in the region, both at home in their communities and at primary and secondary schools. In urban and rural classifications, the region has nine and more than 30 kebeles (third level administrative units in Ethiopia) in urban and rural settings. The study was conducted from February to March 2022 using a primary data collection method.

2.2. Study design and population

A community-based cross-sectional study was conducted on a randomly selected adolescent group in Dire Dawa town to assess the relationship between various dietary patterns and the risks of overnutrition. The study findings targeted all adolescent girls in the study area, and these could indicate the burden of overnutrition and its predictors. Hence, we excluded those with vertebral deformities, spinal curvatures, and diagnosed chronic illnesses, which might affect the proper height measurement and may restrict an individual's dietary intake.

2.3. Sample size determination and sampling procedure

The minimum sample size required for this study was determined for the first and second objectives and compared. A single proportion sample size estimation formula was used assuming the prevalence of overnutrition ($p = 26.1$) (17), at a 95% confidence level, 5% significance level, and 10% response rate, the final sample for the first objective became 510. For the second objective, associated factors, the minimum sample size was estimated using empirical evidence from Epi Info software for important factors affecting overnutrition among adolescents. We considered a power of 80%, a confidence level of 95%, and a significance level of 5%. Hence, taking snacking (AOR = 3.05), sweet food preferences (AOR = 2.86), and sex (AOR = 3.57), the sample sizes become 236, 296, and 210, which is smaller than the sample calculated for the first objective. Thus, we took the larger sample size of 510, calculated for the first objective, as the minimum sample size for this study.

A stratified sampling technique with a proportional allocation method was employed for this study. First, four kebeles were randomly selected using simple random sampling, and then, four blocks or villages were selected from each kebele, where the sample size is proportionally allocated relative to the number of adolescents in each village. Finally, we employed a systematic random sampling technique with a sampling fraction calculated from the total number of adolescents and the allocated sample size. With the assistance of community-based health extension workers, adolescents were tracked in the selected households.

The proportional allocation formula $ni = \left(\frac{n}{N}\right) \times Ni$ was used to allocate samples for each kebele and block, where, "n" is the total sample size calculated, "N" is the total adolescent population (target population), "N_i" is the total number of adolescents in a particular stratum, and "n_i" the sample size for each stratum.

2.4. Variables of the study

The dependent variable was overnutrition, which is a composite indicator calculated from BAZ scores from weight and height mesurements at appropriate cutoff points. While the major dietary patterns identified from the dietary consumption captured through food frequency (FFQ) were the major independent variables of this research, socio demographic variables (age, sex, socioeconomic status, education, occupation, family size), eating behaviors (skipping breakfast, cereal products, legumes, fruit and vegetables, milk and milk products, beverages, snacks, sweet foods), sedentary lifestyles (watching television, using the computer, and playing video games), and level of physical activity (total physical activity cumulated using work, transport, and leisure time–related physical activity) were also assessed as confounding variables in assessing the association between major dietary consumption patterns with the risks of overnutrition among adolescents.

2.5. Operational definitions of variables

In this study, "skipping meals" was defined as the omission or lack of consumption of one or more of the traditional main meals (breakfast, lunch, or dinner) throughout the day (21). In addition, low consumption of fruits and vegetables occurs when the daily consumption of fruit and vegetables is below 400 grams (24).

Based on the standardized BAZ score, a BAZ score above +2 was classified as having obesity, while a BAZ score between + 1 SD and − 2 SD was classified as overweight adolescents and otherwise normal. Hence, the burden of overnutrition was quantified as the sum of overweight and obesity prevalence among adolescents (25).

On the other hand, the level of physical activity was assessed using the standard and highly valid General Physical Activity Questionnaire (GPAQ) and scored as a metabolic equivalent (MET) depending on the intensity and duration of each activity. Hence, we defined a physically active adolescent when the total physical activity MET minute per week is at least 600 and physically inactive otherwise (26). Thus, moderate exercises are defined based on low-impact aerobic exercise classes, brisk walking or hiking, recreational team sports (volleyball, soccer, etc.), while vigorous exercises include an activity that causes large increases in respiratory rate or heart rate like carrying or lifting heavy loads, digging or construction work, running or jogging, high–intensity aerobic classes, competitive full–field sports (soccer) or basketball (27).

2.6. Data collection procedures

Data were collected using a combined approach through face-to-face interviews using a structured and pretested questionnaire, anthropometric measurements of height and weight using a standard procedure. The questionnaire was prepared in English and the respective local languages. The tool is composed of socio-demographic characteristics, eating behavior, dietary pattern, and lifestyle. The data was collected by a trained pair of recently graduated health professionals.

More importantly, we employed a validated 80-item FFQ used in the Ethiopian context. The tool is modified and contextualized for the study setting, with the inclusion of important food items and the exclusion of unnecessary items. The semiqualitative FFQ includes relevant and specific food items from cereal products, legumes, fruit, vegetables, meat, milk and milk products, sweet foods, snacks, and other food consumption over the past 1 month, where the frequency is ranked from "never" to "everyday" from one to seven (22, 28). We gathered data on the frequency of consumption of various foods on each day of the previous month from all study participants. This method allows one to obtain qualitative data on the usual intake of food and the class of food over a long period of time (1 month). The FFQ validated for Ethiopian adults has been contextualized and pretested to capture the dietary intake of adults. A validation study showed that the contextualized tool was valid and reliable in measuring the dietary micro- and macronutrient intake of adults in Ethiopia (28). In pilot analysis, the FFQ tool was found to be highly reliable with a Cronbach's alpha value above 0.86, indicative of a reproducible tool (29).

The 16-item GPAQ validated tool developed by WHO for physical activity surveillance was employed to assess the level of physical activity of adolescents in three domains, including activity at work, travel to and from places, recreational activities, and sedentary behavior, through face-to-face interviews. The activity level of the study participants was evaluated according to the standard WHO total physical activity calculation guide, and the level of total physical activity was categorized as physically active or inactive as detailed in the previous section (27, 30).

The height was measured using a Seca standing height measuring device by a trained and reliable anthropometric measurer to the nearest 0.1 cm. The weight was measured using a calibrated adult electronic scale, taking two consecutive measurements, and the average weight was recorded to the nearest 0.1 kg. Hence, the BMI was calculated by dividing the weight in kilogram by the height in meters squared. Based on this, the BMI is transformed into a standardized BAZ to rank the nutritional status of adolescents.

2.7. Data quality control

Data were entered into controlled data entry software (Epi Info) with validity and consistency checks. Close supervision was employed during data collection, in addition to a two-days training given to data collectors and supervisors to maintain the quality of the data. Further training of data collectors was done on proper anthropometric measurements using a standard method. Moreover, pretesting was conducted on 10 samples to evaluate the tool and assess the reliability and validity of the data collector. The technical error measurement (TEM) was calculated for each data collector, and those with a TEM above 1.5 and 2% for intra- and inter-observer measurements were excluded from collecting the data (31).

2.8. Data processing and analysis

Data were entered and coded using EPI–info version 7.2.1.0 for data exploration and cleaning. The cleaned data was exported to SPSS version 21 for data transformation and statistical analysis. The data were presented using frequency, percent, mean, standard deviations, statistical tables, and graphs. The data were checked for outliers, distribution skewness, and collinearity.

The age, sex, height, edema, and weight of the adolescents were further exported to WHO Anthroplus version 1.0.4 to calculate the BAZ score, where they were further exported and merged with the primary data. The BAZ score was recoded as overnourished (overweight and obesity), otherwise normal as per the standard cutoff point (25).

The FFQ was standardized and converted into a daily frequency equivalent based on previous literature. The monthly frequency of consumption was scored as 0, 0.1, 0.25, 0.571, 1, and 2-times per day (32, 33). We conducted an exploratory factor analysis (EFA) using the principal component approach using the varimax rotation. All relevant assumptions for the EFA—correlation, adequate sample, higher factor loading and absence of complex structure, were checked, and items that did not fulfill the criteria were excluded sequentially (34, 35). A Kaiser-Meyer-Olkin sample value >0.5 was considered adequate, and Bartlett's *p*-value was below 0.05. A minimum load value above 0.3 was considered adequate for the set of variables (36, 37). Hence, we used the EFA for two purposes: to derive a ranked wealth index and to identify the major dietary patterns from the FFQ (19, 20). The wealth index was ranked into three categories: low, middle, and high.

Adolescent physical activity level was assessed in three comprehensive sets of domains, including work (moderate and vigorous), transport, and leisure time-related physical activity (moderate and vigorous). Based on the GPAQ tool, each level of physical activity was transformed into MET in minutes per week, and then the sum of sub-activities' MET minutes per week was calculated. Then, we multiplied the number of days involved in a certain level of physical activity per week by the daily duration (in minutes) and the metabolic equivalents considering the physical activities in minutes done in a week (4.0 METS for moderate, 8.0 for vigorous and 3.0 for transport related walking or cycling) (27, 38). Hence, we calculated the total MET minutes/week and classified them to determine the physical activity level.

Bivariable and multivariable binary logistic regression were conducted to assess the associations between dependent and several independent variables. A multivariable logistic regression analysis was employed to identify factors associated with overnutrition after controlling for potential confounding variables. A crude and adjusted odds ratio with a 95% confidence interval was computed to assess the level of association between ranked dietary patterns and the risks of overnutrition. A variance inflation factor (VIF > 10) and an inflated standard error (SE > 2) were considered to assess the possibility of multicollinearity between independent variables (39). Important predictors of overnutrition found in previous studies and associations with a value of p below 0.2 in the bivariable analysis were included in the multivariate logistic regression model. Hence, we adjusted for potential confounding variables (factors) where model fitness was evaluated using Hosmer and Lemeshow's test (value of p above 0.05) and the Omnibus test (*p*-value below 0.05) (40, 41). We also checked for an interaction or effect modification between the independent variables using a *p*-value (39). Statistical significance was declared for associations with a value of p below 0.05.

2.9. Ethical considerations

This study was reviewed and approved by the Dire Dawa University Institutional Research Ethical Review Board (DDU/IRB/0012/13). A letter of cooperation was taken to the respective offices before data collection. We gave a detailed and translated information sheet, and assent was obtained from the parents or guardians of adolescents aged below 18 years, while informed written consent was obtained from them directly for those aged at least 18 years. Participation in the study was on a voluntary basis, and no enforcement was implied. We conducted the interview in a secure place, and the collected data were not shared with a third party to assure confidentiality.

3. Results

3.1. Sociodemographic characteristics of participants

Of the total sample of 510 respondents, 48% were male. In addition, the majority, 208 (40.8%) and 326 (63.9%), were aged 10 to 13 years and were Muslims. Regarding maternal education, about 12.0, 16.5, 42.0, and 29.6% of them had no formal education, primary education, secondary education, or had at least a college education, respectively. Concerning occupational status, about 30.2% were housewives. About 200 (39.2%) and 161 (31.6%) of adolescents were from low and medium socioeconomic class families, respectively. Moreover, more than half (53.9%) of adolescents live in families where there are 3–5 family members (Table 1).

3.2. Major dietary patterns of adolescents

Data collected using FFQ was used in PCA to assess the dietary patterns of adolescents, where the 7 food groups from my pyramid were used to find foods that correlate highly to describe particular dietary patterns in PCA. All assumptions were checked stepwise, and items not fulfilling the assumptions were excluded sequentially. The sampling adequacy was checked by Kaiser Mayer Olkin (KMO) of 0.5, and there was a significant correlation among items ($X^2 = 101$, df = 21, value of p below 0.0001). Four major dietary patterns were identified, and these explained 67% of the total variation in the dietary consumption of adolescents. The identified dietary patterns had a factor loading above 0.5 in each food group, which indicates a significant correlation (Table 2).

Food group items with a complex structure (a higher loading for more than one factor) were excluded, and we derived four major dietary patterns with dominant food item loadings for each component. These are cereal, energy, and discretionary calorie foods; fatty and milk products; protein-rich foods and vegetables; and fruits. A factor score was generated using the Bartlett procedure, which is a robust and unbiased estimate of the true factor score. Then, the factor score was categorized into three terciles (low, medium, and high). Four dietary patterns, including "cereal, energy, and discretionary calorie foods," "oil, fatty foods, and milk products," "protein-rich foods, and vegetables," and "fruits," were identified as indicated in Table 2.

3.3. Prevalence of overnutrition among adolescents

In this study, a total of 115 (22.5%) and 33 (6.5%) were found to be affected by overweight and obesity, respectively. The

TABLE 1 Socio–demographic characteristics of community dwelling adolesccents in eastern Ethiopia, 2022.

Variable		Frequency	Percentage
Sex	Male	245	48%
	Female	265	52%
Age	10–13	208	40.8%
	14–16	184	36.1%
	17–19	118	23.1%
Religion	Orthodox	129	25.3%
	Muslim	326	63.9%
	Catholic	4	0.8%
	Protestant	46	9.0%
	Jewish, and adventist	5	1.0%
Mother education	No formal education	62	12.0%
	Primary education	64	16.5%
	Secondary education	214	42%
	College and above	151	29.6%
Father education	No formal education	77	15.1%
	Primary education	70	13.7%
	Secondary education	147	28.8%
	College and above	216	42.4%
Father occupation	Government employer	191	37.5%
	Merchant	135	26.5%
	Farmer	6	1.2%
	Daily labor	85	16.7%
	NGO employer	60	5%
	Self-employed	33	6.5%
Mother occupation	Government employer	152	29.8%
	Merchant	124	24.3%
	House wife	141	27.6%
	Daily labor	48	9.4%
	NGO employer	38	7.5%
	Self-employed	7	1.4%
Family size	3–5	275	53.9%
	6 and above	235	46.1%
Wealth index	Low	200	39.2%
	Medium	161	31.6%
	High	149	29.2%

combined prevalence of overnutrition (both overweight and obesity) was 29% (95% CI: 27–31%). Related to these, 2% of adolescents were found to be thin. When disaggregated by certain relevant factors, the burden of overnutrition was higher among females (15.6%) and among mid-adolescents aged 14–16 years (10.3%) as compared to males (13.1%) and older adolescents (7.1%), respectively. More importantly, the burden was significantly higher among private schools (22.5%) as compared to those who attend public schools (3.6%), excluding those who did not attend school during the study.

3.4. Factor associated with over–nutrition among adolescents

A bivariable binary logistic regression was conducted, and the association between socio-demographic, dietary/eating habits, physical activity, sedentary lifestyle, and dietary consumption pattern related factors with overnutrition among adolescents was evaluated. Hence, the state of overnutrition was significantly associated with maternal education, higher wealth status, family size, habits of snacking, skipping breakfast, being physically inactive, sedentary life,

TABLE 2 Summary of the major dietary patterns including the contribution of each food group to the total variance explained by the major dietary patterns among adolescent in eastern Ethiopia.

S.No.	Food groups	DP–1 (Factor 1)	DP–2 (Factor 2)	DP_3 (Factor 3)	DP–4 (Factor 4)
1.	Cereal and energy foods	0.684			
2.	Discretional and calories foods	0.723			
3.	Oil and fatty foods		0.853		
4.	Milk and milk products		0.592		
5.	Protein rich foods			0.842	
6.	Vegetables			0.591	
7.	Fruits				0.924
Total variance (66.9%)		20.8%	16.1%	15.5%	14.5%

DP refers to major dietary patterns derived from the reported individual food consumption.

and a dietary pattern characterized by cereal and energy-rich foods at a *value of p* of less than 0.05.

Older adolescents (COR = 1.23; 95% CI: 0.75–2.01), females (COR = 1.13; 95% CI: 0.77–1.65), and those from the wealthiest families (COR = 1.58; 95% CI: 1.00–2.50) had a higher risk of overnutrition as compared to their counterparts. In addition, adolescents from literate families (COR = 94.3; 95% CI: 50.1–177.6) and smaller family sizes (COR = 1.59; 95% CI: 1.03–2.46) were significantly associated with a higher burden of overnutrition compared to adolescents from illiterate families and larger family sizes (> 5). Furthermore, snacking (COR = 2.68; 95% CI: 1.70–4.23) and skipping breakfast (COR = 2.56; 95% CI: 1.68–3.89) significantly increased the risk of overnutrition by 2.7- and 2.6-folds, respectively. Physical inactivity (MET below 600 MET minutes per week) (COR = 1.61; 95% CI: 1.08–2.39) and sedentary lifestyle (COR = 4.68; 95% CI: 2.96–7.42) were significant factors positively associated with the risks of overnutrition among adolescents (Table 3).

Regarding the association between major dietary patterns and the risks of overnutrition, low and medium percentiles of cereal and energy food consumption patterns (COR = 1.53; 95% CI: 0.94–2.49) and higher percentiles of fatty food consumption patterns (COR = 1.15; 95% CI: 0.73–1.81) were associated with a higher risk of overnutrition among adolescents as compared to those with low terciles of energy and fatty food consumption. While those with low (COR = 1.35; 95% CI: 0.83–2.18) and medium protein-rich foods and vegetable consumptions (COR = 1.55; 95% CI: 0.96–2.49) were positively associated with a higher odd of overnutrition among adolescents (Table 3).

Variables associated with overnutrition in bivariable analysis and important factors explored in previous literature were included and tested in multivariable binary logistic regression analysis. A Hosmer and Lemeshow's goodness of fit value of 0.98 was identified, which indicates a fitted regression model for a given dataset. In addition, the effects of further addition or removal of factors on the model fitness were evaluated using an omnibus test (*value of p* < 0.0001), indicating an improved model. Variables with a significant decline in model fitness on removal were retained in the final model despite a higher *value of p* as shown in Table 4.

Based on fitting a regression model, we found that maternal literacy, family wealth status, physical activity, sedentary lifestyle, snacking, skipping breakfast, and four major dietary patterns were found to be important factors that could potentially predict risks of overnutrition among adolescents. For instance, adolescents from the highest wealth quintile (AOR = 1.82; 95% CI: 0.75–4.42) and less extended families (AOR = 2.00; 95% CI: 0.89–4.48) had an almost twofold increased risk of overnutrition compared to their counterparts. Physical inactivity (600 MET minutes per week) was associated with a more than sixfold increase in the risk of overnutrition (AOR = 6.27; 95% CI: 2.75–14.3) when compared to those who were physically active. Adolescents from educated families (literate mothers) were statistically significantly associated with a higher occurrence of overnutrition (AOR = 111.3; 95% CI: 50.0–247.8), indicating the majority of the overnutrition cases were concentrated among adolescents from educated families. Moreover, those with a habit of snacking (AOR = 1.80; 95% CI: 0.69–4.67) and skipping breakfast (AOR = 2.05; 955 CI: 0.84–5.04) were significantly associated with a twofold increased risk of overnutrition compared to those without habits of snacking and those with a regular meal. As compared to those with higher percentiles of cereals and discretionary food consumption patterns, adolescents with low (AOR = 1.69; 95 CI: 0.71–4.04) and medium (AOR = 2.28; 95 CI: 0.94–5.55) cereal consumption had 69 and 128% higher risks of being overnourished, respectively. Adolescents with a relatively medium tercile of protein-rich and vegetable consumption (medium) have a 2.3-times higher risk of overnutrition (AOR = 2.30; 95% CI: 0.97–5.46) as compared to those with a higher percentile of protein-rich and vegetable consumption. Hence, a higher tercile of protein-rich and vegetable consumption lowered the risks of overnutrition among adolescents (Table 4).

4. Discussion

Overnutrition is considered a global epidemic, and the burden is increasing (1, 2). It is a major risk factor for a number of chronic diseases, including type 2 diabetes, cardiovascular disease, hypertension, dyslipidemia, and premature death (3, 4). Hence, evaluation of the role of nutritional and eating behaviors in reducing the risks of overnutrition is crucial for better dietary recommendations. Therefore, the purpose of this study was to assess the burden of overnutrition and identify the association between different dietary patterns and the risks of overnutrition among adolescents. According to our study, 22.5 and 6.5% of adolescents were victims of overweight and obesity, with a total burden of overnutrition reaching 29%. The prevalence of overweight and obesity in this study is higher than the prevalence reported by studies conducted in Addis Ababa (5), Gondar (6), Jimma (7), Bahir

TABLE 3 Bivariable logistic regression analysis of factors associated with over nutrition among adolescents in eastern Ethiopia, 2022.

Factors	Options	Overnutrition		COR (95% CI)	*p–value*
		Yes	No		
Age of the respondents in years	10–13	58	150	1	
	14–16	52	132	1.02 (0.66–1.58)	0.934
	17–19	38	80	1.23(0.75–2.01)	0.411
Sex	Male	68	177	1	
	Female	80	185	1.13 (0.77–1.65)	0.545
Wealth index	Low	54	146	1	
	Medium	39	122	0.86 (0.54–1.39)	0.549
	High	55	94	1.58(1.00–2.50)	0.049*
Maternal education	Illiterate	20	339	1	
	Literate	128	23	94.3 (50.1–177.6)	0.0001**
Family size	<5	85	175	1.59 (1.03–2.46)	0.036*
	> =5	63	187	1	
Skipping breakfast	Yes	109	189	2.56 (1.68–3.89)	0.0001**
	No	39	173	1	
Snacking	Yes	119	219	2.68 (1.70–4.23)	0.0001**
	No	29	143	1	
Physical activity level (MET min/week)	< 600	98	199	1.61 (1.08–2.39)	0.020*
	≥ 600	50	163	1	
Sedentary life	< 3 h	120	173	4.68 (2.96–7.42)	0.0001**
	>3 h	28	189	1	
Cereal and energy foods (DP–1)	Low	58	112	1.80 (1.11–2.91)	0.017*
	Medium	52	118	1.53 (0.94–2.49)	0.086
	High	38	132	1	
Fatty foods and milk (DP–2)	Low	51	119	1	
	Medium	41	129	0.74 (0.46–1.20)	0.223
	High	56	114	1.15 (0.73–1.81)	0.559
Protein rich and vegetables (DP–3)	Low	51	119	1.35 (0.83–2.18)	0.223
	Medium	56	114	1.55 (0.96–2.49)	0.072
	High	41	129	1	
Fruits (DP–4)	Low	51	119	1	
	Medium	41	129	0.78 (0.48–1.27)	0.319
	High	56	114	1.50 (0.95–2.34)	0.082

1–refers to the reference category and MET indicates metabolic equivalents in minutes per week; DP–refers to the major dietary Patterns derived through exploratory factor analysis. Also, * refers to significant factors at a *p*–value below 0.05 (*) and 0.001 (**).

Dar (8), and Dire Dawa (9), which indicated 10–21% of adolescents had overnutrition in different parts of Ethiopia. As a result, overnutrition is a major public health issue that warrants more comprehensive and effective preventive strategies to halt its progression (10, 11). In addition, the hot weather conditions of the study area might have greatly affected the lifestyle, minimizing physical activities and walks with a preference for sweet foods produced in the area (12). Moreover, people residing in hot environment tends to consume fasting, fried food, and unfortunately, sweet food productions are common in the study area that may increase the risk. Partly due to weather, people may tend to consume foods in streets which are mainly unhealthy diets.

Overnutrition was found to be a major problem among adolescents from literate and wealthier families. A study among women also showed that there is a significant interaction between education and wealth for predicting obesity risks (value of p <0.0001). It is also indicated that the impact of wealth on the risk of obesity is higher for those with lower educational status (AOR = 1.78) than for those who are well-educated (13, 14). This might be due to the fact that adolescents from uneducated families have poor dietary behavior and are more likely to be stunted during early life (15). Hence, exposure to a highly nutritious diet with increasing wealth later may impose a severe risk of obesity. This might be linked to the role of early nutritional insults in the later development of obesity and other

TABLE 4 Multivariable logistic regression analysis output indicating the association between major dietary consumption patterns and other lifestyle factors with the development of overnutrition among adolescent in eastern Ethiopia, 2022.

Factors	Options	Overnutrition		AOR (95% CI)	*P–value*
		Yes	No		
Sex	Male	68	177	1	
	Female	80	185	1.32 (0.63–2.76)	0.462
Wealth index	Low	54	146	1	
	Medium	39	122	1.50 (0.62–3.62)	0. 373
	High	55	94	1.82 (0.75–4.42)	0. 187
Maternal education	Illiterate	20	339	1	
	Literate	128	23	111.3 (50.0–247.8)	0.0001**
Family size	<5	85	175	2.00 (0.89–4.48)	0.092
	>=5	63	187	1	
Skipping breakfast	Yes	109	189	2.05(0.84–5.04)	0.117
	No	39	173	1	
Snacking	Yes	119	219	1.80 (0.69–4.67)	0.0230*
	No	29	143	1	
Physical activity level (MET minutes/week)	< 600	98	199	6.27 (2.75–14.3)	0.0001**
	≥ 600	50	163	1	
Sedentary life	< 3 h	120	173	6.41 (2.84–14.5)	0.0001**
	>3 h	28	189	1	
Cereal and energy foods (DP–1)	Low	58	112	1.69 (0.71–4.04)	0.236
	Medium	52	118	2.28 (0.94–5.55)	0.070
	High	38	132	1	
Protein rich and vegetables (DP–3)	Low	51	119	1.06 (0.44–2.55)	0.891
	Medium	56	114	2.30 (0.97–5.46)	0.058
	High	41	129	1	

** refers to associations with a *p*–value below 0.001 (**) and 0.05 (*).

cardiovascular complications (16, 17). On the contrary, risk of sedentary behaviors and consumptions of ultra-processed and high energy foods are more common among the literate and the wealthier families due to access and price affordability.

Adolescents with a habit of snacking and skipping breakfast had almost a twofold increased risk of overnutrition among adolescents. In previous studies, skipping breakfast and snacking were associated with an increased risk of overnutrition (9, 18). In addition, skipping meals could increase the risk of obesity by fourfold (AOR = 3.55, *p*-value <0.05) (19, 20). A systematic review and meta–analysis from China using data from different countries confirmed that skipping breakfast is 1.44 times more likely to increase the risk of overweight or obesity than non-skipping breakfast (21). Adolescents having ≥3 snacks per day tend to consume more calories and be less physically active, with a higher total energy intake compared to those with a regular meal. Snacking, according to previous research, increases the risk of overnutrition and its associated health risks (20, 22). However, the type and size of snacks play a significant role in predicting overnutrition risks, as high-quality and low-energy snacks may supplement daily physiological requirements and diet quality (19, 23). On the other hand, we found that a higher number of adolescents reported skipping breakfast. Evidence also showed that a healthy breakfast could create satiety, reduce binge eating, and allow people to have optimal weight (24, 25). Hence, adolescents should not skip meals, as it affects school performance and health consumption, in addition to higher tendency for junk food consumption (26).

In this study, we found that lower consumption of cereals and higher consumption of discretionary food dietary patterns determine the risk of overnutrition. In addition, lower tercile of protein rich and vegetable dietary patterns were important factors associated with overnutrition among adolescents. A study from China also indicated that subjects in the highest quartiles had a higher risk of obesity (27). It is clear that wholegrain cereal consumption rich in dietary fiber has the potential to limit energy consumption and decrease glucose and cholesterol absorption (28, 29). On the other hand, foods rich in protein and vegetables could have a weight control effect by maintaining a healthy diet and optimum weight. Hence, diets rich in cereals, protein, and vegetables could have paramount importance in preventing overnutrition among adolescents (30). However, adolescents' dietary behavior may tend to favor unhealthy dietary preferences such as discretionary, high-calorie, and processed foods (31). This would be high among those who skip meals and have snack, where they consume high energy and processed foods that predispose adolescents to higher risks of overnutrition (23, 32). This would be further aggravated by the influence of peers (33, 34).

Physical activity (PA) and a sedentary lifestyle, are among causes of overweight or obesity in teenagers. A sedentary lifestyle is quite

relaxed, including sitting, lying down, etc., every day at work (working at the computer, reading, etc.) and at home (watching TV, playing games, etc.) (35, 36). There is no consensus about a single cutoff point to define PA to prevent overweight and obesity, but one of the main factors contributing to increased adiposity is lower energy expenditure caused by decreased PA (37, 38). In this study, the odds of being overweight or obesity among adolescents with higher hours of sedentary behaviors were 6 times more likely than those who did not have a sedentary life. This finding is higher than the study conducted in Jimma and Dire Dawa, which found that children and adolescents who watched TV for more than 4 h a day (7, 9) were more prone to obesity than those who watched for less than 4 h/day (39). This finding might be related to the lack of physical activity, which causes low energy expenditure and ultimately predicts the risk of obesity (40). The physical activity level of adolescents is low in urban setting below the daily minimum of 600MET per week. This could be further limited by the hoot weather condition of the study area. One study has showed that only 28% has the recommended PA level and less than 50% use walk from home to school and this worst in the urban setting (41).

Generally, dietary consumption patterns, physical activity level, snacking, skipping meals, and maternal literacy were associated with the risks of overnutrition among adolescents. Proper characterization of the diet is critical in linking dietary risk factors with overnutrition among adolescents (42, 43). Dietary consumption could be better characterized using dietary pattern analysis, which is a new nutritional epidemiological approach that can better predict nutritional outcomes than individual food and nutrient intakes (44). This study gives the first insight into how to create a link between dietary patterns and the risks of overnutrition among adolescents. Hence, the findings of this study would help in designing more practical dietary recommendations for the optimal nutrition of adolescents.

Although this study generates valid information quantifying the relationship between eating behavior and overnutrition among adolescents using a reliable method, the use of cross-sectional data might make it difficult to establish causality (45, 46). The current study is well conducted in a large adolescents' cohort from the same geographic area, however assessing adolescents' habits over the last month might not show their usual habits and the findings of this study may tend to have some limitations. Some respondent biases, inherent errors in anthropometric measurements, and social desirability bias could not be avoided totally. Moreover, respondents may tend to respond positively or negatively to the daily dietary consumption, which might bias the overall diet quality and be associated with overnutrition (47, 48). Hence, it is imperative to consider such limitations in interpreting the results of the current study.

5. Conclusions and recommendations

Overnutrition is a public health concern affecting one-third of adolescents, and it is closely linked with dietary consumption patterns, skipping breakfast, the habit of snacking, wealth status, literacy, and level of physical activity. Therefore, public health interventions to curb overnutrition among adolescents targeting unhealthy eating patterns and lifestyles are urgently needed to halt its emergence. Furthermore, parents of adolescents should promote an enabling environment for healthy dietary consumption and a better nutritional status for their children. Schools and the health bureau should strengthen access to physical activity facilities and regular physical activities through school competitions and healthy clubs.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Dire Dawa Univesity Institutionl Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

FG participated in conceptualization, design, data curation, project administration, data analysis, writing a report, and reviewing and approving the manuscript. AO participated in conceptualization, design, validation, supervision, methodology, data acquisition, data preparation, data visualization, and formal data analysis. In addition, AO substantially contributed to writing the draft manuscript, manuscript preparation, reviewing, and submitting the manuscript. ID participated in drafting the manuscript, critically reviewing it, and editing the drafted manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Glossary

A/COR	Adjusted/crude/Odds Ratio
BMI	Body Mass Index
BAZ	Body Mass Index for Age
CI	Confidence Interval
CVD	Cardiovascular Disease
DP	Dietary Patterns
EFA	Exploratory Factor Analysis
FFQ	Food Frequency Questionnaire
GPAQ	General Physical Activity Questionnaire
METS	Metabolic Equivalents
PCA	Principal Component Analysis
NCDs	Non communicable Diseases
SD	Standard Deviations
SE	Standard Error
TEM	Technical Error of Measurement
UNICEF	United Nations International Children Education Fund
VIF	Variance Inflation Factor
WHO	World Health Organization

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Association between tea drinking and disability levels in older Chinese adults: a longitudinal analysis

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Objective: As the global population ages, disability among the elderly presents unprecedented challenges for healthcare systems. However, limited research has examined whether dietary interventions like tea consumption may alleviate and prevent disability in older adults. As an important dietary therapy, the health benefits of tea drinking have gained recognition across research disciplines. Therefore, this study aimed to investigate the association between tea drinking habits and disability levels in the elderly Chinese population.

Methods: Leveraging data from the 2008 to 2018 waves of the Chinese Longitudinal Healthy Longevity Survey, we disaggregated tea drinking frequency and activities of daily living (ADL) measures and deployed fixed-effect ordered logit models to examine the tea-disability association for the first time. We statistically adjusted for potential confounders and conducted stratified analyses to assess heterogeneity across subpopulations.

Results: Multivariable fixed-effect ordered logistic regression suggested tea drinking has protective effects against ADL disability. However, only daily tea drinking was associated with lower risks of basic activities of daily living (BADL) disability [odds ratio (OR) = 0.61; 95% confidence interval (CI), 0.41–0.92] and lower levels of instrumental activities of daily living (IADL) disability (OR = 0.78; 95% CI, 0.64–0.95). Stratified analyses indicated heterogeneous effects across age and income groups. Daily tea drinking protected against BADL (OR = 0.26 and OR = 0.28) and IADL disability (OR = 0.48 and OR = 0.45) for adults over 83 years old and high-income households, respectively.

Conclusion: We found that drinking tea almost daily was protective against disability in elderly people, warranting further research into optimal dosages. Future studies should utilize more rigorous causal inference methods and control for confounders.

KEYWORDS

tea drinking, disability levels, elderly, IADL, BADL

1. Introduction

The growing prevalence of disability among the elderly has become a critical global issue. An estimated 100 million older adults suffer from varying degrees of disability (1). Disability in the elderly refers to the loss or limitation of their ability to perform daily activities and maintain living skills (2). Treatable pathological factors, such as diabetes or malnutrition, may cause these disabilities (3–5). Therefore, interventions such as treating diseases or improving nutrition may enhance disability status in the elderly. Neurodegenerative diseases, Alzheimer's disease, and other cognitive disorders lead to a decline in memory, thinking, and behavior in the elderly, impacting their daily living skills and independence (6, 7). There is no complete solution for the disability caused by these degenerative diseases in the elderly. Therefore, adopting preventive strategies is crucial.

China faces a severe aging crisis, with disability rates among older adults increasing from 7% in 2015 to 7.45% in 2020 (8, 9). Projections from China's Old Age Association show the disabled elderly population over 65 will grow from approximately 187 million in 2020 to over 520 million by 2050. The proportion of disabled elderly people in the total population will also continue to rise, with the disabled elderly population accounting for approximately 13.68% of the total elderly population in 2050 (10).

Tea contains antioxidants and bioactive compounds, such as flavonoids, catechins, polyphenols, and gallic acid (11). These substances all have biological activities and can reduce the risk of dementia by alleviating oxidative stress and inhibiting inflammatory responses (12). Using data from adults aged 65 years and above in Taiwan, Chiu et al. (13) found that higher tea intake was associated with lower disability levels in both men and women. Tao et al. (14) demonstrated that frequent iced tea and tea drinking had protective effects against ADL disability in the elderly. In a cross-sectional study in China, a lack of tea consumption was identified as one of the predictors of functional disability by Zhang et al. (15).

Apart from the above studies, little research has explored the health impacts of tea drinking on disability. For over 4,000 years, people in China, widely recognized as the origin of tea cultivation, have noted tea's health benefits and therapeutic properties. Chinese people have been the world's largest consumers of tea since 2006 (16). Therefore, this study aimed to determine the association between tea drinking and disability levels in older adults, which is important for reducing disability risks, improving quality of life, and alleviating caregiving burdens on families and society for the rapidly aging population.

2. Materials and methods

2.1. Study sample

The Chinese Longitudinal Healthy Longevity Survey (CLHLS), initiated in 1998 by the Center for Healthy Aging and Development Studies at Peking University's National School of Development, aims to examine the health determinants of individuals aged 65 and above. From 1998 to 2018, approximately half of the counties in 23 provinces, cities, and autonomous regions nationwide were randomly chosen for eight successive surveys, culminating in approximately 113,000 household visits. The survey specifics have been elaborated in previous studies (17, 18). The gathered data encompass demographic and residential information, marital status, lifestyle, socioeconomic attributes, health status, and an extensive array of personal data pertaining to the elderly.

To compensate for participant attrition due to death or loss to follow-up, the CLHLS incorporated new participants, mirroring the characteristics of the departed, to maintain study consistency. All surveys were administered through in-person interviews at the participants' residences, with each participant providing a signed informed consent form. In cases in which a participant was incapable of signing, a close relative signed on their behalf. This study adhered to the principles of the Declaration of Helsinki.

Data for this study were gleaned from four CLHLS surveys conducted in 2008, 2011, 2014, and 2018, which included the participants who were surveyed about their tea consumption at baseline and followed up afterward. The sample selection process is shown in **Figure 1**.

2.2. Dependent variables

This study used the Katz Index to gauge disability levels among elderly participants, incorporating both basic activities of daily living (BADL) and instrumental activities of daily living (IADL). BADL ability was evaluated based on six items: bathing, dressing, transferring, toileting, eating, and continence. If the respondent could complete an activity without assistance, it was coded as 1 and otherwise as 0, with scores ranging from 0 to 6. A new variable, "BADL," was calculated as the sum, in which a maximum score was assigned "1" (representing "non-disabled"); a score of 4–5 was assigned "2" (representing "mild disability"); a score of 2–3 was assigned "3" (representing "moderate disability"); and a score of 0–1 was assigned "4" (representing "severe disability").

The IADL assessment included eight items: visiting neighbors, shopping, cooking, washing, walking 1 km continuously, lifting 5 kg, crouching and standing up three times continuously, and taking public transport alone. Each item was coded as 1 if the respondent could complete it independently and 0 otherwise, with scores ranging from 0 to 8. A new variable "IADL" was calculated as the sum, in which a maximum score was assigned "1" (representing "non-disabled"); a score of 6–7 was assigned "2" (representing "mild disability"); a score of 3–5 was assigned "3" (representing "moderate disability"); and a score of 0–2 was assigned "4" (representing "severe disability") (19–21).

2.3. Independent variable

The drinking of tea was measured by the question: "How often do you drink tea?" The response options include almost daily; not every day but at least once a week; not every week but at least once a month; not every month but sometimes; and rarely or never. As the study's independent variable, drinking tea almost daily was assigned a value of 5; not every day but at least once a week was assigned 4; not every week but at least once a month was assigned 3; not every month but sometimes was assigned 2; and rarely or

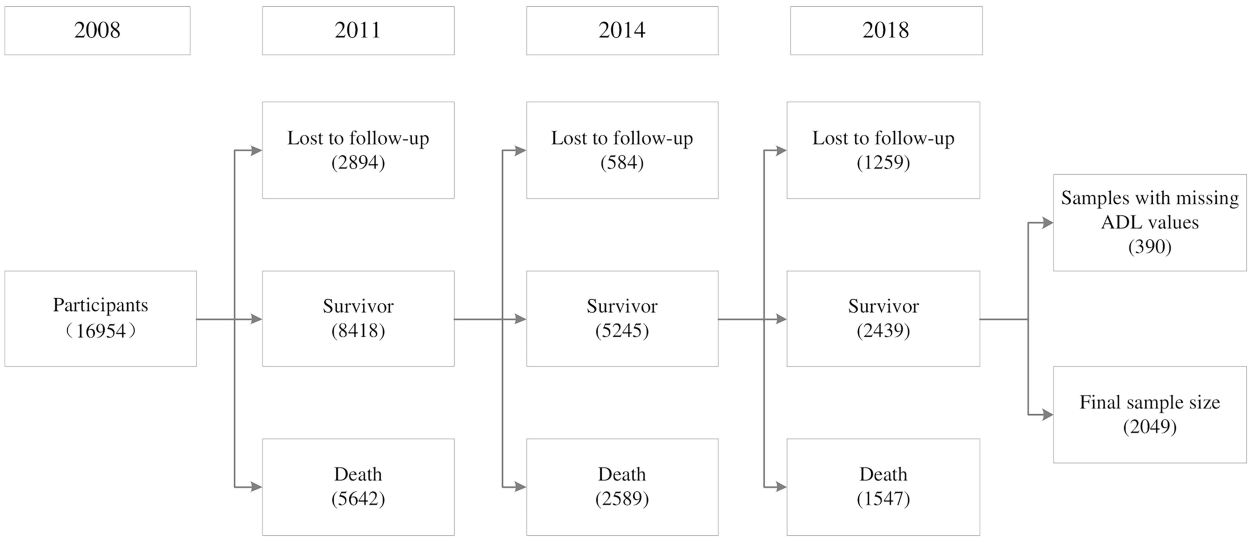

FIGURE 1
Participant inclusion and exclusion criteria.

never was assigned 1. Higher scores indicate a higher frequency of tea drinking.

2.4. Covariate measurements

This study critically examines several potential covariates, including sociodemographic factors, socioeconomic status, and health-related behaviors. Sociodemographic characteristics mainly included age (65–75, 75–83, and 83+), gender (male or female), marital status (married or unmarried), education level (illiteracy, primary school or below, or junior high school or above), and residential category (urban, town, or rural). For socioeconomic status, whether retired with a pension (yes or no), financial support (dependence or independence) and household income ($\leq$ RMB 20,000 or $>$ RMB 20,000) were mainly considered. For health behaviors, self-rated health (good, normal, and bad), current alcohol drinking and smoking (yes or no), fruit and vegetable consumption (often, occasionally, or rarely), and physical exercise (yes or no) were mainly considered.

2.5. Statistical analysis

In the 2008 survey, 16,954 respondents participated and were interviewed. In subsequent follow-ups, 4,737 individuals were lost to follow-up, 9,778 died, and 390 had missing ADL scores; these samples were excluded. A total of 2,049 participants completed the survey four times and were eventually included in the balanced panel data analysis (Figure 1). There were 623 missing values for sociodemographic characteristics and socioeconomic status, which we replaced with the individual's data from the previous year.

Based on the baseline characteristics summarized by tea consumption frequency, we employed the chi-square test and univariate analysis to examine categorical variables, and variance analysis for continuous variables. Taking into account time-invariant individual characteristics, we utilized panel data methods and applied the fixed effect ordered logit model to assess the odds ratio (OR) and 95% confidence interval (95% CI) for the impact of tea consumption on the level of disability in the elderly during the 2008–2018 follow-up period. Model 1 was a univariate analysis without adjustment. Model 2 adjusted for age, gender, marital status, education level, and residence. Model 3 added retirement status, financial support, self-rated health, drinking, smoking, exercise, and fruit and vegetable intake. For subgroup analyses, we grouped age and income by terciles and dichotomy, respectively, and all models adjusted for demographics, socioeconomics, and health behaviors.

Analyses were performed in STATA 17.0. All p-values are two-sided with $p < 0.05$ considered statistically significant.

3. Results

3.1. Descriptive characteristics

Table 1 displays the baseline descriptive characteristics of the study cohort categorized by tea consumption frequency. The sample consisted of 2,049 respondents with an average age of 75.07 years; 1,072 were female (52.32%), 61.01% were married, and 12.49% resided in urban areas, with the rest living in rural areas. Although the vast majority of the elderly were financially independent (78.28%), 74.82% of them belonged to households with an annual income of less than RMB 20,000. The proportion of the elderly who perceived their health status as good was 56.91% and the proportions of the elderly who smoked and drank were relatively low at 22.99 and 22.69%, respectively. Almost everyone (91.61%) frequently consumed fresh vegetables; only 42.41% ate fresh fruits often and 34.46% engaged in physical exercise. In the total sample, 48.32% of the participants drank tea almost every day and 36.07% rarely or never drank tea. The

TABLE 1 Baseline characteristics of participants stratified by tea drinking frequency.

Characteristics	*N* (%)	Tea frequency					*P*
		Drink little or never	Sometimes drink	Drink at least once a month	Drink at least once a week	Almost every day	
Gender							0.000
Male	977 (47.68)	437 (44.73)	56 (5.73)	20 (2.05)	63 (6.45)	401 (41.04)	
Female	1,072 (52.32)	302 (28.17)	59 (5.50)	32 (2.99)	90 (8.40)	589 (54.94)	
Age group							0.127
65–75	1,213 (59.20)	446 (36.77)	64 (5.28)	31 (2.56)	99 (8.16)	573 (47.24)	
76–83	526 (25.67)	183 (34.79)	39 (7.41)	15 (2.85)	30 (5.70)	259 (49.24)	
83+	310 (15.13)	110 (35.48)	12 (3.87)	6 (1.94)	24 (7.74)	158 (50.97)	
Marital status							0.000
Married	1,250 (61.01)	505 (40.40)	74 (5.92)	27 (2.16)	94 (7.52)	559 (44.72)	
Unmarried	790 (38.56)	234 (29.62)	41 (5.19)	25 (3.16)	59 (7.47)	431 (54.56)	
Residence							0.000
Urban	256 (12.49)	96 (37.50)	24 (9.38)	2 (0.78)	16 (6.25)	118 (46.09)	
Town	414 (20.20)	207 (50.00)	17 (4.11)	10 (2.42)	37 (8.94)	143 (34.54)	
Rural	1,379 (67.30)	436 (31.62)	74 (5.37)	40 (2.90)	100 (7.25)	729 (52.86)	
Education							0.000
Illiteracy	962 (46.95)	292 (30.35)	48 (4.99)	28 (2.91)	73 (7.59)	521 (54.16)	
Primary school or below	786 (38.36)	307 (39.06)	47 (5.98)	18 (2.29)	60 (7.63)	354 (45.04)	
Junior high school or above	301 (14.69)	140 (46.51)	20 (6.64)	6 (1.99)	20 (6.64)	115 (38.21)	
Financial							0.000
Independence	1,604 (78.28)	614 (38.28)	95 (5.92)	40 (2.49)	118 (7.36)	737 (45.95)	
Dependence	445 (21.72)	125 (28.09)	20 (4.49)	12 (2.70)	35 (7.87)	253 (56.85)	
Income (RMB)							0.105
≤20,000	1,533 (74.82)	524 (34.18)	86 (5.61)	40 (2.61)	109 (7.11)	774 (50.49)	
>20,000	516 (25.18)	215 (41.67)	29 (5.62)	12 (2.33)	44 (8.53)	216 (41.86)	
Exercise							0.004
Yes	706 (34.46)	279 (39.52)	42 (5.95)	25 (3.54)	49 (6.94)	311 (44.05)	
No	1,343 (65.54)	460 (34.25)	73 (5.44)	27 (2.01)	104 (7.74)	679 (50.56)	
Drinking							0.000
Yes	465 (22.69)	230 (49.46)	23 (4.95)	10 (2.15)	31 (6.67)	171 (36.77)	
No	1,584 (77.31)	509 (32.13)	92 (5.81)	42 (2.65)	122 (7.70)	819 (51.70)	
Smoking							0.000
Yes	471 (22.99)	214 (45.44)	25 (5.31)	7 (1.49)	35 (7.43)	190 (40.34)	
No	1,578 (77.01)	525 (33.27)	90 (5.70)	45 (2.85)	118 (7.48)	800 (50.70)	
Health							0.000
Good	1,166 (56.91)	466 (39.97)	62 (5.32)	36 (3.09)	84 (7.20)	518 (44.43)	
Normal	61 (29.33)	202 (33.61)	37 (6.16)	10 (1.66)	50 (8.32)	302 (50.25)	
Bad	282 (13.76)	71 (25.18)	16 (5.67)	6 (2.13)	19 (6.74)	170 (60.28)	
Work							0.000
Yes	391 (19.08)	180 (46.04)	39 (9.97)	6 (1.53)	27 (6.91)	139 (35.55)	
No	1,658 (80.92)	559 (33.72)	76 (4.58)	46 (2.77)	126 (7.60)	851 (51.33)	

(Continued)

TABLE 1 (Continued)

Characteristics	*N* (%)	Tea frequency					*P*
		Drink little or never	Sometimes drink	Drink at least once a month	Drink at least once a week	Almost every day	
Fruit							0.000
Often	869 (42.41)	361 (41.54)	49 (5.64)	18 (2.07)	56 (6.44)	385 (44.30)	
Occasionally	781 (38.12)	258 (33.03)	69 (8.83)	29 (3.71)	47 (6.02)	258 (33.03)	
Rarely	399 (19.47)	120 (30.08)	19 (4.76)	5 (1.25)	28 (7.02)	227 (56.89)	
Vegetable							0.000
Often	1,877 (91.61)	682 (36.33)	105 (5.59)	44 (2.34)	133 (7.09)	913 (48.64)	
Occasionally	150 (7.32)	50 (33.33)	8 (5.33)	8 (5.33)	19 (12.67)	65 (43.33)	
Rarely	22 (1.07)	7 (31.82)	2 (9.09)	0 (0.00)	1 (4.55)	12 (54.55)	
BADL							0.000
Non-disabled	2,002 (97.71)	726 (36.26)	111 (5.54)	50 (2.50)	148 (7.39)	967 (48.30)	
Mild disability	36 (1.76)	8 (22.22)	3 (8.33)	2 (5.56)	3 (8.33)	20 (55.56)	
Moderate disability	10 (0.49)	4 (40.00)	1 (10.00)	0 (0.00)	2 (20.00)	3 (30.00)	
Severe disability	1 (0.05)	1 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	
IADL							0.000
Non-disabled	1,431 (69.84)	539 (37.67)	85 (5.94)	38 (2.66)	105 (7.34)	664 (46.40)	
Mild disability	329 (16.06)	122 (37.08)	17 (5.17)	6 (1.82)	26 (7.90)	158 (48.02)	
Moderate disability	164 (8.00)	41 (25.00)	7 (4.27)	6 (3.66)	13 (7.93)	97 (59.15)	
Severe disability	125 (6.10)	37 (29.60)	6 (4.80)	2 (1.60)	9 (7.20)	71 (56.80)	
Total (*N*)	2,049 (100.00)	739 (36.07)	115 (5.61)	52 (2.54)	153 (7.47)	990 (48.32)	

Education: education level, divided into illiterate, primary school and below, and junior high school and above. Financial: whether elderly peoples' sources of income are sufficient, using dependence and independence to indicate whether elderly people are economically independent. Income: the annual income of the whole family, grouped by median. Work: whether they enjoy pension or retirement benefits. Health: self-rated health status. IADL, instrumental activities of daily living; BADL, basic activities of daily living. Yes and No indicate whether a certain activity was performed.

remaining three categories accounted for only 15.62% of the total sample.

Those who did not benefit from a retirement system were more likely to drink tea almost daily than those who did, a difference that is statistically significant (p = 0.000). Similarly, individuals with higher educational levels and those who did not smoke, drink, and regularly consume fresh fruits and partake in other healthy behaviors were more likely to drink tea, with these differences also being statistically significant ($p < 0.01$). Only 2.29% of all participants suffered from varying degrees of BADL disability, whereas the incidence rate of IADL disability was as high as 30.16%. Those without disabilities were more inclined to consume tea.

3.2. Logistic regression results

In Table 2, unadjusted fixed effects ordered logit models indicated almost everyday tea drinking protected against BADL (OR = 0.53; 95% CI, 0.34–0.83) and IADL disability (OR = 0.74; 95% CI, 0.61–0.89) compared with drink little or never. After adjusting for sociodemographic characteristics, socioeconomic status, and healthy behaviors, almost everyday tea drinking still had a protective effect against IADL (OR = 0.78; 95% CI, 0.64–0.95) and BADL disability (OR = 0.61; 95% CI, 0.41–0.92).

3.3. Subgroup analysis

Previous studies indicate that tea consumption effects on cognition vary by age and economic status in the elderly (22, 23). This section explores whether tea-disability associations differ by age and income. Stratified regression by age (Table 3) showed that drinking frequencies above drink at least once a month have a protective effect against BADL disability in elderly individuals aged 83 and above (OR = 0.36, OR = 0.42, and OR = 0.26). At least once a month (OR = 0.51; 95% CI, 0.2–0.91) and almost everyday drinking (OR = 0.48; 95% CI, 0.33–0.69) were also associated with less IADL disability. These findings indicate that tea drinking may help prevent ADL ability decline and functional deterioration in the oldest section of the population.

Income was dichotomized into high and low groups. Stratified analysis (Table 4) showed that almost everyday tea drinking had a positive protective effect against BADL disability in high-income elderly people (OR = 0.28; 95% CI, 0.15–0.50). Sometimes and almost everyday drinking also protected against IADL disability decline (OR = 0.78 and OR = 0.45, respectively). However, tea drinking did not significantly impact BADL or IADL disability in low-income elderly people.

TABLE 2 Associations between tea drinking and disability among older Chinese people.

Item (*n*)	IADL (OR 95% CI)		
	Model 1	Model 2	Model 3
Tea frequency [drink little or never (2,175)]			
Almost every day (4,869)	0.74 (0.61, 0.89)***	0.74 (0.60, 0.91)***	0.78 (0.64, 0.95)**
Drink at least once a week (451)	1.12 (0.88, 1.43)	1.13 (0.85, 1.49)	1.12 (0.87, 1.44)
Drink at least once a month (193)	0.91 (0.56, 1.49)	0.89 (0.58, 1.37)	0.95 (0.60, 1.54)
Sometimes drink (508)	0.99 (0.76, 1.30)	0.99 (0.74, 1.33)	1.00 (0.76, 1.34)
Item (*n*)	BADL (OR 95% CI)		
	Model 1	Model 2	Model 3
Tea frequency [drink little or never (2,175)]			
Almost every day (4,869)	0.53 (0.34, 0.83)***	0.50 (0.32, 0.77)***	0.61 (0.41, 0.92)***
Drink at least once a week (451)	1.19 (0.67, 2.11)	1.20 (0.71, 2.05)	1.05 (0.66, 1.69)
Drink at least once a month (193)	0.58 (0.23, 1.45)	0.61 (0.25, 1.47)	0.72 (0.30, 1.71)
Sometimes drink (508)	1.26 (0.71, 2.24)	1.26 (0.70, 2.27)	1.35 (0.75, 2.42)

*** and ** represent 1 and 5% significance levels, respectively. OR, odds ratio; 95% CI, 95% confidence interval. All three models controlled for fixed effects of year and province. The first model did not adjust for any covariates. The second model controlled for demographic and socioeconomic characteristics. The third model built upon the second model by further adding health behaviors and other related variables. *n* is the number of individuals grouped after the total sample size over 4 years.

TABLE 3 The association between tea drinking and disability stratified by age.

Item (*n*)	IADL (OR 95% CI)		
	65–75 (2,948)	76–83 (2,766)	83+ (2,482)
Tea-frequency (drink little or never)			
Almost every day	1.16 (0.75, 1.77)	0.67 (0.45, 1.00)*	0.48 (0.33, 0.69)***
Drink at least once a week	1.29 (0.71, 2.35)	0.95 (0.47, 1.89)	0.89 (0.66, 1.21)
Drink at least once a month	1.21 (0.45, 3.30)	1.30 (0.47, 3.60)	0.51 (0.28, 0.91)**
Sometimes drink	1.35 (0.77, 2.38)	0.47 (0.21, 1.04)*	0.73 (0.42, 1.24)
Item (*n*)	BADL (OR 95% CI)		
	65–75 (2,948)	76–83 (2,766)	83+ (2,482)
Tea frequency (drink little or never)			
Almost every day	2.12 (0.65, 6.92)	0.42 (0.16, 1.07)*	0.26 (0.16, 0.44)***
Drink at least once a week	2.55 (0.65, 9.95)	3.14 (0.72, 13.67)	0.42 (0.29, 0.62)***
Drink at least once a month	0.51 (0.07, 3.93)	0.31 (0.02, 4.23)	0.36 (0.13, 0.98)**
Sometimes drink	11.12 (1.24, 99.40)	0.64 (0.04, 9.51)	0.55 (0.26, 1.16)

***, **, and * represent 1, 5, and 10% significance levels, respectively. OR, odds ratio; 95% CI, 95% confidence interval. The models all controlled for confounding factors such as demographic characteristics, socioeconomic status, health behaviors, and other related variables. All the models controlled for fixed effects of year and province. *n* is the number of individuals grouped after the total sample size over 4 years.

4. Discussion

In this large prospective elderly cohort, we found that frequent tea drinking (almost daily) could alleviate the deterioration of daily living activities and lower risks of BADL and IADL disability, whereas occasional tea drinking did not provide protective effects. Our findings provide new evidence that frequent tea consumption could help prevent disability in the elderly.

In the context of widespread tea culture, tea drinking has always been considered as a promising non-pharmacological health strategy and has always been used to assist the management of hypertension, obesity, and diabetes (24). Tea and its components have been extensively used in functional foods and supplements to prevent and treat diverse conditions, including Parkinson's disease (25), stroke (26), and dementia (12), among others. Certain tea types, including black tea and oolong tea, contain abundant tea polyphenols like catechins and theaflavins, conferring beneficial properties such as antioxidant, anti-inflammatory, and neuroprotective activities that positively associate with health-related quality of life in aging populations (27). White tea is abundant in xanthine glycosides, flavonoid glycosides, and methylated flavan-3-ols, exhibiting antihypertensive and antioxidant actions (28). Rodent experiments by Li et al. (29) revealed white tea extract (WTE) can modulate lipid metabolism in cultured rat adipocytes and hepatocellular carcinoma cells. Shen et al. (30) reported green tea epigallocatechin and epicatechin can

TABLE 4 The association between tea drinking and disability stratified by income.

Item (*n*)	IADL (OR 95% CI)	
	Low income (4,600)	High income (3,596)
Tea frequency (drink little or never)		
Almost every day	0.89 (0.66, 1.19)	0.45 (0.29, 0.70)***
Drink at least once a week	0.91 (0.58, 1.43)	0.80 (0.50, 1.27)
Drink at least once a month	1.17 (0.63, 2.18)	0.86 (0.45, 1.66)
Sometimes drink	1.11 (0.73, 1.69)	0.78 (0.35, 1.76)***
	BADL (OR 95% CI)	
Item (*n*)	Low income (4,600)	High income (3,596)
Tea frequency (drink little or never)		
Almost every day	0.83 (0.34, 2.04)	0.28 (0.15, 0.50)***
Drink at least once a week	1.14 (0.36, 3.55)	0.94 (0.50, 1.79)
Drink at least once a month	1.54 (0.36, 6.68)	0.30 (0.61, 1.52)
Sometimes drink	2.07 (0.83, 5.15)	0.64 (0.21, 1.98)

*** represents a 1% significance level. OR, odds ratio; 95% CI, 95% confidence interval. The models all controlled for confounding factors such as demographic characteristics, socioeconomic status, health behaviors, and other related variables. All the models controlled for fixed effects of year and province. *n* is the number of individuals grouped after the total sample size over 4 years.

stimulate bone formation by modulating osteoblast differentiation and proliferation. These catechins also suppress inflammation and bone resorption to benefit bone health. Animal studies have demonstrated various protective effects of green tea, including antioxidant, anti-inflammatory, antihypertensive, antidiabetic, and hepatoprotective activities (31–33). Sustained tea intake may positively impact physiological health (34), thereby improving quality of life (35) and promoting healthy aging. Consequently, tea drinking may play an important role in disability protection for the elderly population.

The findings of this study demonstrated protective effects of tea drinking on BADL and IADL disability and that almost daily tea drinking was associated with lower levels of disability in older people, a finding that contrasts with several previous studies. Tea contains a variety of molecular compounds, including caffeine, oxalic acid, and tannic acid. Numerous scientific studies have shown that excessive caffeine intake can lead to insomnia, anxiety, rapid heartbeat, and other harmful effects (36). Additionally, high consumption of oxalic acid may adversely impact kidney function (37). The tannic acid in tea may be associated with reduced iron absorption (38). Additionally, lack of sleep and poor kidney function can increase the risk of disability in the elderly (39, 40).

Contrary to the potential negative effects noted earlier, some research indicates that adequate and regular tea drinking may promote health benefits in the elderly population (41). Elderly individuals who regularly drink tea have better cognitive function, and regular tea drinking (at least once a week) is associated with a lower risk of cognitive impairment (22, 42). A diminished capacity for activities of daily living among older adults is associated with cognitive decline (43), which critically predicts functional impairment and disability in this population (44, 45). Elderly people with greater cognitive function encounter a lower disability risk (46), suggesting that tea drinking may reduce disability prevalence by protecting against cognitive decline.

Cognitive decline in elderly people is mainly caused by three factors: neurodegenerative diseases (47), neurotransmitter imbalances (48), and brain atrophy (49), which often have complex interactions with oxidative stress and inflammation. Tea possesses abundant bioactive constituents associated with anti-inflammatory and antioxidant mechanisms (13, 50), which are capable of conferring antioxidant, anti-inflammatory, and neuroprotective properties that may enhance cognitive health and mitigate disability risk in older populations. Tea polyphenols manifest antioxidant, anti-inflammatory, and neuroprotective qualities that help reduce oxidative damage, suppress neuroinflammation, and protect neurons from harm (51). Catechins alleviate oxidative stress and inflammation, decelerating the progression of neurodegenerative diseases (52). Caffeine inhibits brain fatty acid amide hydrolase and decreases amyloid-beta accumulation, thus reducing susceptibility to neurodegenerative conditions like Alzheimer's disease (53). L-theanine has anxiolytic and antidepressant effects that can alleviate cognitive impairment by regulating neurotransmitters such as GABA, serotonin, and dopamine (54), partially validating the foregoing analysis.

Our stratified regression analysis showed that tea drinking was associated with higher BADL and IADL scores in those over 83 years old. This aligns with previous studies showing that frequent tea drinking is associated with better cognition in Chinese octogenarians (22) and improves cognition in Japanese people over 70 years old who consume green tea (55). Advanced age confers a risk for disability (56). Statistics indicate that the disability rate is nearly three times higher in Chinese people aged 75–84 versus 65–74, with nearly half of the over 85 s eventually developing total disability (57). Our findings suggest that tea consumption helps prevent disability in the very old. IADL represents the ability needed for social interaction activities in middle-aged and elderly people, who are more sensitive to subtle functional defects (58). Assessing IADL enables the early detection of physical and cognitive decline in elderly people, allowing timely intervention.

Economic status influences diet (59, 60). Tea consumption and associated health benefits also depend on income (61). Thus, we conducted income-stratified analyses (high vs. low), controlling for socioeconomic factors. The results revealed differing tea-disability patterns by income. Drinking tea almost every day has a protective effect against IADL and BADL disability in elderly people from high-income households, whereas no significant impact was observed in low-income elderly people. This may reflect higher stroke, dementia, and disability rates among those of a lower economic status (62, 63). Although beneficial, tea alone may be insufficient as treatment. Higher tea consumption frequency and quality among high-income elderly likely stems from health motivations, which confer preventive effects (64).

The advantage of our study is the use of a fixed effects ordered logit model to analyze panel data. This controlled for individual heterogeneity and provided more reliable association measurements than Cox models. This model also allowed us to evaluate the treatment effect of tea drinking within individuals, overcoming the limitations of previous studies that did not control for time-invariant unobserved characteristics (65–67).

Furthermore, we refined the independent and dependent variables to identify the tea consumption frequency with the greatest impact on disability in the elderly and quantify the protective effects of different frequencies. Using both IADL and BADL provided comprehensive assessments of disability; IADL was more sensitive in capturing mild disability and early functional decline, helping timely discovery and intervention. Our conclusions show that only drinking tea almost every day confers protective effects against disability, rather than casual tea drinking. This study has several limitations. First, owing to the limitations of the questionnaire items, this study used the frequency of drinking tea as the independent variable, and the questionnaire did not include questions regarding the types and doses of tea intake. Future studies can explore the effects of different types of tea and tea doses on disability in elderly people. Second, although this paper selected the ADL scale as an indicator of disability level, the scoring criteria were rather rough due to the limitations of the answer types in the questionnaire.

5. Conclusion and recommendations

Tea drinking among older adults was found to help reduce the risk of increased disability levels. Regular tea drinking exerted a certain protective effect against IADL and BADL disability in the elderly population; daily drinking appeared to be the optimal frequency. The protective effects of tea drinking were more pronounced in the very old and high-income elderly. These findings may have important implications for public health efforts aimed at preventing functional capacity decline in older adults. Additional rigorous observational studies are warranted to further elucidate this relationship, accounting for tea type and potential interactive effects.

Disability can profoundly impact the quality of life and mental wellbeing of older adults and impose tremendous socioeconomic burdens (68), as disabled elderly people often require more care, healthcare, and rehabilitation services, undoubtedly increasing the economic burden on families and society (69). Given global aging trends, the number of disabled older adults continues to rise. Long-term care systems are widely deemed to be fundamental for addressing looming crises in the care of elderly people and protecting health in later life. Our findings may also provide new perspectives on developing better long-term care models.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://opendata.pku.edu.cn/dataverse/CHADS.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethical Review Committee of Peking University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

YM: obtained funding, conceptualized the study, assisted with statistical analysis, helped conduct the literature search and review, wrote, and revised the manuscript. YZ: conducted the literature search and review, analyzed the data, assisted with statistical analysis, wrote, and revised parts of the manuscript. DH and HZ: conducted statistical analysis, drafted the manuscript, wrote, and revised parts of the manuscript. LL: contributed to the writing of the final version of the manuscript. All authors have read and agreed to the published manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Vitamin D levels in the pre- and post-COVID-19 pandemic periods in pediatric patients with chronic kidney disease

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Introduction: Vitamin D (VD) deficiency is common in children with chronic kidney disease (CKD) because of multiple factors. During the coronavirus disease 2019 (COVID-19) pandemic, it increased because of medicine shortage and no enough medical service for patients with non-COVID-19 diseases.

Objective: To analyze the effects of the COVID-19 pandemic-related lockdown on the serum levels and status of 25-hydroxyvitamin D3 (25-[OH]D) in children with CKD.

Materials and methods: This retrospective study included patients (6–18 years old) who were diagnosed with CKD stage 2–5 and routinely measured for serum VD levels between May 2019 and December 2022. Serum 25-(OH)D levels were measured before, during, and after the pandemic (2019, 2020–2021, and 2022, respectively). The daily dose of cholecalciferol supplementation and the readjustment (if required) were recorded.

Results: This study included 171 patients (median age: 12 years). Before the pandemic, the median serum VD level was 25.0 ng/mL (19.3% VD deficiency). Then, VD supplementation was adjusted to 400–1,200 UI daily in 98.8% ($n = 169$) of patients. During the pandemic, the median VD level decreased to 22.5 ng/mL (43.3% VD deficiency). Hence, the supplementation was readjusted, and after the pandemic, the level was 28.7 ng/mL (18.7% VD deficiency), indicating a statistically significant increase in serum VD levels from the prepandemic period ($p = 0.007$).

Conclusion: Decreased serum VD levels and increased VD deficiency frequency were observed in patients with CKD during the COVID-19 but improved after readjustment of supplementation.

KEYWORDS

COVID-19 pandemic, vitamin D, chronic kidney disease, pediatric, cholecaciferol

1. Introduction

Vitamin D (VD) is a fat-soluble steroid hormone that has a specific cytosolic receptor. Initially, VD was related to calcium and phosphorus metabolism; however, more recently, it has been found to have a role on multiple central extraskeletal effects on several target organs, such as adipose tissue, blood cells, the immune system, skin, muscles, endocrine pancreas, and blood vessels (1, 2). The VD receptor (VDR), which is expressed in almost all organs, acts via the genomic (nuclear VDR) and nongenomic (membrane VDR) pathways. Humans acquire most of their VD from sunlight-induced cutaneous synthesis (approximately 80%), and the remainder from diet and supplementation (3, 4). However, the factors associated with VD deficiency included dark skin, sedentary periods, insufficient sun exposure, air pollution, obesity, and lack of VD supplementation (5).

VD is also important in chronic kidney disease (CKD)-related mineral bone disorder, considering that 1-α hydroxylase, which is essential for bone formation and resorption, is found in the kidneys. Low serum levels of 25-hydroxyvitamin D3 (25-[OH]D) cause negative calcium balance, secondary hyperparathyroidism, and bone disease. In CKD, hyperphosphaturic osteocyte-derived hormone (FGF-23) increases to compensate for phosphate retention and further inhibits renal 1α-hydroxylase expression and induces 24-hydroxylase expression responsible for 1,25(OH)D degradation. Poor 25(OH)D absorption caused by kidney disease is the main cause of 1,25(OH)D deficiency (4). Thus, patients with terminal CKD are deficient in activated VD as well as nutritional VD (6).

Taking into account that serum 25(OH)D level <20 ng/mL indicates VD deficiency, and >30 ng/mL is needed for optimal health, the Kidney Disease Outcomes Quality Initiative (KDOQI) and Kidney Disease Improving Global Outcomes (KDIGO) guidelines recommend measuring 25(OH)D levels once a year in children with CKD stages 2–5 and starting supplementation if levels are <30 ng/mL (7). The KDOQI guidelines also recommend the administration of cholecalciferol for treating VD failure in CKD stages 3 and 4, and active VD hormone for VD deficiency in patients with stage 5 CKD who also have secondary hyperparathyroidism. The data clearly indicate that 25(OH)D insufficiency persists as patients progress from stage 3 to stage 5 CKD (8).

During the coronavirus disease 2019 (COVID-19) pandemic, people were quarantined for 1 year (2020) (9). In Mexico, children were quarantined for 2 years (2020–2021), predisposing them to possible significant long-term effects on health. Confining oneself indoors for a longer period reduces sunlight exposure time, leading to a decrease in cholecalciferol synthesis. On the other hand, during the pandemic, there were medicine shortages and patient care was limited, including those with chronic diseases. Epidemiological studies have reported that the COVID-19 pandemic has changed the VD levels in children (10, 11). Patients suffering from chronic diseases, such as CKD, are highly at risk for VD deficiency (12), which might have worsened during the pandemic; however, data from the COVID-19 pandemic period are lacking or conflicting.

Hence, our study aimed to analyze the effects of the COVID-19 pandemic-related lockdown on the serum levels and status of 25-(OH) D in pediatric patients with CKD.

2. Materials and methods

2.1. Subjects

In Mexico, the first case of COVID-19 was reported on February 27, 2020, and a few days later (March 11, 2020), the WHO officially declared a pandemic. On March 31, 2020, the Mexican government officially announced a nationwide lockdown, which implies the total closure of schools, universities, public squares, and all shops, except for supermarkets, grocery stores, and pharmacies (13, 14).

This is a retrospective cohort study with pediatric patients with CKD stages 2–5 who, aged 6–18 years old. All patients were routinely measured for serum VD levels before and after the pandemic period at a tertiary pediatric hospital (Hospital Infantil de Mexico Federico Gómez) in Mexico City between May 2, 2019 and December 31, 2022. All patients were treated in the outpatient clinic of the Nephrology department, and met the definition of CKD proposed by KDIGO, since they had deterioration in renal function >3 months, and to determine the severity of CKD each patient was staged according to the KDIGO criteria (stages 2 to 5). Patients with diseases that prevent normal metabolism of the VD were excluded (diabetes, heart disease, or had been treated for cancer within the previous 5 years or genetic rickets), as well as those with incomplete clinical and biochemical evaluation. The cohort follow-up duration was 36 months. All included patients were selected using a consecutive sampling technique.

As of 2019, the hospital laboratory began to measure 25(OH)D because it was previously requested externally. In other words, not all patients underwent 25(OH)D measurement. Hence, the demographic and anthropometric data were collected at the beginning of the follow-up, particularly from the nephrology consultation in 2019 (pre-COVID-19 pandemic). We collected the data on the serum concentrations of 25(OH)D, the dose of cholecalciferol supplementation, and the need for supplementation readjustment from that consultation. After 24 months follow-up and COVID-19 immunization among adults in Mexico, the attendance of consultation in patients with CKD was regularized in 2021. From this consultation and 6–12 months thereafter, the data on 25(OH)D levels, the cholecalciferol supplementation dose, and the need for another supplementation readjustment were collected. At follow-up, adherence to VD supplementation was assessed.

2.2. Variables

The main outcome measures were serum 25(OH)VD concentrations and VD status, and the primary exposure variable was the cholecalciferol supplementation doses administered during the 36 months of surveillance. Serum 25(OH)VD concentrations and VD status at the beginning of follow-up were considered as predictors; while adherence to treatment, the COVID-19 pandemic period, and whether the patient had a kidney transplant were the confounding variables.

Patients with body mass index (BMI) <5th percentile were considered malnutrition, normal with BMI >5th percentile and <85th

Abbreviations: 25-[OH]D, 25-hydroxyvitamin D3; CKD, chronic kidney disease; COVID-19, coronavirus disease 2019; VD, vitamin D; VDR, vitamin D receptor.

percentile, obesity with BMI > 95th percentile, and overweight with BMI > 85th percentile, according to the 2000 CDC Growth Charts (15). Patients with <2 standard deviations of height for age, BMI was calculated considering the age that corresponds to the 50th percentile of actual height.

From 204 potentially eligible patients, three did not meet the inclusion criteria (two cancer patients undergoing chemotherapy treatment, and one patient with tetralogy of Fallot), and another five patients were excluded because of incomplete medical records. 25 patients were eliminated because they were discharged to adult hospitals upon turning 18 years old. Thus, 171 patients were analyzed (Figure 1).

According to the Declaration of Helsinki, the study protocol was approved by hospital ethics and research committee (registry number: HIM-2020-023).

2.3. Vitamin D determination

In the Hospital Infantil de Mexico Federico Gomez clinical laboratory, the serum concentrations of 25(OH)D were measured using the Abbot chemoluminescence technique with the equipment Archirech 1,000. A serum level of <20 ng/mL was considered as VD deficiency, 20–29.99 ng/mL as insufficiency, and >30 ng/mL as normal (12).

2.4. Statistical analyses

The quantitative variables were analyzed using Shapiro–Wilk test, and a nonparametric distribution was observed. We calculated the median and interquartile range (IQR) for the quantitative variables and the frequency and percentage for the qualitative variables. Differences in 25(OH)D at study onset, after 24 months, and 30–36 months were determined using the repeated measures Wilcoxon test. We also used Mann–Whitney *U* test and chi-square test for group comparison.

A value of $p < 0.05$ was considered statistically significant. STATA v.12.0 (Stata Corp., College Station, TX, United States) was used for all statistical analyses.

3. Results

3.1. Baseline

Table 1 shows the baseline characteristics of the 171 included patients, who were 9–14 years old and had similar sex ratio. The majority had a normal nutritional status (68.4%), while 32 (18.7%) were overweight or obese. During evaluation, 110 (64.3%) had stage 2 CKD, followed by 35 (20.5%) with stage 5 CKD. Of these patients

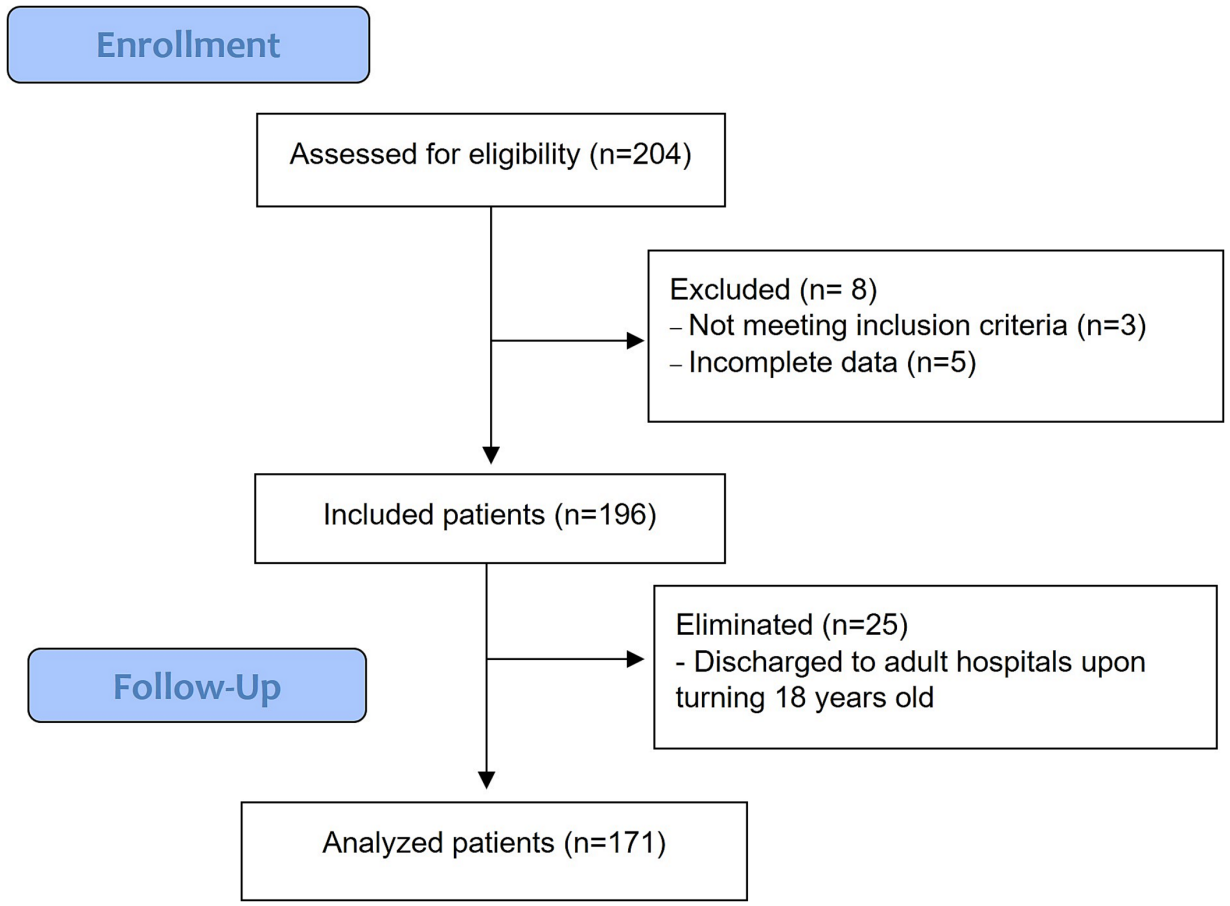

FIGURE 1
Flow diagram of individuals at each stage of study.

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with stage 5 CKD, 26 (74.3%) underwent hemodialysis as replacement treatment, 7 (20.0%), and 2 underwent kidney transplant (Table 1).

The median serum VD level among all patients was 25.0 ng/mL (IQR: 20.7, 29.8 ng/mL) (Table 1 and Figure 2); but only 23.4% ($n = 40$) had normal VD levels, 33 (19.3%) patients had VD deficiency and 98 insufficiency (57.3%) (Figure 3). As for supplementation, during this period 47.3% received cholecalciferol supplementation at a median dose of 400 IU per day (IQR: 400 to 800 IU). Therefore, according to VD serum levels, cholecalciferol supplementation was readjusted to a median of 800 IU per day (IQR: 400 to 1,200 IU) in 98.8% of the patients.

3.2. Follow-up (24 months)

After 24 months follow-up, the median 25(OH)D level was 22.5 ng/mL (IQR 16.3, 28.1 ng/mL) (Figure 2), and only 19.9% ($n = 34$) had normal levels, indicating a statistically significant decrease compared to baseline data ($p = 0.007$). The median delta 25(OH)D level from the baseline to the 24 months follow-up was −3.1 ng/mL (IQR: −11.9, 5.7 ng/mL).

Thus, the VD deficiency worsened as compared with that at the first evaluation (19.3% vs. 43.3%, $p < 0.001$) (Figure 3A). The 33 patients who had VD deficiency at baseline, 36.4% ($n = 12$) remained deficient and 45.5% ($n = 15$) progressed to insufficiency (Figure 3D). In the case of the 98 patients with VD insufficiency, 44.9% ($n = 44$) progressed to deficiency and 35.7% ($n = 35$) remained as insufficient (Figure 3C). Lastly, among the 40 patients with normal VD levels, most progressed to levels considered deficiency or insufficiency ($n = 31$, 77.5%) (Figure 3B).

During the pandemic, at 24 months of the follow-up, the median cholecalciferol supplementation was 800 IU per day (IQR, 400 to 1,200 IU per day). At 24 months of the follow-up was identified that up to 67.2% ($n = 115$) did not present adequate adherence to cholecalciferol supplementation.

3.3. Follow up (36 months)

After 6–12 months of follow-up of the cholecalciferol supplementation readjustment (30–36 months of follow-up at the beginning of the cohort study), the median serum VD level was 28.7 ng/mL (IQR: 22.6, 40.3 ng/mL) (Figure 2), where 47.4% ($n = 81$) had normal VD levels (Table 2). Thus, the level showed a statistically significant increase compared with the previous measurement (22.5 ng/mL vs. 28.7 ng/mL, $p = 0.007$) (Figure 2), as well as an increase in the proportion of patients with normal VD levels (19.9% vs. 47.4%) (Table 2). The median delta 25(OH)D level between the 24 months follow-up and the 30–36 months follow-up was 8.4 ng/mL (IQR: −0.5, 17.6 ng/mL).

During consultation and VD level verification, cholecalciferol supplementation was readjusted to a median dose of 4,000 IU per day (IQR, 2,000 to 4,000 IU; $n = 78$ [45%] dose ≤2,000 IU per day). Hence, cholecalciferol supplementation was increased as compared to that at the first evaluation (cholecalciferol supplementation 800 UI vs. 4,000 UI per day, $p < 0.001$). The patients were also recommended to increase intake of foods with a high VD content (Table 2).

At the end of follow-up (36 months), of the patients who started with VD deficiency, eight persisted with deficiency and 16 achieved normal levels (Figure 3D); Of the patients with insufficiency, 17 presented deficiency and 51.0% ($n = 50$) achieved normal levels (Figure 3C) and of the patients who started with VD sufficiency, 17.5% ($n = 7$) ended up with VD deficiency (Figure 3B).

At the end of follow-up (36 months), it was identified that 40 (23.4%) patients did not present adequate adherence to cholecalciferol supplementation, including the 32 patients who ended up with deficiency and 8 patients with VD insufficiency. It should be noted that of the 8 patients who persisted with deficiency during follow-up did not present adequate adherence to cholecalciferol supplementation. The median delta 25(OH)D level between the 24 months follow-up and the 30–36 months follow-up in patients did not present adequate adherence to cholecalciferol supplementation was lower that (0.59 ng/mL [IQR: −4.84, 7.6 ng/mL]) patients with adequate adherence (12.1 ng/mL [IQR: 3.29, 19.6 ng/mL]) ($p < 0.0001$).

TABLE 1 Baseline characteristics of pediatric patients with chronic kidney disease before the COVID-19 pandemic period (2019).

Characteristics	Total $n = 171$	
Age, *y*		
	Median (IQR)	12.0 (9.0, 14.0)
Sex, %		
	Female	93 (54.4)
	Male	78 (45.6)
Nutritional status, %		
	Normal	117 (68.4)
	Malnutrition	22 (12.9)
	Overweight/obesity	32 (18.7)
Stage chronic kidney disease, %		
	2	110 (64.3)
	3	12 (7.0)
	4	14 (8.2)
	5	35 (20.5)
CKD etiology		
	CAKUT	93 (54.4)
	Glomerulopathy	33 (19.3)
	Immunological	28 (16.4)
	Nephrectomy for neoplastic pathology	11 (9.9)
Cholecalciferol supplementation, %		
	Yes	81 (47.3)
Cholecalciferol supplementation dose, UI ($n = 81$)		
	Median (IQR)	400 (400, 800)
25(OH)D, ng/mL		
	Median (IQR)	25 (20.7, 29.8)
Vitamin D status, %		
	<20 (deficiency)	33 (19.3)
	20–29.9 (insufficiency)	98 (57.3)
	≥30 (normal)	40 (23.4)

25(OH)D, 25-hydroxyvitamin D3; IQR, interquartile range; CAKUT, congenital anomalies of the kidney and the urinary tract; CKD, chronic kidney disease.

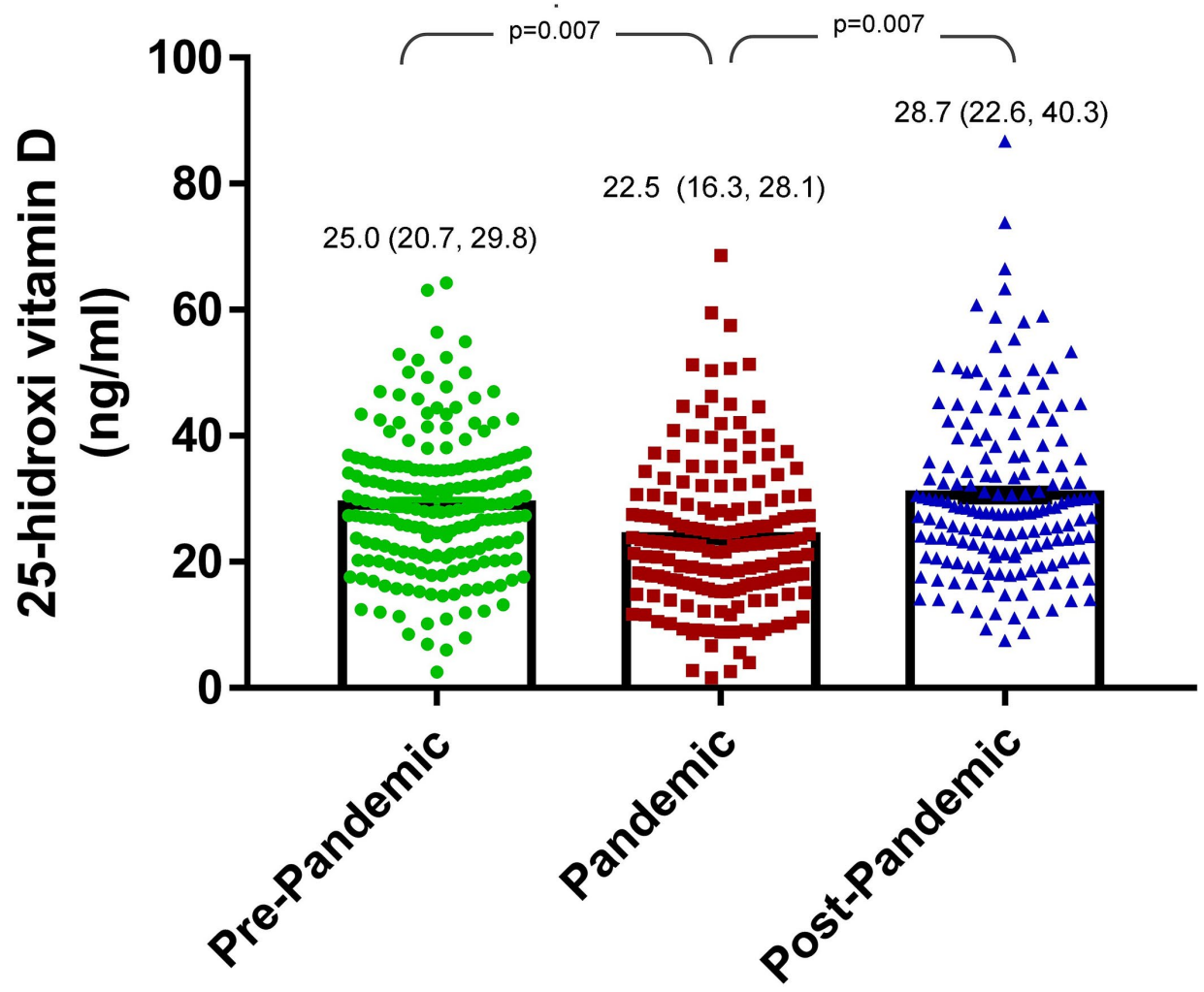

FIGURE 2
Change in vitamin D levels from before, during, and after the COVID-19 pandemic in pediatric patients with chronic kidney disease.

3.4. Confounding variables

The proportion of patients with VD deficiency was lower at the end of the follow-up than at the beginning (18.7% vs. 23.4%, $p = 0.04$). This result is related to the increase in cholecalciferol dose compared with the dose at the initial follow-up (4,000 UI vs. 400 UI, $p < 0.001$).

10 patients underwent kidney transplantation, with no statistical difference in VD levels in the post-COVID-19 pandemic period between patients with and without kidney transplantation (26.4 ng/mL in those with kidney transplant vs. 21.8 ng/mL in those without kidney transplant; $p = 0.225$).

4. Discussion

VD deficiency and insufficiency have now become a global public health problem despite the availability of supplements. In pediatric patients with CKD, its prevalence has reached 62.5 to >80% (16, 17), similar to our study finding prior to the start of the pandemic (76.6%).

Different tissues unrelated to calcium and phosphorus metabolism express VDR and 1 alpha-hydroxylase (CYP27B1), which regulates gene expression in various tissues (18). Hence, VD is important in extraskeletal tissues as well as at the immunological, metabolic, and cardiovascular levels, among other systems (19, 20).

The most abundant source of cholecalciferol is from cutaneous synthesis on UV-B exposure from sunlight (21). Therefore, low sun exposure, sunscreen use, dark skin, and pollution lead to a decrease in VD synthesis (22). In addition, the dietary sources of cholecalciferol are limited to fatty fish, beef liver, and egg yolk, and Mexico has no fortified foods (23). Some chronic diseases, such as CKD, obesity, and diabetes mellitus, can also result in the decrease in VD bioavailability, worsening the VD levels (24).

During the COVID-19 pandemic, many factors contributed to VD level decrement; one factor was social confinement, which decreases sun exposure (10, 25). In Mexico, social confinement of children lasted for almost 2 years (2020 and part of 2021). Other factors include low intake of high VD food sources and shortage in medications, including cholecalciferol. In addition, contagion in Mexico City during the first year of the pandemic was positively related to COVID-19 mortality (26).

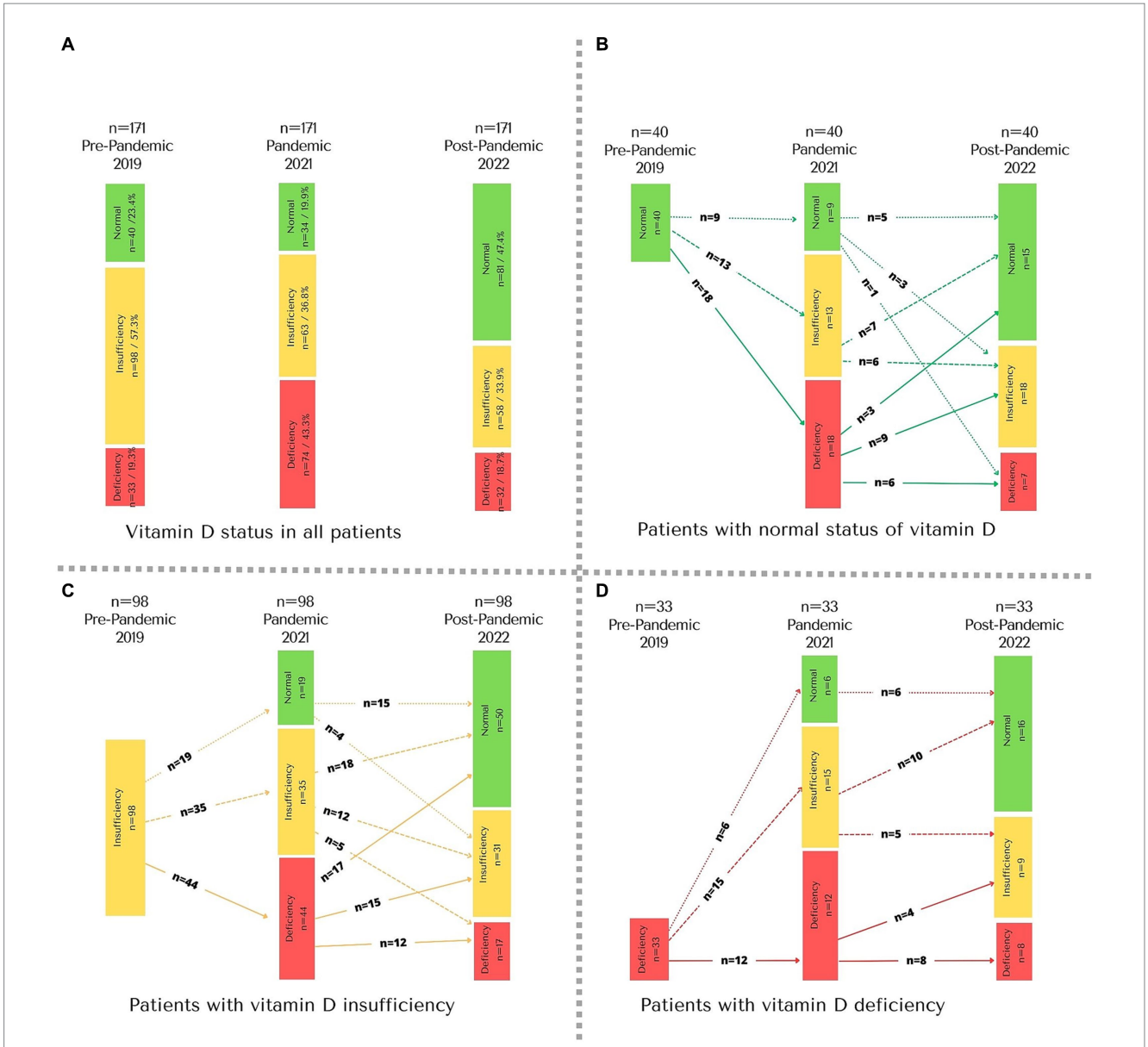

FIGURE 3
Change in vitamin D status from before, during, and after the COVID-19 pandemic in pediatric patients with chronic kidney disease. **(A)** All patients; **(B)** patients with normal status of vitamin D before the COVID-19; **(C)** patients with vitamin D insufficiency before the COVID-19; **(D)** patients with vitamin D deficiency before the COVID-19.

We found several retrospective studies that demonstrate the impact of restrictions during the COVID-19 pandemic on VD levels in the pediatric population, and VD insufficiency and deficiency were observed (25). Beyazgül et al. evaluated the impact of the first year of the pandemic on VD levels in preschoolers, schoolchildren, and adolescents (1–6, 6–12, and 12–18 years, respectively) at two different periods (pre- and post-pandemic); the found that the rate of deficiency values was significantly higher during the pandemic in schoolchildren and adolescents, with the latter group being the most affected (median VD level: 11.20 ng/mL, $p = 0.003$) (10). During the pandemic, our study similarly identified a statistically significant decrease of 3.1 ng/mL in serum VD levels in pediatric patients who received cholecalciferol supplements at a median dose of 800 IU per day. Therefore, we can assume that multiple factors negatively influenced these levels during the pandemic period, thereby increasing the need for closer monitoring and frequent supplementary readjustments. Similarly, Wong et al. conducted a retrospective study with a similar methodology wherein blood samples from 303 patients aged 2–24 months were analyzed; they found that patients recruited during the pandemic period had decreased VD levels ($p < 0.001$) (11). Dyussenova et al. also retrospectively examined 40 children with CKD with KDIGO stage 1–5 classification between January 2020 and September 2020 and demonstrated that 62.5% of these children had VD deficiency and that low levels correlate with a decrease in the glomerular filtration rate (17).

Populations vulnerable to VD deficiency are those with clinical conditions such as osteoporosis (primary or secondary), metabolic bone diseases, chronic renal disease, malabsorption

TABLE 2 Characteristics of pediatric patients with chronic kidney disease after the pandemic period.

Characteristics		24 months after (2021)	30–36 months after (2022)	*p*
		Total *n* = 171		
Cholecalciferol supplementation, %				
	Yes	169 (98.8)	171 (100)	0.889
Cholecalciferol supplementation dose, UI				
	Median (IQR)	800 (400, 1,200)	4,000 (2000, 4,000)	<0.001
25 (OH)D, ng/mL				
	Median (IQR)	22.5 (16.3, 28.1)	28.7 (22.6, 40.3)	0.007
Vitamin D status, %				
	<20 (deficiency)	74 (43.3)	32 (18.7)	<0.001
	20–29.9 (insufficiency)	63 (36.8)	58 (33.9)	
	≥30 (normal)	34 (19.9)	81 (47.4)	

25(OH)D, 25-hydroxyvitamin D3; IQR, interquartile range.

syndrome, liver failure, type 1 diabetes mellitus, and cancer who could benefit from 25(OH)D concentrations maintained at 30–60 ng/mL (27).

The initial cholecalciferol supplementation in our pediatric population was only between 400 and 1,200 IU daily prior to the start of the pandemic, mainly because our country did not have pediatric presentations that had doses greater than 1,200 IU and children were also recommended to consume foods with high VD content to achieve adequate supplementation (2,000–4,000 IU), as recommended in patients with CKD (28). However, after the first year of the pandemic, new presentations of cholecalciferol from 2,000 to 4,000 IU emerged, as well as lower VD levels than those previously found in patients (25.0 ng/mL vs. 22.5 ng/mL, $p = 0.007$); the supplementation was then adjusted to a dose between 2,000 and 4,000 IU. With this latest adjustment, we observed that the proportion of VD deficiency decreased and that the VD levels were higher than those presented before the start of the pandemic (29).

In a healthy pediatric population, VD supplementation at a dose of 2,000 IU per day for 6 months to reach levels >30 ng/dL of 25[OH]D is effective up to approximately 92.9% (30). In the present study, after the pandemic, the dose of cholecalciferol in 45% of the patients was ≤2,000 IU per day, so most probably the majority of patients had low serum levels of VD. However, in studies in CKD pediatric patients with VD supplementation at doses of 4,000 IU, 36 to 91% achieved levels >30 ng/mL (31, 32); these data seem to correspond to our results, since despite cholecalciferol supplementation (up to 4,000 IU per day), at the end of follow-up only 47.4% reached VD sufficiency levels. The failure to achieve optimal VD levels, despite adequate supplementation, has been explained previously; Demburg et al. reported that glomerular disease may be associated with changes in vitamin D metabolism that is affected by urinary losses of vitamin D-binding protein (VDBP) secondary to glomerular and/or tubular damage in CKD (33). Furthermore, it has been observed a complex relationship between VDBP, free-25OHD and biologically available form of 25OHD in children with renal disease (33, 34). Therefore, it seems necessary to conduct pharmacokinetic studies of VD in CKD pediatric patients to better understand the relationship of dose supplementation and inter-individual variation.

The extraskeletal effects demonstrated that increasing serum 25(OH)D suggested promising effects in reducing the progression to diabetes mellitus type 2, decreasing cancer mortality, and reducing the incidence of autoimmune diseases (35–37).

In patients with CKD, nutritional supplementation with VD has potential benefits, including reduction of parathyroid hormone levels, beneficial impact on arterial and cardiac diseases, improvement of response to erythropoietin-stimulating agents, proteinuria decreases in respiratory and gastrointestinal infections of viral origin (38, 39).

One of the strengths of the study is that it is a longitudinal study with various measurements of VD levels, as well as modifications in VD supplementation with cholecalciferol. However, the index of sun exposure, food intake, or drugs that can modify VD bioavailability was not examined; therefore, these data are limited to a similar population according to the index of sun exposure and chronic disease. Furthermore, the observational nature of the study, while demonstrating associations, does not allow the drawing of definitive conclusions about causality.

In conclusion, decreased serum levels of VD and increased frequency of VD deficiency were observed during the COVID-19 pandemic in patients with CKD but improved after the readjustment of cholecalciferol supplementation. However, given that not all patients achieved normal VD levels, continuous monitoring seems necessary.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by According to the Declaration of Helsinki, the study protocol was approved by hospital ethics and research committee (registry number: HIM-2020-023). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

IP-O: Conceptualization, Investigation, Writing – original draft. JZ-C: Conceptualization, Data curation, Formal analysis,

Methodology, Writing – original draft. IO-F: Writing – review & editing. BR-N: Investigation, Writing – review & editing. MV-K: Supervision, Writing – original draft, Writing – review & editing. BM: Data curation, Investigation, Writing – review & editing. VD-C: Investigation, Writing – review & editing. JR-V: Data curation, Investigation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Characteristics of individuals at risk of malnutrition in Thailand: an investigation focusing on income insecurity

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Without understanding the characteristics of disadvantaged individuals who are at risk of malnutrition, it is impossible for policymakers to develop and implement effective policies to combat malnourishment among individuals facing income insecurity. With an accurate picture of who is at the greatest risk, policymakers will be able to target the most vulnerable population and develop interventions tailored to their needs. However, there is a dearth of research in Thailand which presents such characteristics and makes it more difficult to design appropriate policy interventions. This study we applied a logit regression model on data collected by Food and Agriculture Organization (FAO) in 2021 (n = 981). The findings of this study indicate that gender, age, place of residence, educational attainment, and family composition are all strong predictors of access to adequate nutrition among those who are financially disadvantaged. Specifically, we observed that women aged 30–44 years old are 11.5% more likely to not have access to adequate nutrition due to financial constraints compared to those aged 18–29 years old. In consideration of these important predictors, policymakers are recommended to take bold steps including these aforementioned factors while formulating strategies and policy interventions to address malnutrition among the financially disadvantaged.

KEYWORDS

malnutrition, undernourishment, undernutrition, income insecurity, poverty, food security, characteristics, Thailand

1 Introduction

Malnutrition is an ongoing problem for many individuals and families living in financial insecurity that restricted their access to healthy foods and their ability to acquire knowledge about proper nutrition (Bain et al., 2013; Drammeh et al., 2019). The lack of nutritional intake has been shown to have severe repercussions on the physical and psychological health of those affected, such as the increased risk of cancer, mental health disorder, and depression. This intense situation highlights government's intervention that is crucial in not only providing help for those in need (Ihab et al., 2015; Devine and Lawlis, 2019) but in addressing the systemic issues that lead to malnutrition in the first place (Deolalikar, 2005; Huang et al., 2013; Sansón-Rosas et al., 2021).

One of the primary reasons individuals in vulnerable populations suffer from food malnutrition is due to the lack of financial stability. Without secure income streams, they are

unable to afford adequate nutrition to maintain their and their families' health. In some cases, this cyclical poverty results in difficult decisions when it comes to budgeting and ultimately purchasing food. Without an income instability, individuals are more likely to opt for cheaper and less nutritious options, posing a real threat to their health and wellbeing.

Since 2014, the number of undernourished people in Thailand has been steadily rising (Food and Agriculture Organizations, 2021b), greatly impacting the country's economic growth due to its effects on individuals' health and productivity (The Nation, 2018; Tiwasing et al., 2018; Okubo et al., 2020). The COVID-19 pandemic has worsened the situation significantly, pushing an additional 8.8 million people in Thailand towards the brink of undernourishment in 2020, with children and older people in low-income households being the most affected (Mayurasakorn et al., 2020; Shinsugi and Mizumoto, 2022; Vicerra et al., 2022). This increased level of malnutrition presents an imminent challenge that the Thai government needs to address by implementing urgent policies, strategies and interventions, to ensure their citizens lead healthy and productive lives.

Despite the needs to identify and safeguard households in Thailand that are at high risk of being undernourished due to financial insecurity, there is a lack of research on the subject to provide adequate amount of information regarding the characteristics such as age, community, cognitive ability and family arrangements. In search of this, this paper we aim to investigate the characteristics of people who are at risk of malnutrition which results from the lack of financial resources, utilizing data from the survey of Food Insecurity Experience Scale 2021 in Thailand by the United Nation's Food and Agricultural Organization (FAO) (Food and Agriculture Organizations, 2021a).

The results of this analysis are expected to support policies to promote livelihoods and reduce the malnutrition risk of those who are in a financially disadvantaged conditions, especially after the COVID-19 pandemic that has severely affected their wellbeing.

2 Literature review on people at risk of malnutrition from income insecurity

Malnutrition and income insecurity are linked to each other in many ways (Steiber et al., 2015; Paslakis et al., 2021). Malnutrition is often the result of an inability to access adequate and nutritious food which frequently due to conflict, health, seasonal access to natural resources, or even unequal opportunities in all spheres of society, such as education, technology, and work (Rojer et al., 2016; Soeters et al., 2017; Khan, 2023; Luc et al., 2023; Saleem, 2023), while income insecurity is the state of not having enough income to cover basic needs (Young, 2022). This infers that people facing income insecurity are more likely to suffer from malnutrition as they may not have enough money to purchase nutrient-rich food (Painter, 2016; Loopstra, 2018). This issue is exacerbated by the fact that in many countries, the least healthful food options, such as processed foods and sugary drinks, are often cheaper than the healthier options (Monteiro et al., 2010; Popkin and Ng, 2022). In addition, people in low-income households that struggle to make ends meet must choose between purchasing high-quality food and cover other essential costs such as family expenses (Loopstra, 2018; Young, 2022). As a result, this lack of financial resources increases the risk of malnutrition further as it can lead to a decreased overall food intake and changes in eating habits (Xie et al., 2021).

In addition to income insecurity, other important associated elements are gender, age, place of residence, educational achievement, and family arrangement (El Shikieri, 2023; Kandapan et al., 2023; Sultan and Iram, 2023).

Considering gender influence, within the same households, women and girls often face greater risks of malnutrition due to the perpetuation of gender roles (Hwang and Shon, 2014; Frize et al., 2021). Duties of family works can result in females receiving less access to quality food and nutrition than men and boys. Furthermore, globally, women are more likely to live in poverty than men (Okin, 2015) which mean that women are more likely to experience hardship in accessing the food and nutrition that they need (Ivers and Cullen, 2011; Botreau and Cohen, 2020). In addition, limited access to credit, education, and employment opportunities can leave women especially vulnerable to economic instabilities, further exacerbating their risk of malnutrition (Ngoma and Mayimbo, 2017; Abrahams et al., 2018).

Regarding age, as people grow older, they tend to have more money to spend than younger people. This gives them a better chance of being able to afford nutritious foods, and therefore decreases their risk of malnourishment in comparison to younger people with financial constraints (Imamura et al., 2015; Munt et al., 2017). This is especially true for prepared retirees who may have pension or government benefits to supplement their income, and thus, their food choices may be sufficient for their nutrition needs (Imamura et al., 2015).

In terms of residency, the prevalence of malnutrition varies drastically between urban and rural environments due to income insecurity (Anríquez et al., 2013; Hong et al., 2020). Urban citizens often have to pay higher prices for housing and transportation, leaving them with less disposable income for food, and therefore, more vulnerable to malnutrition (Mohiddin et al., 2012; Tacoli, 2019). In contrast, rural residents are generally able to access cheaper living costs, allowing them to purchase healthier foods. However, in some cases, there may not be a difference in malnutrition levels between urban and rural areas (Meenakshi, 2016; Tacoli, 2019; Mittal and Vollmer, 2020). One reason might be that urban areas often offer various nutritious options at competitive prices (Anríquez et al., 2013; Meenakshi, 2016).

Regarding educational factors, the connection between education achievement and malnutrition is direct and clear. A higher level of schooling leads to better economic opportunities, and hence, allowing individuals to make smarter decisions about their spending and diets (Kramer and Allen, 2015; Damião et al., 2017; Dutta et al., 2019). By having the knowledge on effective financial management and nutrition, those with more education are better equipped to access nutritious foods and less likely to be at risk of undernourishment (Dutta et al., 2019).

Lastly, when looking at profiles of households, a larger family can find themselves more exposed to the risk of malnutrition. For example, families with more members are likely to be disproportionately affected (Mishra et al., 2014; Asim and Nawaz, 2018) because it is more difficult for them to make ends meet and have resources to buy enough food for all (Mishra et al., 2014; Khan and Raza, 2016).

In summation, the individual factors that contribute to the risk of malnutrition are multifaceted, including family structure, age, gender, place of residence, and educational attainment. Such elements are interconnected, and when combined, can created a complex environment that enhance an individual's probability of being malnourished. In the context of Thailand, while existing research acknowledges the multifaceted nature of individual factors contributing to the risk of malnutrition, there remains a notable research gap that requires further exploration. Specifically, there is a need for more in-depth investigations into how the unique socio-cultural and economic landscape of Thailand influences the interconnected dynamics of family structure, age, gender, place of residence, and educational attainment in relation to malnutrition risk. The existing literature provides a foundation by recognizing the complexity of these elements, but a deeper understanding of their interplay within the Thai context is essential for developing targeted interventions and policies.

3 Research design

3.1 Dataset

This study utilized the 2021 Food Insecurity Experience Scale (FIES) survey data from Thailand, collected by the United Nation's Food and Agriculture Organization (FAO) Statistics Division via a telephone sample design of 1,033 responses (Food and Agriculture Organizations, 2021a). Unit of analysis is individuals. After filtered the responses taking their comprehensive detail into consideration, 981 data points were deemed applicable to the investigation. The dataset provided information on various demographic variables like the number of adults and children in the household, age, education level, rural or urban area, gender, and income. Moreover, the FIES survey module focused on the respondents' experiences in the past 12 months such as their worries about inadequate food, their inability to access healthy and nutritious food, or their reliance on a limited variety of edibles (Food and Agriculture Organizations, 2021a).

3.2 Empirical model

- Dependent variable

The dependent variable is "UHY," as indicated by the question in the Thailand FIES 2021 dataset inquiring "Were you unable to eat healthy and nutritious food because of lack of money or other resources?." This variable is a dichotomous variable, with "Yes" representing the respondent's experience of being unable to eat healthy and nutritious food due to the lack of money or other resources, and "No" indicating the opposite

- Independent variables

Six predictor variables, derived from a literature review, were utilized in this study. They were gender (GDR) and area of residence (AOR), which were dichotomous variables. Meanwhile, ordinal variables were number of adults in the household (NAH), number of children in the household (NCH), age (AGE), income of respondent (INC), and education (EDU).

3.3 Model construction

This study utilized logistics model to investigate the characteristics of people who are at risk of malnutrition by considering the characteristics of selected dependent variable, namely, UHY. The logistics regression model (logit) was fundamentally used for analyzing the dichotomous variable. It attempted to estimate the probability of being in one category compared to being in another category (Hosmer et al., 2013).

The estimation method is denoted as follows:

$$P = \left(\mathrm{UHY}_{i,j} = 1\right) = \frac{e^{\beta X_i}}{\sum ie^{\beta X_i}} \quad (1)$$

and

$$X_i = \alpha_0 + \beta_2 GDR_i + \beta_1 AGE_i + \beta_2 INC_i + \beta_3 AOR_i + \beta_4 EDU_i + \beta_5 NAH_i + \beta_6 NCH_i$$

where $\mathrm{UHY_i}$ is individual respondent *i*; P (UHY = 1) is the probability of the individual respondent having an experience of being unable to eat healthy and nutritious food due to the lack of money or other resources; X is defined as a set of independent variables; and β, α is a set of coefficients.

According to Eq. (1), the probability of success event P (UHY = 1) was quantified by β in the set of predictors X. Marginal effect was used to interpret the meaning of β, indicating as the following equation:

$$\text{Marginal Effect:} \quad \frac{\partial \hat{P}}{\partial X} = \hat{B}_X \hat{P}\left(1 - \hat{P}\right) \quad (2)$$

In Eq. (2), the partial derivative of the probability, P (UHY = 1), with respect to X yielded the marginal effect. A positive sign in the marginal effect indicated that, when the predictor or independent variable increased by one unit, there was an increase in the probability of a successful event of the same magnitude. Conversely, a negative sign in the marginal effect implied that, as the predictor or independent variable increased by one unit, the probability of a failed event decreased by the same magnitude.

3.4 Limitations

This paper focused on investigating how an individual's profile and background could increase their risk of being unable to consume nutritious meals. Unfortunately, our analysis did not include other influential biological and behavioral factors such as dietary and eating preferences, or lifestyle factors. Despite this, our analysis still provides insight into the crucial effects that financial disadvantage could have on malnutrition. Therefore, our research serves to illustrate who is most at risk for malnourishment due to limited access to healthy meals, as well as the socioeconomic components which limit nutrition.

Additionally, while we utilizing cross-sectional data in our research on malnutrition and individual income security, it is essential to acknowledge certain limitations. Especially, cross-sectional data captures

a snapshot at a specific point in time, making it challenging to establish causal relationships between malnutrition and individual income security. Despite these limitations, this static perspective is particularly beneficial for identifying co-occurring patterns and disparities among various demographic groups (Zaman, 2023). Therefore, significant contributions of our study would unveil a deepened understanding of the complex interplay between malnutrition's predictors and individual income security in the given temporal snapshot.

4 Results

4.1 Descriptive statistics

Table 1 presents data of 981 respondents from the 2021 Food Insecurity Experience Scale (FIES) survey conducted by the United Nation's Food and Agriculture Organization (FAO) Statistics Division in Thailand, comprising 438 males and 543 females. Results showed that 190 female respondents had experienced being unable to consume nutritional food due to the lack of financial resources, compared to 101 male respondents. It was noteworthy that females in Bangkok had a higher risk of undernourishment than males, with ratios of 0.54 and 0.30, respectively. In terms of residence areas, people who live in rural areas were more likely to be malnourished as compared to those in urban areas (ratio Rural 0.53 > Urban 0.34).

Regarding age, it was discovered that the risk of malnutrition among Thai people did not rise with age. 52% of those aged between 18 and 29 experienced malnutrition due to a lack of financial resources, while that of those over 60 years of age decreased to 18%. This was mirrored by the income quintile as the ratio of malnourishment dropped from 1.43 among the poorest dropped to 0.18 among the richest. This suggested that the risk of malnutrition in Thailand was heavily connected to the lack of financial resources.

Upon further examination of educational attainment, a startling trend appears. Specifically, the ratio of individuals who have only completed elementary school to those at risk of malnutrition is surrounding one (ratio = 1.04). This appeared that the majority of individuals with only an elementary school education have faced difficulty to consume a healthy food due to limited financial resources.

Regarding family arrangement, it was observed that bigger families were at a greater risk of undernourishment compared to smaller ones. The data revealed that only 38% of families with no children were exposed to the risk of being unable to access healthy food due to financial constraints. Conversely, this figure rises to 41, 59, and 67%, respectively, for families that had 1, 2, and 3 or more children, respectively.

TABLE 1 Descriptive statistics of used dataset of the 2021 food insecurity experience scale (FIES).

Variables	Individuals who are unable to eat healthy and nutritious food due to lack of financial resources (UHY)			
	No	Yes	Total	Ratio (Yes/No)
Gender (GDR)				
Male	337	101	438	0.3
Female	353	190	543	0.54
Age of respondents (AGE)				
18–29 years old	148	77	225	0.52
30–44 years old	303	132	435	0.44
45–59 years old	188	73	261	0.39
60 years old and above	51	9	60	0.18
Income quintile (INC)				
Poorest_20%	40	57	97	1.43
Second_20%	56	59	115	1.05
Middle_20%	99	76	175	0.77
Fourth_20%	157	56	213	0.36
Richest_20%	338	43	381	0.13
Area of residence (AOR)				
Urban/Suburb	402	138	540	0.34
Towns/Rural	288	153	441	0.53
Education (EDU)				
Elementary	75	78	153	1.04
Secondary	143	104	247	0.73
College	464	106	570	0.23
Not specified	8	3	11	0.38
No. of adults 15 years of age and above in household (NAH)				
1	145	49	194	0.34
2	173	78	251	0.45
3	128	59	187	0.46
4	124	49	173	0.4
5 people and above	120	56	176	0.47
No. of children under 15 years of age in household (NCH)				
0	450	171	621	0.38
1	133	54	187	0.41
2	74	44	118	0.59
3 children and above	33	22	55	0.67
Total observation = 981 respondents				

The 2021 Food Insecurity Experience Scale (FIES), the United Nation's Food and Agriculture Organization (FAO) Statistics Division in Thailand.

4.2 Empirical results

Results of analyses of data from the survey, conducted with calculation methods described in the Section 3.2, are presented in Table 2. Regarding the relation between gender and experience of being unable to eat healthy food due to lack of financial resources, the female respondents had a significantly higher probability of facing this problem than male respondents (probability of 7.1%). This suggested that gender was a significant predictor of experiencing difficulty in eating healthy food due to financial constraints.

In regard to age, it was revealed that people aged 60 years old and above are significantly less likely to experience difficulties with accessing healthy food when compared to individuals aged 18–29 years old, with a risk reduction of about 19%. This result highlights the connection between age and the ability to afford nutritious food.

TABLE 2 Factors influencing risks of malnutrition due to income insecurity in Thailand.

Independent variables	Prob (UHY = 1)		
	mfx	S.E	*p*-value
Gender (GDR)			
Male (based value)			
Female	0.071	0.030	0.016**
Age of respondents (AGE)			
18–29 years old (based value)			
30–44 years old	0.011	0.037	0.774
45–59 years old	−0.062	0.038	0.108
60 years old and above	−0.194	0.034	0.000**
Income quintile (INC)			
Poorest_20% (based value)			
Second_20%	−0.040	0.051	0.432
Middle_20%	−0.076	0.045	0.091*
Fourth_20%	−0.192	0.037	0.000**
Richest_20%	−0.363	0.043	0.000**
Area of residence (AOR)			
Urban/Suburb (based value)			
Towns/Rural	0.003	0.030	0.934
Education (EDU)			
Elementary	0.197	0.054	0.000**
Secondary	0.112	0.039	0.005**
College (based value)			
No. of adults 15 years of age and above in household (NAH)			
1 (based value)			
2	−0.019	0.046	0.684
3	−0.064	0.045	0.155
4	−0.057	0.047	0.230
5 people and above	−0.086	0.045	0.055*
No. of children under 15 years of age in household (NCH)			
0 (based value)			
1	−0.047	0.037	0.196
2	−0.033	0.044	0.444
3 children and above	−0.047	0.057	0.412
Total observation = 981 respondents			

mfx, marginal effect; *, ** = significance at level 0.1 and 0.05, respectively.

When taking income quintiles into consideration, the findings suggested that individuals in the fourth to richest quintiles experienced significantly lower risks of 19.2 and 36.3% when compared to those in the poorest quintile. No significant differences were observed when comparing the second quintile to the poorest quintile, however, suggesting that people in these quintiles are likely to face similar issues.

Moreover, this study also found that where an individual resides made no significant difference in their risk of being unable to eat healthy food due to financial shortages. There were no significant findings regarding the impact of rural or urban areas on this issue.

More importantly, the effects of education level on risk of malnutrition were significant. At the 0.05 level of significance, individuals who had only received elementary education were 19.7% more likely to have malnutrition compared to those with college degrees. This risk decreased to 11.2% for those with a secondary school diploma.

As the number of family members increased, the probability of people exposed to the risk of malnutrition has increased mind significantly at a level of 0.10. Results showed that families with more than four adult members had a higher risk at 8.6% of not being able to eat healthy food due to financial limitations compared to families with only one adult. However, there was no significant correlation found between the risk and the total number of children in the family.

5 Discussion

The risk of malnutrition in regard to financial insecurity among individuals can differ based on their background and environment. In terms of gender, we can support that women were found to be at a particularly elevated risk of facing financial restrictions that can limit their access to quality food. This might be due to their extra responsibility for family work. This limits the amount of time and energy a woman has to pursue nutritional items that promote their health (Hwang and Shon, 2014; Frize et al., 2021).

Regarding age, the findings found that age does not play a large role in determining the risk of being unable to eat healthy food due to financial shortage; however, those aged 60 and over significantly face a 24.3% lower risk of not having enough money to purchase nutritious foods than younger populations aged 18 to 30. It is likely due to aged-wealth accumulation (Imamura et al., 2015; Munt et al., 2017). Thai older people tend to have more money to spend than younger people, enabling them to purchase better-quality and more nutritious food. A possible explanation for this could be that many older individuals have financial means in form of pensions, government benefits, or other retirement sources that they can use to supplement their income, thus allowing for improved food choices that meet their nutritional needs.

Further discussion, we found no strong association between living in either urban or rural areas and an inability to access healthy food due to financial constraints. This indicated similar levels of malnutrition regardless of the area's geographic location which were in line with global studies (Meenakshi, 2016; Tacoli, 2019; Mittal and Vollmer, 2020). Affordable, nutritious options can be found in urban environments; however, the prevalence of malnutrition varies according to one's income security and costs of food choices (Anríquez et al., 2013; Meenakshi, 2016; Hong et al., 2020). Therefore, the access to healthy food ultimately depends on one's monetary capability (Painter, 2016; Loopstra, 2018). Regarding educational factors, the link between educational attainment and malnutrition was unambiguous. Thais with higher levels of education were supposed to have greater access to economic resources that could allow them to make appropriate choices regarding their diets and expenses (Kramer and Allen, 2015; Damião et al., 2017; Dutta et al., 2019).

Lastly, when examining profiles of households, Thai families with more adults are likely to expose to higher risk of malnutrition due to the strain it puts on their resources to buy food, as there are more people to feed, making it both more expensive and scarce in terms of access to nutritious food (Mishra et al., 2014; Asim and Nawaz, 2018). Curiously, when it comes to the number of children in the family, this was not found to be a predictive factor in malnutrition. This could suggest that Thai children may be eating the same food as their parents, which lessens the financial burden of buying food choices (Wang et al., 2011).

6 Concluding remark

This study we could identify the groups of Thais who were most at risk of malnutrition due to financial hardship. Despite not including other influential biological and behavioral aspects of eating, our analyses still revealed the significant relationship between one's profile and background of those facing income insecurity such gender, age, place of residence, educational achievement, and family arrangement and the probability of them being malnourished.

Policymakers should take bold steps to rectify the concerning situation of malnutrition among those facing financial insecurity, by taking into account the aforementioned factors while formulating strategies and policy interventions. In the short term, policymakers should focus on implementing targeted nutritional assistance programs and subsidy initiatives to provide immediate relief to those facing financial insecurity. This may include the distribution of food vouchers, nutrition education campaigns, and collaborations with local community organizations to ensure that essential nutritional needs are met promptly. For the mid-term to long-term, policymakers should consider interventions that address the root causes of malnutrition among financially insecure populations. This may involve the development of skill-building programs and vocational training opportunities to enhance employment prospects and income stability.

In addition, future studies, where panel data available, should explore on assessing the effectiveness of implemented policies and interventions over time. The study may analyse the evolving socio-economic landscape and its impact on malnutrition, providing policymakers with updated information to adapt strategies accordingly.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author. Dataset can be downloaded upon request at https://microdata.fao.org/index.php/catalog/2200/study-description.

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

Author contributions

WP: Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft. PB: Conceptualization, Project administration, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Association between obesity and age-related cataract: an updated systematic review and dose–response meta-analysis of prospective cohort studies

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Objective: There are inconsistent findings on the association between obesity and age-related cataract (ARC). This systematic review was done to summarize available findings on the association between obesity [defined by body mass index (BMI)] and ARC by performing a dose–response meta-analysis on eligible prospective cohort studies.

Methods: We performed a systematic search in PubMed, Scopus, ISI Web of Knowledge, and Google Scholar until June 2022 to identify eligible publications.

Results: In total, 16 studies with a total sample size of 1,607,125 participants were included. Among all of these studies, there were 103,897 cases of ARC. In the follow-up periods ranging between 4 and 28 years, 4,870 cases of nuclear cataract, 1,611 cases of cortical cataract, and 1,603 cases of posterior subcapsular cataracts (PSC) were detected. By comparing the highest and lowest categories of BMI, we found that higher BMI was associated with an increased risk of ARC (RR: 1.18, 95% CI: 1.09–1.28) and PSC (RR: 1.44, 95% CI: 1.08–1.90). In the dose–response analysis, each 5 kg/m^2 increase in BMI was associated with a 6 and 27% increased risk of ARC (RR: 1.06, 95% CI: 1.01–1.12) and PSC (RR: 1.27, 95% CI: 1.14–1.41), respectively. In addition, we found a positive association for cortical cataract among high-quality studies, in which higher BMI was associated with a 20% increased risk of cortical cataract (RR: 1.20, 95% CI: 1.02–1.42). In terms of nuclear cataract, we found no significant association either in the comparison between the highest and lowest categories of BMI or in the dose–response meta-analysis.

Conclusion: Obesity (defined by BMI) was associated with an increased risk of ARC, PSC, and cortical cataract in adults. However, such a positive association was not seen for nuclear cataract.

PROSPERO registration: CRD42022357132.

KEYWORDS
age-related cataract, body mass index, meta-analysis, obesity, cataract

1 Introduction

Cataract is one of the top causes of visual impairment and blindness among the elderly (1, 2). The subtypes of cataracts include cortical, nuclear, and posterior subcapsular cataracts (PSC), with an age-standard pooled prevalence of 8.05, 8.22, and 2.24%, respectively, in the general population (3). In addition to morbidities, the presence of cataracts is associated with increased mortality (4).

Research has focused on age-related cataracts (ARC) as an inevitable aging issue, which has an increased risk in the presence of genetic and environmental factors (5). Among environmental and lifestyle factors, it has been shown that illiteracy, smoking, wine drinking, as well as underlying diseases such as hypertension and diabetes mellitus (DM) are the risk factors for ARC (6). Since obesity contributes to the etiology of DM and hypertension, it may affect the risk of ARC (7–9). However, the results from epidemiological studies investigating the association between obesity and ARC are inconsistent (10–25). In a cohort study of 1,312,051 adults, Floud et al. reported a significant positive association between obesity and ARC risk. However, some studies reported no significant association in this regard (10, 13, 14). Also, we found a cohort study in which obesity was associated with a reduced risk of ARC (22).

Two meta-analyses of Ye et al. (26) and Pan et al. (2), published in 2014, assessed the association between obesity and ARC and reported a significant positive association for ARC. However, findings from the two meta-analyses for cataract subtypes were different: Pan et al. reported a significant positive association in terms of nuclear and cortical cataracts, while Ye et al. did not find any significant association in this regard. It should be noted that these meta-analyses missed some eligible studies (14–18, 20, 25). In addition, these meta-analyses included some studies that were not eligible for this topic. For instance, in the association between body mass index (BMI) and ARC, they included the study of Chang et al. in which the link between weight change and ARC was evaluated (27). Also, Ye et al. (26) included the study of Lindblad et al. in which the relation between waist circumference and ARC was examined (28). These limitations may affect the results of these meta-analyses. Furthermore, none of these meta-analyses determined linear and non-linear dose–response associations between BMI and ARC. Therefore, the current systematic review and dose–response meta-analysis was conducted to determine the relation between BMI and ARC by summarizing available findings from prospective cohort studies.

Abbreviations: ARC, Age-related cataract; BMI, Body mass index; CI, Confidence interval; DM, Diabetes mellitus; HR, Hazard Ratio; MeSH, Medical subject heading terms; NOS, Newcastle Ottawa Scale; OR, Odds Ratio; PSC, Posterior subcapsular cataracts; PRISMA, Preferred reporting items for systematic review and meta-analysis; RR, Relative risk.

2 Methods

2.1 Search strategy and study selection

This study was conducted using the preferred reporting items for systematic review and meta-analysis (PRISMA) standards (29). To find pertinent papers up to June 2022, we conducted a thorough search of the online databases of PubMed, Scopus, and ISI Web of Science. In the systematic search, we utilized both MeSH (medical subject heading terms) and non-MeSH terms (Supplementary Table 1). The publishing schedule and language of the pieces were both unrestricted. Following the thorough search, all of the results were imported into Endnote software before the screening process began. In Endnote, duplicate citations were eliminated. We also performed a web-based search in Google Scholar using the phrases "body mass index" and "cataract" in addition to the databases already listed. In order to ensure that we did not overlook any publications, we lastly checked the reference list of the chosen articles.

The following criteria were considered to select eligible studies in the screening step: (1) studies with prospective cohort designs, such as prospective cohort, nested case–control, and case-cohort studies; (2) studies on healthy adults (18 years); (3) studies measuring BMI to assess general obesity; (4) studies taking into account ARC or its subtypes, such as nuclear, cortical, or PSC as an outcome variable; and (5) studies reporting hazard ratio (HR), risk ratio (RR), and odds ratio (OR), with 95% confidence intervals for the association between obesity and ARC. If we found two papers that were published on a population, only the paper with higher quality or the most number of cases was included in our systematic review and meta-analysis. We disregarded retrospective, case–control, and cross-sectional studies as well as cohort studies that enrolled critically ill patients or people with chronic illnesses including diabetes mellitus and chronic kidney disease. Additionally, studies that did not report relative risks for the link between obesity and cataracts or lacked the necessary information to calculate these effect sizes were disregarded. Two independent reviewers chose the studies by taking the inclusion and exclusion criteria into account.

2.2 Data extraction and quality assessment

Two independent reviewers extracted data from each selected article and entered the data in an Excel-based form that was previously designed. Any discrepancies were discussed with a third reviewer in order to be rectified. Based on the form, the following information was extracted from each article: first author's name, year of publication, cohort name, geographical region, characteristics of participants (age and gender), sample size, number of cases with ARC, follow-up period, methods used for the assessment of obesity and cataract, relative risk estimates, including ORs, RRs, and HRs for the link between obesity and ARC risk, and confounding variables adjusted in statistical analysis. If research did not offer the necessary estimations, we calculated them using conventional techniques.

We used the Newcastle Ottawa Scale (NOS), designed for prospective cohort studies, to assess the quality of included studies (30). Based on the NOS, each cohort study can get a maximum of nine points: four for the selection of participants, two for comparability, and three for the assessment of outcomes. In the current study, we categorized studies based on the median score of NOS in which studies with a score more than the median were considered high-quality ones.

2.3 Statistical analysis

We included the RRs, HRs, or ORs and 95% CIs reported for the association between obesity and ARC risk into the meta-analysis. These RRs were calculated based on the comparison between the highest versus lowest categories of BMI. However, it should be noted that some studies reported RRs of ARC per one-SD increment in BMI. To include in the meta-analysis, we converted the per SD increment risk estimates to the RRs for the comparison of the top versus bottom tertiles of BMI using the method suggested by Danesh et al. in which the log risk estimates reported for the comparison between the top and bottom tertiles of exposure variable are equivalent to 2.18 times of the log risk estimates for a 1-SD increase in that variable (31). This method assumes that the exposure is a normally distributed variable and that the association with disease risk is log-linear. To combine the RRs of ARC, a random-effects model was used. Random-effects models take into consideration different sources of uncertainties including within-study (sampling or estimation) error and between-studies variance (32, 33). To assess heterogeneity among studies, we used Cochran's Q test and the I^2 statistic. For the I^2 statistic, we considered the I^2 values of >50% as high between-study heterogeneity (34). To find possible sources of heterogeneity, subgroup analyses were conducted. Publication bias was examined using Egger's linear regression test for the associations with more than 10 effect sizes (35). In the case of substantial publication bias, the trim-and-fill method was used to detect the effect of possibly missing studies on the overall RR (36). To assess the dependency of overall ES on one study, sensitivity analysis was done using a random-effects model in which each study was excluded to examine the influence of that study on the overall estimate.

Since the highest and lowest categories of BMI were different across the included studies, we performed a dose–response meta-analysis to determine the RR of ARC at different levels of BMI. We applied the method described by Crippa et al. to do a dose–response meta-analysis (37). In this method, the number of participants and cases of cataract and also the RR of ARC in each category of exposure (BMI) were required. In each category of BMI, we considered the median or mean amount of BMI as the corresponding RR of ARC. For studies that reported BMI as ranges, we estimated the midpoint in each category by calculating the mean of the lower and upper bound. When the highest or lowest category was open-ended, the length of the open-ended interval was assumed to be the same as that of the adjacent interval. We conducted the one-stage dose–response meta-analysis using restricted maximum likelihood estimation to assess linear and non-linear associations (37). This method estimates the study-specific slopes and combines them to obtain an overall average slope in a single stage, and is a more precise, flexible, and efficient method than the traditional two-stage method. Statistical analyses were conducted using STATA version 14.0. $p < 0.05$ was considered statistically significant for all tests, including Cochran's Q test.

3 Results

3.1 Findings from the systematic search

In our initial search, we found 3,777 articles among the online databases, of them, 750 papers were duplicated. After excluding duplicate papers, we screened the remaining articles ($n = 3,027$) and disqualified any research that failed to fulfill the inclusion requirements ($n = 2,997$) (Supplementary Figure 1). After full-text reviews, nine articles were excluded because of being conducted on patients who underwent kidney transplantation or those with chronic diseases ($n = 2$) (38, 39), having a case–control or cross-sectional design (40–42), assessing waist circumference, weight or weight changes rather than BMI (28, 43, 44), and reporting incomplete data (45). Also, we excluded the study of Yuan et al. because they genetically predicted BMI (46). In addition, we found three different articles from the Physicians' Health Study (21, 47, 48), two different papers from the UK Biobank (12, 49), and two different publications from the Blue Mountains Eye Study (22, 50). Since these publications evaluated similar associations, only the study with the highest quality or the greatest number of cases was considered for each dataset (12, 21, 22) and the duplicate papers were excluded (47–50). Moreover, two articles were published on the Beaver Dam Eye Study; however, both assessed different exposure and outcome variables in terms of BMI and cataract, and therefore, both were included (14, 16). After these exclusions, 16 articles containing 16 prospective cohort studies were included in the current systematic review and meta-analysis (10–25): 10 articles assessed BMI and risk of ARC (10–14, 21–25), 10 articles evaluated BMI and risk of nuclear cataract (13–15, 17–23), 6 papers assessed BMI and risk of cortical cataract (13, 16, 17, 20–22), and 7 publications assessed BMI and risk of PSC (13, 16, 17, 20–23). The flowchart of study selection is shown in Supplementary Figure 1.

3.2 Characteristics of studies

Characteristics of prospective studies included in the current systematic review and meta-analysis are shown in Table 1. The sample size of these studies ranged from 372 to 1,312,051 participants. In total, these studies recruited 1,607,125 participants with an age range of ≥40 years. In addition, during follow-up periods ranging between 4 and 28 years, 103,897 cases of ARC, 4870 cases of nuclear cataract, 1,611 cases of cortical cataract, and 1,603 cases of PSC were detected. The included articles were published between 1998 and 2016. Among the 16 articles, one article included only males (21), two articles performed analysis on only females (12, 19), and the remaining articles included both genders in statistical analysis (10, 11, 13, 15–18, 20, 22) or presented gender-stratified risk estimates (14, 23–25). In terms of geographical region, included studies were conducted in the US (11, 13, 14, 16, 18–21, 23, 24), Europe (10, 12, 15), Asia (17, 25), and Australia (22). In 7 articles, researchers measured weight and height using a standard protocol for calculating BMI (13, 15,

TABLE 1 Characteristics of prospective cohort studies investigating the association between BMI and risk of ARC in adults.

Author	Country/ cohort name	*n*	Age, y	Gender	Cases	follow-up	Exposure	Outcome	Outcome assess	Comparison (kg/m^2)	ES	Adjustments
Floud et al. 2016	UK: UK biobank	1,312,051	50–64	Female	89,343	11	BMI: self-reported	Cataract surgery	Medical records/ registries	BMI: ≥30 vs. <25	RR: 1.12 (1.10–1.14)	Age, residence, education, smoking, alcohol intake, physical activity, treatment for diabetes, age at menarche, parity, oral contraceptive use, hormone therapy
Kuang et al. 2013	Taiwan: SES	309	>65	Both	91	7	BMI: Measurement	Nuclear cataract	Examination	BMI: ≥25 vs. <25	RR: 1.04 (0.73–1.48)	None
		326			162			Cortical cataract		BMI: ≥25 vs. <25	RR: 0.92 (0.73–1.16)	
		372			30			PSC		BMI: ≥25 vs. <25	RR: 0.28 (0.10–0.79)	
Richter et al. 2012	US: LLES	3,187	>40	Both	196	4	BMI: Measurement	Nuclear cataract	Standard photographic grading	BMI: ≥30 vs. 18.5–25	RR: 0.89 (0.57–1.38)	None
		3,131			140			Cortical cataract		BMI: ≥30 vs. 18.5–25	RR: 1.10 (0.61–1.96)	
		3,007			16			PSC		BMI: ≥30 vs. 18.5–25	RR: 0.80 (0.17–3.73)	
Appleby et al. 2011	UK: EPIC-Oxford	27,670	>40	Both	1,484	11.4	BMI: self-reported	Total cataract	Medical records/ registries	BMI: ≥27.5 vs. <20	IRR: 1.09 (0.92–1.29)	Age, sex, method of recruitment, residence, smoking
Karppi et al. 2011	Finland: KIHD	1,689	61–80	Both	108	4	BMI: Measurement	Nuclear cataract	Medical records/ registries	BMI: T3 vs. T1 Per 1 SD increase	RR: 0.75 (0.45–1.21) RR: 0.97 (0.92–1.02)	Age, sex, smoking, alcohol consumption, serum LDL and HDL, education, corticosteroid use, history of diabetes and hypertension, current use of antihypertensive drugs
Mares et al. 2010	US: WHI	1808	50–79	Female	736	7	BMI: Measurement	Nuclear cataract	Examination	BMI: ≥35 vs. 22.5–25	OR: 1.61 (1.02–2.53)	Age, iris pigmentation, healthy Eating Index, smoking, pulse pressure, dietary variables, energy
Yoshida et al. 2010	Japan: JPHC	35,365	45–74	Male	1,004	5	BMI: self-reported	Total cataract	Self-reported	BMI: ≥25 vs. <19	OR: 1.15 (0.96–1.39)	Age, history of hypertension and diabetes, alcohol intake, smoking, PHC area
		40,825	45–74	Female	1807			Total cataract		BMI: ≥25 vs. <19	OR: 1.19 (1.04–1.36)	

(Continued)

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TABLE 1 (Continued)

Author	Country/ cohort name	*n*	Age, y	Gender	Cases	follow-up	Exposure	Outcome	Outcome assess	Comparison (kg/m^2)	ES	Adjustments
Williams et al. 2009	US: NRHS	29,025	NR	Male	733	7	BMI: self-reported	Total cataract	Self-reported	BMI: ≥27.5 vs. <20 Per 1 unit increase	RR: 1.65 (1.04–2.84) RR: 1.03 (1.00–1.07)	Age, intake of meat, fish, fruit, and alcohol, physical activity
		11,967	NR	Female	179			Total cataract		Per 1 unit increase	RR: 0.97 (0.91–1.03)	
Tan et al. 2008	Australia: BMES	2,421	>48	Both	431	10	BMI: Measurement	Cataract surgery	Standard photographic grading	BMI: ≥30 vs. <25	RR: 0.67 (0.48–0.94)	Age, sex, sun-related skin damage, impaired fasting glucose, diabetes, steroids use, smoking, myopia, pulse pressure, diabetes, hypertension
		1782			498			Cortical cataract		BMI: ≥30 vs. <25	RR: 1.22 (0.91–1.64)	
		2013			182			PSC		BMI: ≥30 vs. <25	RR: 1.45 (0.92–2.28)	
		1,248			444			Nuclear cataract		BMI: ≥30 vs. <25	RR: 1.15 (0.82–1.61)	
Chodick et al. 2008	US: USRT	35,705	24–44	Both	2,315	20	BMI: self-reported	Total cataract	Self-reported	BMI: ≥30 vs. <20	HR: 1.44 (1.21–1.72)	Age, sex, marital status, education, iris color, skin complexion, hair color, ultraviolet exposure, smoking, alcohol intake, Hypercholesterolemia, Myocardial infarction, hypertension, arthritis, diabetes, intake of vitamin C, E, and multivitamin supplements, aspirin use
Leske et al. 2002	US, BES	2,609	40–84	Both	240	4	BMI: Measurement	Nuclear cataract	Examination	BMI: ≥25 vs. <25 Per 1 unit increase	RR: 0.64 (0.50–0.81) RR: 0.95(0.92–0.98)	None
Weintraub et al. 2002 (NHS)	US: NHS	49,259	>44	Female	3,241	16	BMI: self-reported	Total cataract	Self-reported	BMI: ≥30 vs. <23	RR: 1.39 (1.25–1.54)	Age, smoking, intake of Lutein/zeaxanthin
	US: HPFS	32,445		Male	1,189	10		Total cataract		BMI: ≥30 vs. <23	RR: 1.22 (0.97–1.54)	
	US: NHS	49,259		Female	993			Nuclear cataract		BMI: ≥30 vs. <23	RR: 1.02 (0.84–1.25)	
	US: HPFS	32,445		Male	268			Nuclear cataract		BMI: ≥30 vs. <23	RR: 1.21 (0.77–1.9)	
	US: NHS	49,259		Female	435			PSC		BMI: ≥30 vs. <23	RR: 2.05 (1.57–2.69)	
	US: HPFS	32,445		Male	138			PSC		BMI: ≥30 vs. <23	RR: 1.64 (0.86–3.15)	
Klein et al. 2003	US: BDES	2,710	43–84	Both	NR	5	BMI: self-reported	Cortical cataract	Standard photographic grading	BMI: T3 vs. T1 Per 1 unit increase	OR: 1.12 (0.89–1.59) OR: 1.01(0.99–1.04)	Age, sex
		2,863						PSC		BMI: T3 vs. T1 Per 1 unit increase	OR: 1.78 (1.26–2.76) OR: 1.05(1.02–1.09)	

(Continued)

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TABLE 1 (Continued)

Author	Country/ cohort name	*n*	Age, y	Gender	Cases	follow-up	Exposure	Outcome	Outcome assess	Comparison (kg/m^2)	ES	Adjustments
Howard et al. 2014	Australia: BMES	1,131	43–84	Male	NR	15	BMI: self-reported	Cataract surgery	Standard photographic grading	BMI: T3 vs. T1	HR: 1.04 (0.78–1.43)	Age, physical activity, hypertension, diabetes
								Nuclear cataract		BMI: T3 vs. T1	HR: 0.74 (0.46–1.21)	
		1,480		Female	NR			Cataract surgery		BMI: T3 vs. T1	HR: 1.16 (0.91–1.46)	
								Nuclear cataract		BMI: T3 vs. T1	HR: 0.79 (0.58–1.07)	
Schaumberg et al. 2000	US: PHS	17,150	40–84	Male	1727	14	BMI: self-reported	Total cataract	Self-reported	BMI: ≥27.8 vs. <22	IRR: 1.2 (1–1.45)	Age, aspirin use, carotene intake, smoking, alcohol intake, diabetes mellitus, gout, systolic blood pressure, exercise, multivitamin use
		17,150			1,512			Nuclear cataract		BMI: ≥27.8 vs. <22	IRR: 1.26 (1.03–1.55)	
		17,150			652			Cortical cataract		BMI: ≥27.8 vs. <22	IRR: 1.18 (0.86–1.6)	
		17,150			721			PSC		BMI: ≥27.8 vs. <22	IRR: 1.38 (1.02–1.86)	
Hiller et al. 1998	US: FES	714	52–80	Both	444	28	BMI: Measurement	Total cataract	Examination	BMI: ≥27.8 vs. <22 Per 1 unit increase	OR: 1.38 (0.71–2.67) OR: 1.69 (0.8–3.55)	Age, sex, education, diabetes, smoking
		714			282			Nuclear cataract		BMI: ≥27.8 vs. <22 Per 1 unit increase	OR: 1.02 (0.52–2.02) OR: 1.04 (0.49–2.21)	
		714			159			Cortical cataract		BMI: ≥27.8 vs. <22 Per 1 unit increase	OR: 2.19 (0.98–4.92) OR: 1.91 (0.83–4.42)	
		714			81			PSC		BMI: ≥27.8 vs. <22 Per 1 unit increase	OR: 1.24 (0.45–3.42) OR: 6.13 (1.94–19.3)	

ARC, age-related cataract; BMI, body mass index; PSC, posterior subcapsular cataract; SES, Shihpai Eye Study; LLES, Los Angeles Latino Eye Study; KIHD, Kuopio Ischaemic Heart Disease Risk Factor Study; WHI, Women's Health Initiative; PHS, Physicians' Health Study; NRHS, National Runners' Health Study; BMES, The Blue Mountains Eye Study (BMES); USRT, US Radiologic Technologists Study; BES, Barbados Eye Studies; BDES, Beaver Dam Eye Study; FES, Framingham eye study; COSM, Cohort of Swedish Men; NRHS, National Runners' Health Study; SMC, The Swedish Mammography Cohort; NHS, Nurses' Health Study; HPFS, Health Professionals Follow-up Study; JPHC, Japan Public Health Center-based Prospective Study.

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17–20, 22), while in 9 studies, self-reported weight and height were used (10–12, 14, 16, 21, 23–25). Regarding outcome assessment, researchers performed a direct examination for cataract diagnosis in four articles (13, 17–19) and used data from medical records/registries in 3 articles (10, 12, 15). Among the remaining articles, self-reported data were used for cataract assessment. Of the 16 included articles, 13 papers presented adjusted risk estimates for the association between BMI and cataract risk (10–16, 19, 21–25). Some important confounding variables including age ($n = 12$), smoking ($n = 9$), and having diabetes mellitus ($n = 8$) were adjusted in these studies. By considering the median NOS score of 7, 13 articles, of the 16 papers, had high quality or low risk of bias in most components of NOS (10–16, 19–24) (Supplementary Table 2).

3.3 Findings from the systematic review

Of the 10 articles that assessed the association between BMI and risk of ARC, 6 papers showed a significant positive association (11, 12, 21, 23–25) and others did not find any significant association. In addition, two articles, among the 10 publications on the link between BMI and risk of nuclear cataract, indicated a significant positive association (19, 21), while the remaining articles reported a non-significant association. None of the studies that examined the association between BMI and risk of cortical cataract revealed a significant association. In terms of BMI and risk of PSC, a significant positive association was reported in 3 articles (16, 21, 23) of the 7 publications.

3.4 Findings from the meta-analysis

In this section, we included all studies that were evaluated in the systematic review. Below, findings from the meta-analysis were reported for ARC and its subtypes.

3.4.1 Meta-analysis on BMI and risk of ARC

Ten articles that included 11 studies assessed the association between BMI and risk of ARC (10–14, 21–25). The overall RR by comparing the highest and lowest categories of BMI was 1.18 (95% CI: 1.09–1.28, $I^2 = 67.7$, $P_{heterogeneity} < 0.001$), indicating a significant positive association between BMI and ARC (Figure 1). However, between-study heterogeneity was significant in this regard. Subgroup analyses based on geographical region, gender, follow-up duration, and study quality reduced the heterogeneity, otherwise, these variables can be considered as possible sources of the observed heterogeneity. In the subgroup analyses, we found a significant positive association between BMI and risk of ARC in all subgroups except for studies that had a sample size of <10,000 participants.

All articles in this section were included in the dose–response meta-analysis. We found a significant linear association between BMI and risk of ARC (Figure 2A); such that, the overall RRs of ARC per 1, 5, and 10 kg/m^2 increase in BMI were 1.01 (95% CI: 1.00–1.02), 1.06 (95% CI: 1.01–1.12), 1.13 (95% CI: 1.02–1.26). In the non-linear dose–response meta-analysis, we found no evidence of a non-linear association between BMI and risk of ARC (P non-linearity = 0.39) (Figure 3A).

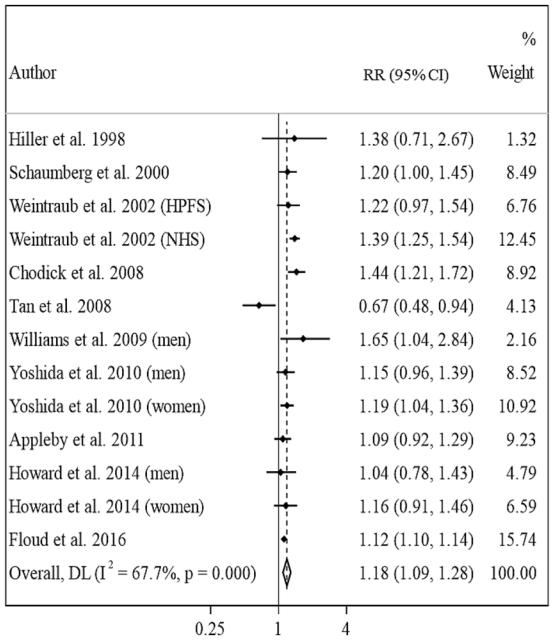

FIGURE 1
Forest plot for the association between BMI and ARC risk by comparing the highest and lowest categories of BMI. The overall RR was obtained from a random-effects model. RR, relative risk; CI, confidence interval; BMI, body mass index; ARC, age-related cataract; NHS, nurse health study; HPFS, health professional follow-up study.

3.4.2 Meta-analysis on BMI and risk of nuclear cataract

Ten papers containing 11 studies were included in the meta-analysis of BMI and nuclear cataract (13–15, 17–23). Combining the RRs of nuclear cataract reported for the highest versus lowest categories of BMI revealed a non-significant association between BMI and nuclear cancer (Pooled RR: 0.97, 95% CI: 0.83–1.14, $I^2 = 61.9$, $P_{heterogeneity} = 0.002$) (Figure 4). Such a non-significant association was also seen in the subgroup analyses (Table 2). In these analyses, we found that different characteristics of studies including geographical location, follow-up duration, sample size, and quality of included studies contributed to the significant heterogeneity observed in the overall analysis. In addition to the highest versus comparison, we found no significant association in the dose–response analysis (P linearity = 0.62, P non-linearity = 0.52) (Figures 2B, 3B).

3.4.3 Meta-analysis on BMI and risk of cortical cataract

In total, we included 6 studies (from 6 papers) in this meta-analysis (13, 16, 17, 20–22). There was no significant association between BMI and risk of cortical cataract when we compared risk between the highest and lowest categories of BMI (Pooled RR: 1.11, 95% CI: 0.96–1.28, $I^2 = 13.4$, $P_{heterogeneity} = 0.32$) (Figure 5). Between-study heterogeneity was not significant in this association. Regarding subgroup analyses, we found a significant positive association between BMI and risk of cortical cataract among cohort studies with a follow-up duration of ≥10 years (Pooled RR: 1.25, 95% CI: 1.02–1.54, $I^2 = 0.7$, $P_{heterogeneity} = 0.36$), those that adjusted for diabetes in their analysis, and those with high quality (Pooled RR: 1.20, 95% CI: 1.02–1.42, $I^2 = 0$, $P_{heterogeneity} = 0.49$) (Table 2). In the dose–response

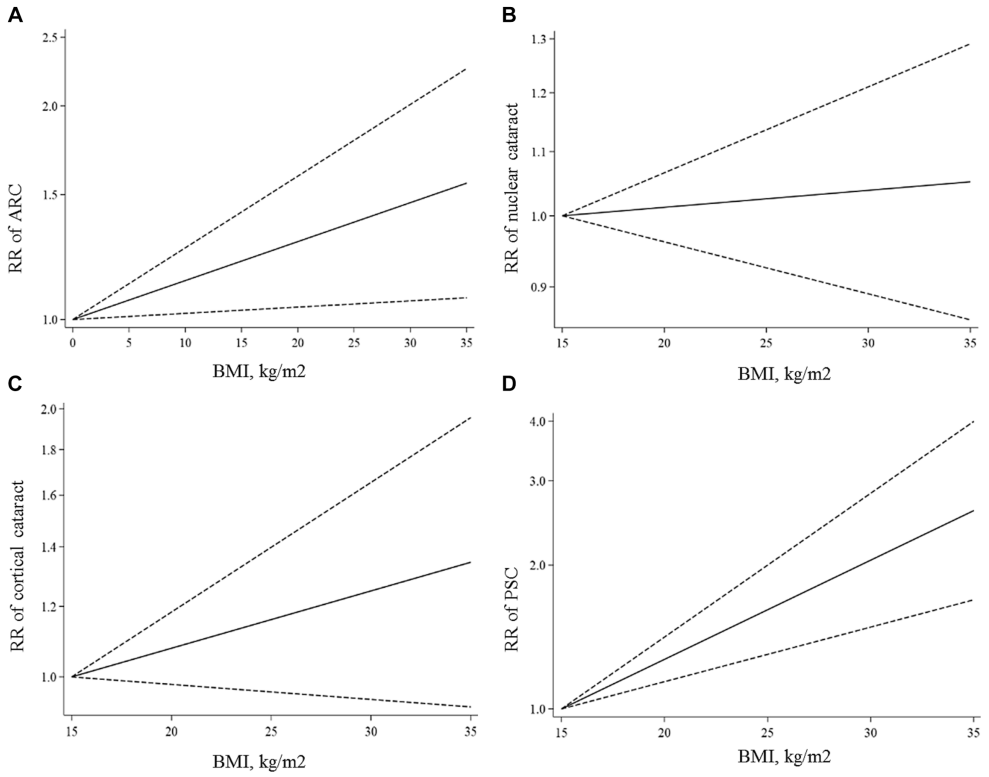

FIGURE 2
Linear dose–response associations of BMI with ARC **(A)**, nuclear **(B)**, cortical **(C)**, and PSC **(D)** cataracts. The solid lines indicate the overall RRs. The dashed lines present the 95% CIs. RR, relative risk; CI, confidence interval; BMI, body mass index; ARC, age-related cataract; PSC, posterior subcapsular cataract.

analysis of four articles containing required data, we found no evidence of linear (P linearity = 0.12) or non-linear (P non-linearity = 0.90) association between BMI and risk of cortical cataract (Figures 2C, 3C).

3.4.4 Meta-analysis on BMI and risk of PSC

Overall, eight studies from seven articles were assessed in the meta-analysis on BMI and risk of PSC (13, 16, 17, 20–23). We found a significant positive association in this regard; such that, people in the highest categories of BMI had a 44% higher risk of PSC compared with those in the lowest category (Pooled RR: 1.44, 95% CI: 1.08–1.90, $I^2 = 57.9$, $P_{heterogeneity} = 0.02$) (Figure 5). However, we found evidence of moderate heterogeneity in this association. Subgroup analyses showed that participants' gender, follow-up duration, study location, and study quality were possible reasons for the observed heterogeneity (Table 2). From these analyses, we also found a significant positive association between BMI and PSC risk among cohort studies conducted in the US and those with high quality such as studies with high follow-up duration, those with larger sample sizes, and studies that controlled their analysis for diabetes.

In the dose–response meta-analysis, five papers (6 studies) on the link between BMI and PSC had required data, and therefore, were included in the dose–response meta-analysis (13, 20–23). There was evidence of a linear association between BMI and risk of PSC (Figure 2D) so that each 1, 5, and 10 kg/m2 increase in BMI was associated with a 5% (Pooled RR: 1.05, 95% CI: 1.03–1.07), 27% (Pooled RR: 1.27, 95% CI: 1.14–1.41), and 61% (Pooled RR: 1.61, 95% CI: 1.30–2.00) higher risk of PSC in adults. We found no evidence of a non-linear association in this regard (Figure 3D).

3.4.5 Publication bias and sensitivity analysis

In the sensitivity analysis, when we excluded the study of Leske et al., the non-significant positive association between BMI and risk of nuclear cataract became significant (Pooled RR: 1.11, 95% CI: 1.01–1.22). Sensitivity analyses for other associations showed that the overall RRs obtained in the current meta-analysis were robust and did not depend on one study. We assessed publication bias using Egger's linear regression test for associations with ≥10 risk estimates and found no substantial publication bias (Figure 6).

4 Discussion

In the current meta-analysis, we found a significant positive association between BMI and risk of ARC and PSC in adults so that each 5 kg/m2 increase in BMI was associated with a 6 and 27% increased risk of ARC and PSC, respectively. In terms of nuclear and cortical cataracts, we found no significant association in the overall analysis; however, in the subgroup analyses, a significant positive association was seen between BMI and cortical cataract among studies with high quality.

ARC is a common disorder among older adults (51). Previous studies have shown that lifestyle-related factors such as smoking, alcohol consumption, and exposure to radiation or environmental pollution contribute to the etiology of ARC (52–54). However, the genetic potential

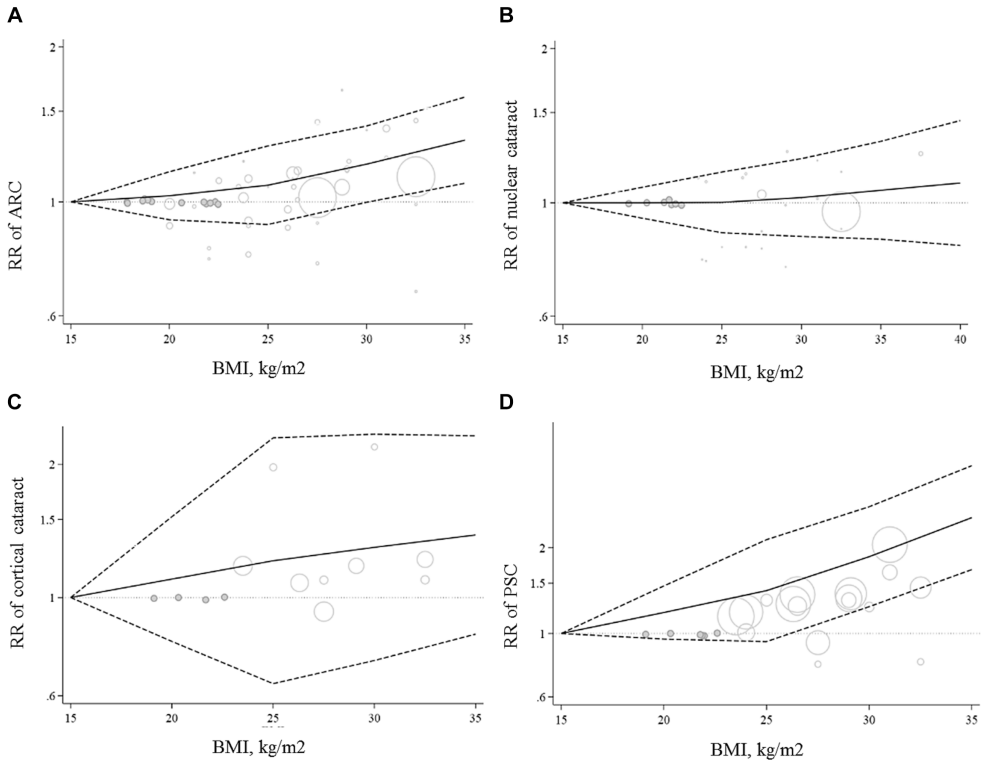

FIGURE 3
Non-linear dose–response associations of BMI with ARC **(A)**, nuclear **(B)**, cortical **(C)**, and PSC **(D)** cataracts. The solid lines indicate the overall RRs. The dashed lines present the 95% CIs. RR, relative risk; CI, confidence interval; BMI, body mass index; ARC, age-related cataract; PSC, posterior subcapsular cataract.

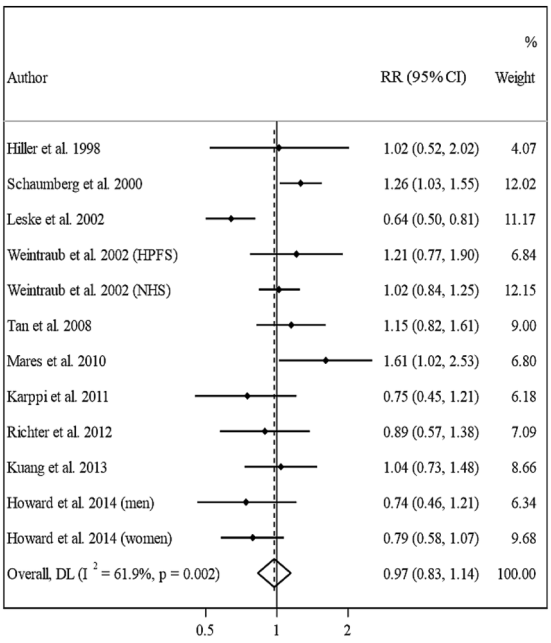

FIGURE 4
Forest plot for the association between BMI and the risk of nuclear cataract by comparing the highest and lowest categories of BMI. The overall RR was obtained from a random-effects model. RR, relative risk; CI, confidence interval; BMI, body mass index; ARC, age-related cataract.

of individuals plays an important role (55). Recently, some cohort studies have shown that obesity may affect the risk of cataract among older adults (10–25). However, findings from these studies were not conclusive. In the current meta-analysis, we found that higher BMI was associated with an increased risk of ARC. Also, in the dose–response meta-analysis, a 5 kg/m^2 increase in BMI was associated with a 6% higher risk of ARC. In a 2014 meta-analysis, Ye et al. reported that obesity is a potential risk factor for ARC (26). In another review article, Line et al. concluded that obesity has a direct association with age-related eye diseases (56). Despite the positive association, some cohort studies included in the current meta-analysis indicated a non-significant association between BMI and risk of ARC (10, 13, 14, 22). This might be explained by the different sample sizes of the studies that were mostly low. Also, in the subgroup analyses, we found a significant positive association between BMI and ARC among studies with higher sample sizes, while this was not significant among small cohorts. In addition, different adjustments in the statistical analysis might be another reason for inconsistent results among the included studies. For instance, three studies that did not include any confounders in models showed no significant association between BMI and ARC and surprisingly indicated a significant inverse association for nuclear and PSC cataracts (17, 18, 20). In contrast, most studies that controlled their analysis for potential confounders revealed a significant positive association between BMI and ARC risk. Further studies are needed to confirm the positive association.

In the current study, we found a significant positive association between BMI and the risk of PSC. Also, each 5 kg/m^2 increase in BMI was associated with a 27% higher risk of PSC. This was in line with a previous

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TABLE 2 Subgroup analyses for the association between BMI and risk of ARC and its subtypes.

	#RR[1]	Pooled RR (95% CI)[2]	*P*[3]	I^2 (%)[4]	P-heterogeneity[5]
BMI and risk of total cataract					
Overall	13	1.18 (1.09–1.28)	<0.001	67.7	<0.001
Subgroup analysis					
Study location					
US	8	1.31 (1.21–1.41)	<0.001	8.3	0.36
Non-US countries	5	1.10 (1.00–1.21)	0.06	59.8	0.04
Gender					
Male	5	1.18 (1.07–1.31)	0.002	0	0.63
Female	4	1.21 (1.07–1.37)	0.002	82.0	0.001
Both	4	1.09 (0.80–1.49)	0.59	82.2	0.001
Follow-up, y					
≥10	10	1.17 (1.06–1.29)	0.002	73.8	<0.001
<10	3	1.19 (1.07–1.33)	0.001	0	0.41
Sample size, participants					
≥10,000	9	1.23 (1.13–1.33)	<0.001	70.5	0.001
<10,000	4	0.99 (0.75–1.32)	0.96	62.2	0.04
Adjustment for DM					
Adjusted	9	1.15 (1.05–1.26)	0.002	57.4	0.01
Non-adjusted	4	1.27 (1.09–1.48)	0.002	56.6	0.07
Study quality					
≥7	11	1.18 (1.07–1.31)	0.001	72.6	<0.001
<7	2	1.18 (1.06–1.31)	0.003	0	0.76
BMI and risk of nuclear cataract					
Overall	12	0.97 (0.83–1.14)	0.75	61.9	0.002
Subgroup analysis					
Study location					
US	9	0.97 (0.79–1.19)	0.77	70.1	0.001
Non-US countries	3	1.02 (0.82–1.27)	0.87	0	0.37
Gender					
Male	3	1.10 (0.81–1.48)	0.54	49.7	0.13
Female	3	1.05 (0.76–1.44)	0.77	69.4	0.04
Both	6	0.88 (0.70–1.10)	0.26	51.0	0.07
Follow-up, y					
≥10	7	1.04 (0.89–1.21)	0.62	34.2	0.16
<10	5	0.92 (0.66–1.27)	0.60	72.3	0.006
Sample size, participants					
≥10,000	3	1.14 (0.98–1.32)	0.08	8.7	0.33
<10,000	9	0.91 (0.74–1.10)	0.32	56.2	0.02
Adjustment for DM					
Adjusted	6	0.97 (0.78–1.20)	0.76	51.9	0.06
Non-adjusted	6	1.00 (0.77–1.28)	0.97	71.2	0.004
Study quality					
≥7	8	1.07 (0.92–1.26)	0.37	42.8	0.09
<7	4	0.80 (0.62–1.02)	0.07	45.1	0.14

(Continued)

TABLE 2 (Continued)

	#RR[1]	Pooled RR (95% CI)[2]	*P*[3]	I^2 (%)[4]	P-heterogeneity[5]
BMI and risk of cortical cataract					
Overall	6	1.11 (0.96–1.28)	0.17	13.4	0.32
Subgroup analysis					
Study location					
US	4	1.18 (0.98–1.44)	0.08	0	0.48
Non-US countries	2	1.04 (0.79–1.37)	0.76	54.1	0.14
Follow-up, y					
≥10	3	1.25 (1.02–1.54)	0.03	0.7	0.36
<10	3	1.00 (0.84–1.19)	0.98	0	0.55
Sample size, participants					
≥10,000	1	1.18 (0.87–1.61)	0.29	–	–
<10,000	5	1.10 (0.92–1.33)	0.29	27.4	0.23
Adjustment for DM					
Adjusted	3	1.25 (1.02–1.54)	0.03	0.7	0.36
Non-adjusted	3	1.00 (0.84–1.19)	0.98	0	0.55
Study quality					
≥7	4	1.20 (1.02–1.42)	0.03	0	0.49
<7	2	0.94 (0.76–1.17)	0.59	0	0.57
BMI and risk of PSC					
Overall	8	1.44 (1.08–1.90)	0.01	57.9	0.02
Subgroup analysis					
Study location					
US	6	1.69 (1.43–2.01)	<0.001	1.3	0.40
Non-US countries	2	0.68 (0.14–3.40)	0.64	87.7	0.004
Gender					
Male	2	1.42 (1.08–1.87)	0.01	0	0.63
Female	1	2.05 (1.57–2.68)	<0.001	-	-
Both	5	1.10 (0.63–1.90)	0.73	64.7	0.02
Follow-up, y					
≥10	5	1.64 (1.36–1.99)	<0.001	10.6	0.34
<10	3	0.78 (0.21–2.83)	0.70	82.2	0.004
Sample size, participants					
≥10,000	3	1.69 (1.27–2.24)	<0.001	46.2	0.15
<10,000	5	1.10 (0.63–1.90)	0.73	64.7	0.02
Adjustment for DM					
Adjusted	3	1.39 (1.09–1.77)	0.008	0	0.95
Non-adjusted	5	1.33 (0.81–2.19)	0.25	72.3	0.006
Study quality					
≥7	6	1.67 (1.43–1.96)	<0.001	0	0.46
<7	2	0.40 (0.15–1.06)	0.06	17.8	0.27

ARC, age-related cataract; BMI, body mass index; PSC, posterior subcapsular cataract; US, United States; DM, diabetes mellitus.
[1]Number of effect sizes.
[2]Obtained from the random-effects model.
[3]Referred to the 95% CIs.
[4]Inconsistency- the percentage of variation across studies due to heterogeneity.
[5]Obtained from the *Q*-test.

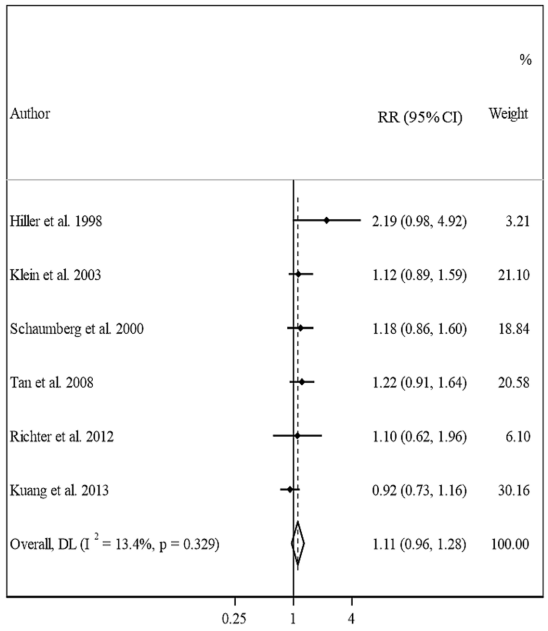

FIGURE 5
Forest plot for the association between BMI and the risk of cortical cataract by comparing the highest and lowest categories of BMI. The overall RR was obtained from a random-effects model. RR, relative risk; CI, confidence interval; BMI, body mass index; ARC, age-related cataract.

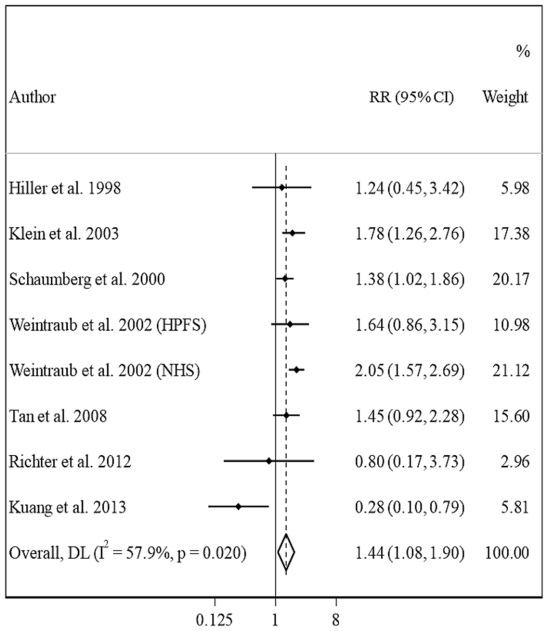

FIGURE 6
Forest plot for the association between BMI and the risk of PSC by comparing the highest and lowest categories of BMI. The overall RR was obtained from a random-effects model. RR, relative risk; CI, confidence interval; BMI, body mass index; ARC, age-related cataract; PSC, posterior subcapsular cataract.

meta-analysis in which elevated BMI increased the risk of PSC. However, the dose–response association between BMI and PSC was not assessed in that meta-analysis (26). Also, in a prospective cohort study, Lindblad et al. reported that metabolic syndrome with the combination of abdominal adiposity, diabetes, and hypertension was associated with an increased risk for cataract extraction (28). Such a positive association was also reported in another cohort study (49). Among 7 papers included in the meta-analysis of BMI and PSC (13, 16, 17, 20–23), 3 articles reported a significant positive association (16, 21, 23), 3 indicated no significant association (13, 20, 22), and one showed an inverse association between BMI and PSC risk (17). The lack of significant positive association among the four studies might be due to the short duration of follow-up, low sample size, and totally low quality of these studies. The involvement of these variables was confirmed in the subgroup analyses in which we found a significant positive association between BMI and PSC risk in studies with high quality, long duration of follow-up (≥10 years), and high sample size (≥10,000 participants).

Elevated BMI or obesity is associated with several complications such as diabetes mellitus, hypertension, and hyperlipidemia (57, 58). These complications are known risk factors of ARC (59). In the subgroup analyses, we found a significant positive association between BMI and ARC among studies that adjusted for diabetes mellitus in their analysis. It means that there are other plausible pathophysiological pathways in addition to obesity complications through which elevated BMI increases the risk of ARC. It has been shown that obese individuals have increased levels of leptin which has a role in the elevation of oxidative stress (60). The role of oxidative stress in the progression of ARC has been well-established (61). In addition, obesity is linked with increased levels of inflammatory biomarkers which are involved in the development of ARC (62, 63).

In the current study, BMI had no significant association with nuclear and cortical cataracts in the overall analysis, however, in the subgroup analyses, a significant positive association was seen between BMI and cortical cataract among studies with high quality. In contrast with our findings, a 2014 meta-analysis showed a significant positive association between obesity and risk of nuclear and cortical cataracts (64). This inconsistency is explained by entering eligible articles, published after 2014, into the current meta-analysis. Unlike the cortical cataract, we found no significant association between BMI and nuclear cataract in any subgroups of the included studies. The lack of significant association for nuclear cataract might be due to the different patterns of formation and progression of this subtype compared with other subtypes of cataracts (65). For instance, PSC is highly overrepresented among extracted cataracts, while other subtypes are less common (61). Therefore, this might be a reason for the stronger association between BMI and PSC compared with other subtypes of cataracts.

Strengths of our meta-analysis included the linear and non-linear dose–response analyses on prospective cohort studies, which help us to draw the shape of the association between BMI and ARC. Since we included prospective cohort studies in the current meta-analysis, our findings are less susceptible to recall and selection bias which is common among retrospective case–control studies. In addition, to combine RRs, we used a random-effects model, that takes between-study variation into account. Despite the strengths, our meta-analysis had some limitations that should be considered when interpreting our results. The methods used for the definition of cataract were different among the included studies and some defined cataract based on self-reported data that may induce underestimates of the number of cataract cases. This problem was also the case for BMI which was calculated based on self-reported weight and height in some studies. Furthermore, in the comparison between the highest and lowest categories of BMI,

we observed different cut-off points for the definition of these categories among included studies. However, we handled this problem by performing the dose–response meta-analysis.

In the current meta-analysis, we concluded that increased BMI is associated with a higher risk of ARC, particularly PSC, in adults. Moreover, we found that a 5 kg/m2 increase in BMI was associated with a 6 and 27% increased risk of ARC and PSC, respectively. We also found a significant positive association between BMI and risk of cortical cataract in high-quality studies. No significant association was seen for nuclear cataract. Future studies should assess the link between abdominal obesity and the risk of ARC.

Author contributions

SN and MM contributed to the literature search and data extraction. MD and SN contributed to data analysis. FD and FN drafted the manuscript which was critically revised for important intellectual content by all authors. RA contributed to the manuscript editing. FD supervised the study. All authors have read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2023.1215212/full#supplementary-material

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Lessons learned by adapting and implementing LUCHA: a deep-structure culturally tailored healthy eating randomized pilot intervention for ethnic-diverse Latinos

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Objectives: To report the adaptation and implementation of LUCHA (Latinos United for a Culturally Healthy Alimentation), a pilot intervention to improve dietary quality and behaviors (primary outcomes) of Latinos in Massachusetts, US, and the lessons learned during the process, including disruptions during the COVID-19 pandemic, to help shape future programs.

Methods: The cultural adaptation process was pre-planned using a framework, grounded in the Theory of Reasoned Action/Planned Behavior, and informed by formative mixed-methods research. A projected 75 self-identifying Latino adults (25–65y) were recruited with community-wide strategies and randomized to receive, in parallel, daily healthy eating text messages for 2months, reinforced for 2 subsequent months, to either control (i.e., surface-level messages based on USDA MyPlate in Spanish), or intervention (i.e., deep-structure messages). The intervention messages were ethnically tailored to Caribbean or non-Caribbean heritages specifically, grounded in entrenched cultural attitudes, norms, and preferences. Trained research assistants administered questionnaires and clinical measurements at baseline, 2-months, and 4-months, in person (pre-pandemic) or via online video calls (at-pandemic). Clinicaltrials.gov registration #NCT04724382.

Results: LUCHA faced challenges and opportunities that conveyed lessons for future cultural adaptation and implementation of healthy eating programs. Recommendations are provided to improve digital programs for diverse ethnicities, such as widening language capabilities in texting services, using familiar video call applications, and instructing participants to measure their own clinical metrics at home using guided standardized protocols.

Conclusion: Tailoring nutrition programs with deep-structure cultural messages is essential when promoting healthy eating in diverse Latino heritages. LUCHA can inform programs for similar ethnic groups.

KEYWORDS

deep structure, cultural adaptation, cultural tailoring, nutrition education, ethnic minorities

Introduction

One of the four foundational recommendations of the United States (US) Dietary Guidelines for Americans 2020-2025 is to "*customize and enjoy nutrient-dense food and beverage choices to reflect personal preferences, cultural traditions, and budgetary considerations*" (1). The guidelines suggest including spices and herbs in place of sugars, saturated fat, and sodium, and relying on the expertise of nutrition professionals with specific cultural knowledge to healthfully prepare foods appropriate for each heritage. While this is a first step in recognizing customized dietary needs and preferences of the diverse cultures in the US, the exact path to achieve culturally appropriate healthy eating is complex and remains unpaved.

Meaningful and culturally relevant programs and interventions could support successful healthy eating behaviors and subsequent disease prevention (2). Several studies have shown higher effectiveness of dietary interventions tailored to an intended ethnic or socioeconomic group over general messages across various diet and health outcomes (3–5). However, most studies fail to report the details of the cultural adaptation, including which materials are being modified and the adaptation process. Moreover, most cultural adaptations have been limited to surface-level content, that is, observable or superficial characteristics of the intended population such as location, language, food, and appearance, rather than the deep-structure features such as embedded cultural, social, historical, environmental, and psychosocial factors that influence the behavior (6, 7). Surface-level adaptations may be well received by the group they have been adapted for, but deep-structure adaptations may be more meaningful to them, increasing their chance of receptivity, effectiveness, and maintenance. For example, a meta-analysis found that training programs for parents of ethnic minority families that had deep-structure sensitivity components were more effective in improving parenting behavior (8). It is important to detail the adaptation process of tailored behavioral interventions to inform future processes in similar populations.

Our study focused on Hispanics/Latinos (hereafter referred to as Latinos to describe individuals of all Hispanic and Latino ethnic heritages and all genders) as they are the largest ethnic group residing in the US and have a high prevalence of cardiometabolic conditions (9). Considerable variations in the prevalence of cardiometabolic conditions as well as in the food preferences and diet quality of Latinos by ethnic heritage have been well established, with individuals of Puerto Rican and Cuban (i.e., Caribbean) heritage generally having poorer diet (i.e., high intake of total energy, total fat, red and processed meat, refined grains, and sodium but low intake of vitamin C, fiber, whole grains, omega-3 fatty acids, and fruit and vegetables) and health outcomes (i.e., elevated abdominal obesity, blood pressure, and plasma glucose), compared to those of Mexican or Central and South American heritage (i.e., non-Caribbean, with generally high intake of vitamin C, calcium, fiber, fruit, poultry, fish, and whole grains, and with elevated triglycerides and low HDL-C) (9–11). However, few diet quality interventions consider the deeply rooted cultural differences that may influence attitudes toward health and diet among Latinos of diverse ethnic heritages.

This article aimed to (1) explain the deep-structure cultural adaptation of healthy eating messages for Latinos of Caribbean and non-Caribbean heritage; (2) describe the implementation of a pilot parallel intervention (LUCHA: Latinos United for a Culturally Healthy Alimentation) comparing the adapted messages to surface-level messages among Latino adults in Massachusetts, US; and (3) contribute the lessons learned during these processes with the goal of informing the design of future programs for diverse Latinos and similar populations. In March 2020, the US government declared a national emergency due to the COVID-19 pandemic (12). By then, our study was underway, and we had to modify the implementation plan; thus, we also reported the modifications made and lessons learned during the pandemic.

Methods

Cultural adaptation

The Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) reporting guidelines on study methodology were used (13). The cultural adaptation process was proactively planned and conducted prior to LUCHA implementation using the Framework for Reporting Adaptations and Modifications-based Implementation Strategies (Figure 1) (14); minor reactive adjustments were done during implementation. Input from researchers, practitioners, community members, and participants was obtained. We identified content, context, and format of healthy eating messages at the individual, group, and heritage level, which entailed tailoring, adding, substituting, and breaking out content of the original source. The process encompassed goals across sociopolitical, organizational, provider-based, and recipient-based reasons.

The original source of healthy eating messages for US Latinos, and thus the control group in LUCHA, was the United States Department of Agriculture (USDA) MyPlate in Spanish website (15). It was selected as it is the communication initiative of the Dietary Guidelines for Americans 2020–2025 to help consumers choose healthier foods. MyPlate illustrates five food groups using a place setting, and includes online tools, containing recipes, graphics, and educational materials. To our knowledge, there is no formal cultural or linguistic adaptation of MyPlate online materials. We identified only surface-level factors in the Spanish materials: language, people, and food. For LUCHA, we copied or slightly abridged selected quotes and recipes directly from the Spanish materials, which best represented the seven selected themes for LUCHA: general nutrition knowledge, cultural aspects of healthy eating, eating habits, access and cost, cooking recipes, self-control strategies, and family meals. Direct translations of the English website were made when the quote was unavailable in Spanish. Changes to the literacy level, or tailoring at any level, were not made.

For the adapted materials (i.e., intervention group), messages were tailored guided by collected published literature and previously conducted formative research consisting of qualitative interviews with nutrition experts and Latino adults in Boston, Massachusetts, and a survey with Latino adults from the same area. Briefly, the formative exploratory sequential mixed-methods research (i.e., key informant qualitative interviews with nutrition experts, participants' semi-structured qualitative interviews, and participants' surveys) was grounded in the Theory of Reasoned Action/Planned Behavior (16), which also guided LUCHA design. The formative research probed for deep-structure attitudes, perceived sociocultural norms, and perceived barriers/motivators (control) that could influence behavior. The published results identified several themes regarding healthy eating

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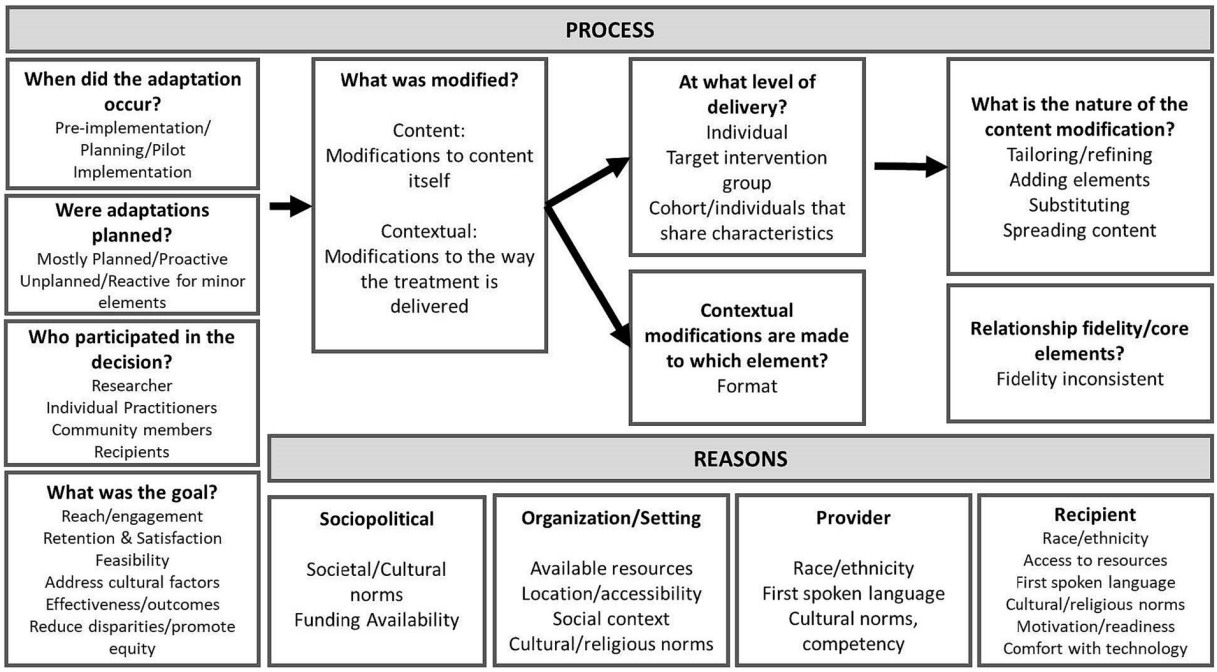

FIGURE 1
Factors for the deep-structure cultural adaptation process of healthy eating messages for Latinos, following the Framework for Reporting Adaptations and Modifications-based Implementation Strategies (with permission from Wiltsey-Stirman).

(probed openly as any food or beverage participants considered beneficial to their health) that were both unique and shared among Latinos of Caribbean and non-Caribbean heritage (17). For example, most participants of all heritages agreed that healthy eating would improve health and physical appearance and that families should eat together. Deeper nuances by ethnic background were noted, though, such that the concept of 'healthy eating' meant limiting types of foods and nutrients and controlling portions for Caribbeans, while it meant eating wholesome and fresh foods for non-Caribbeans. For the construct of family meals, Caribbeans perceived family both as a motivator for support and caring and as a barrier (enabling unhealthy/comfort foods) to eat healthy, while non-Caribbeans focused on family members serving as role models and on the communal experience of eating. Caribbeans (vs. non-Caribbeans) were more likely to respond to statements related to the high cost of healthy foods, healthy foods as needed only for the sick, and low self-efficacy/perceived control (giving in to cravings), while non-Caribbeans were more likely to agree with indulging on special occasions. Additionally, nutrition experts identified the following deep-structure cultural factors: food as cultural identity, resignation about health, emotional regulation with food, and healthy eating as unfamiliar, expensive, and unsatisfying.

Adapted messages were created in Spanish and English by bilingual team members of diverse Latino heritages through an iterative process until consensus was attained. Healthy behaviors and concepts that were already engrained were reinforced in the messages. Misconceptions and negative perceptions of healthy eating were addressed with positive advice. When the formative research and the literature noted differences by heritage, the messages addressed these distinctions. When a topic was generally shared across Latinos, the messages were similar, while still including the deep-structure tailoring done in the first round. In addition to deep-structure components, the messages were tailored at the surface level with appropriate language, food, location, people, holidays, flavors, and strategies reported in the literature (18–20). While language is considered a surface-level factor, we tailored it more deeply as previously done for other Spanish healthy eating materials (21), by using, for example, common words for specific foods for each region or country and using the formal Spanish pronoun for "you" (*usted* rather than the informal pronoun *tú*) that is used across more countries and is considered more respectful. The linguistic readability level was set at the Flesch–Kincaid middle school grade levels. The messages included educational facts, skill-building advice, statements on cultural attitudes, and prompts for behavioral change, as framed on the "knowledge-attitude-behavior" model for health promotion (22). One adapted message was created for each of the seven selected themes and for each heritage.

Table 1 shows examples of original and adapted messages, and the deep structure and/or ethnic-specific components used for the process. For example, the Spanish MyPlate includes tips to make culturally diverse foods and cooking practices in a healthy way, such as "*using foods that are familiar to you and preparing new recipes; adding curry to chickpeas, cilantro to brown rice, or mango to your salads and smoothies*." To deeply adapt this into a message that addressed cultural themes, we first conveyed that 'healthy eating' can be traditional and tasty, given the overall negative attitudes toward their taste mentioned in our formative research. Differences by ethnicity regarding the construct of 'healthy eating' were addressed by tailoring the message for Caribbeans around portion control and specific nutrients that concerned them, and the message for non-Caribbeans around finding wholesome, fresh foods. We concurred to include specific examples of lean meat and fish

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TABLE 1 Examples of healthy eating messages at the surface-level (control) and deep-structure culturally adapted (intervention) for Latinos of Caribbean and non-Caribbean ethnic heritages.

LUCHA theme	USDA MyPlate Spanish (control)	Deep-structure culturally-adapted (intervention)		Deep structure and ethnic-specific adaptation components; as informed by the literature or formative research
		Caribbean	Non-Caribbean	
General knowledge	The dietary fiber in vegetables, which are part of a healthy diet, helps reduce blood cholesterol levels and can reduce the risk of heart disease	To eat more whole grains, substitute a whole grain product for a refined product, such as eating whole grain bread instead of white bread or brown rice instead of white rice. Remember to substitute, instead of adding the whole grain product	To eat more whole grains, substitute a whole grain product for a refined product, such as eating whole wheat bread instead of white bread or whole wheat tortilla instead of flour tortilla. Remember to substitute, instead of adding the whole grain product	• Rice is a staple food in Caribbean cultures • Tortillas are a staple food in Mexico and Central and South American cultures • Appeal to replace product rather than adding, to maintain adequate energy intake
Culture	Use foods that are familiar to you and prepare new recipes. For example, add curry to chickpeas, cilantro to brown rice, or mango to your salads and smoothies	Caribbean food can be healthy and tasty. To follow a healthier diet that includes meat, just try to make it in small quantities and buy low fat meat! Cuts such as "sirloin" or "lean" ground beef have less fat. Poultry and fish are also a good option	To find healthy foods from your country of origin that taste fresh and delicious, shop in Latino stores!	• Address negative attitude among all Latinos that healthy foods are not tasty • Address negative attitude among Caribbeans that traditional foods are unhealthy and have large portions • Concept of "healthy eating" for Caribbeans means limiting types of foods or nutrients (such as sodium and fat) and controlling portions • Concept of "healthy eating" for non-Caribbeans means eating wholesome and fresh food from their country of origin • Caribbeans tend to have high intake of red and processed meats and low intake of fish
Eating habits	Eat fresh, frozen, canned or dried fruits instead of cookies, brownies or other sugary sweets	If you crave dessert, eat fresh or frozen fruit instead of ice cream or *mantecado*, cupcake, or sweet bread. You can make a strawberry shake!	When eating food that has sauce, such as enchiladas, choose a sauce that does not have cream. For example: *enchiladas verdes* instead of *enchiladas suizas*	• Sweets and desserts are a top contributor to energy in Caribbeans • Address perceived barrier (uncontrolled craving of unhealthy food) among Caribbeans • Enchiladas are habitually consumed among non-Caribbeans
Access and cost	Use fresh vegetables and fruits that are in season. They are easy to obtain, have more flavor and tend to be less expensive	Seasonal fruits and vegetables are usually cheaper and fresher! There are healthy low-cost meals available all year: beans, cabbage, sweet potatoes or canned tomatoes low in sodium, apples and bananas	Use fresh vegetables and fruits that are in season. They are easy to obtain, are fresh like the products of your country of origin and are usually less expensive. Your local market is a great source of seasonal products	• Address the notion among all Latinos that healthy food is expensive • Reinforce concept among all Latinos that relate "healthy eating" with more intake of fruits and vegetables • Concept of seasonality may be unfamiliar to new immigrants • Cost as perceived barrier was more salient for Caribbeans • Beans are staple food for Caribbeans • Concept of "healthy eating" for Caribbeans means reducing sodium • Concept of "healthy eating" for non-Caribbeans means eating wholesome and fresh food from their country of origin

(Continued)

TABLE 1 (Continued)

LUCHA theme	USDA MyPlate Spanish (control)	Deep-structure culturally-adapted (intervention)		Deep structure and ethnic-specific adaptation components; as informed by the literature or formative research
		Caribbean	Non-Caribbean	
Cooking recipes	Two-step chicken Potato salad Chocolate and yogurt cookies Light white sauce Chicken, vegetable, and brown rice Sweet and sour chicken Pasta salad French bread	Rice with pink beans Chili with beans Light fruit shake Brown rice with vegetables Oven-fried Yucca Yellow plantain with meat casserole Baked tilapia with tomatoes Grilled vegetable kabobs	Chicken Veracruz Fast and Tasty Pumpkin Flan Corn salad Turkey tacos Cod with chickpeas in Harissa sauce Green enchiladas Healthy arepa of broccoli, carrot, paprika, and cilantro Lentil soup	• Concept of "healthy eating" for Caribbeans means limiting types of foods or nutrients (such as sodium and fat) and controlling portions; recipes included healthy oils, low-sodium, low sugar, whole grain versions of traditional recipes • Concept of "healthy eating" for non-Caribbeans means eating fresh flavorful foods; traditional herbs and spices were emphasized in recipes
Self-control	Cook more at home to control the ingredients of your meal!	It is normal to have cravings. When you eat something unhealthy try to limit the amount. For example, if you are going to eat some potato chips, serve yourself some on a plate and close the bag so you do not eat "without thinking"	When going to a party, walk around the table to see what foods are offered before serving. Save calories with smaller portions. For example, serve yourself a palm sized amount of rice instead of a whole plate of rice	• Concept of "healthy eating" for Caribbeans means limiting types of foods or nutrients and controlling portions • Perceived barrier (uncontrolled craving of unhealthy food) among Caribbeans • Address perceived notion of indulging at special occasions endorsed by non-Caribbeans
Family	Avoid stress at mealtime by planning a weekly menu and posting it in a location for everyone to see, like a chalkboard in the kitchen	When celebrating with the family, remember to serve yourself smaller portions to follow a healthy diet. Staying healthy is important so you can take care of them!	Families can eat healthy together! Try every week for a family member to find a healthy, delicious recipe they want to try as a family!	• Concept of "family" for Caribbeans is a motivator for support and caring and a barrier (enabling unhealthy/comfort foods) to eat healthy • Concept of "family" for non-Caribbeans is being a role model and having a communal experience when eating (around food)

consumption in the Caribbean group, though not the non-Caribbean group, based on published prevalence of intake of these foods. We also decided to encourage non-Caribbeans to shop in Latino food markets as they had expressed familiarity and easy access to these establishments that tend to offer typical Latino food products. In an example for the cost theme, the control group received a message to "*use fresh vegetables and fruits that are in season; they are easy to obtain, have more flavor, and tend to be less expensive*." For the adaptation, we first emphasized that food can be both healthy and affordable to address the notion among all Latinos that healthy food is expensive. We focused on fruits and vegetables to reinforce the concept among all Latinos that these are healthy foods. For ethnic tailoring, we emphasized the message on low-cost for only the Caribbean group, which markedly perceived cost as a barrier. We also highlighted low-sodium options and beans given this group's dietary pattern. For the non-Caribbean group, we emphasized eating wholesome and fresh food from their country of origin, based on their concept of "healthy eating," and reinforced shopping in local Latino food markets. Of note, we decided to keep the message on seasonal foods for both groups, as this concept may be unfamiliar to people relocating to the US from Latin American countries with different or less discernible agricultural seasons.

Study design

LUCHA was designed as a parallel two-arm double-blind randomized pilot and feasibility intervention. The protocol included three visits to administer interviews and collect clinical measurements for intervention and control participants: one at baseline, 2 months, and 4 months. After the baseline visit, eligible participants received daily healthy eating messages sent via text messages for 2 months (delivery phase); after the two-month visit, participants received the same texts again for another two more months and were also given access to the messages on the study website (reinforcement phase) (Figure 2). The control group received surface-level healthy eating messages, while the intervention group received deep-structure messages tailored to their predominant ethnic heritage of Caribbean (e.g., Puerto Rico, Dominican Republic, and Cuba) or non-Caribbean (e.g., Mexico, Central and South America). Each visit was estimated to take about 1-2 h to complete. All participants remained enrolled in the study for its duration unless they were removed from the study, they actively dropped out, or we lost contact. The Institutional Review Board (IRB) of Harvard TH Chan School of Public Health approved this study. LUCHA was registered at clinicaltrials.gov under the identification number NCT04724382.

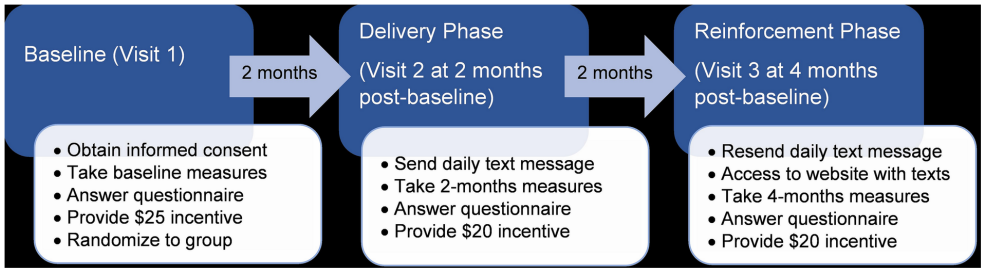

FIGURE 2
Protocol flowchart of Latinos United for a Culturally Healthy Alimentation: a pilot intervention of deep-structure culturally-adapted vs. surface-level healthy eating messages for Latinos in Massachusetts, US.

LUCHA was launched in April 2019 in partnership with community clinics in Boston, Massachusetts, US neighborhoods with high concentrations of Latino residents and Latino-serving organizations. LUCHA had to pause in-person activities on March 2020 due to the COVID-19 pandemic. During a 4-months pause, study protocols were limited to administering pending questionnaires to enrolled participants and asking optional questions on signs, symptoms, management, and behaviors during COVID-19 via online or video platforms; culturally relevant and trustworthy information on COVID-19 from trustworthy national organizations was also provided. Text-based messages were delivered daily as scheduled during this time. On July 2020, LUCHA resumed with changes to the protocol, until completion on September 2021. The Methods describe the protocols as originally designed (denoted as "pre-pandemic"), as well as the changes made in response to the COVID-19 restrictions (denoted as "at-pandemic"). Other changes made to the study during its course that were not in direct response to COVID-19 are described in the Results section as part of the lessons learned.

Recruitment

Pre-pandemic

Research assistants with proper identification approached individuals in public areas of the partner clinics to inform them about the study. Informational flyers were posted in the partner clinics, in Latino-serving community organizations, and in public sites of Latino neighborhoods in the Greater Boston area such as public housing, churches, service shops, markets, food establishments, fairs, festivals, and parking lots. For referrals, participants were asked to give a study flyer to individuals currently not living in the same household. Eligibility criteria included self-identifying Hispanic/Latino individuals aged 25–65y, who had resided in the Greater Boston area for at least the previous 6 months and were not planning to move for the next 6 months, and who had access to a cellphone capable of receiving calls and text messages for the duration of the study. Exclusions included a self-reported diagnosis of cancer, diabetes, gastrointestinal disease, coronary heart disease, stroke or heart attack, severe dietary allergies or restrictions, current pregnancy, or institutionalization. Eligible participants provided signed informed consent.

At-pandemic

Recruitment switched primarily to Facebook (posting on public Latino-oriented community and business pages and groups), with some passive community approaches (i.e., posting flyers) using public health safety precautions. Eligibility criteria remained the same except that the area of residency was expanded to the state of Massachusetts, as social media and video calls (for appointments) allowed for wider recruitment and implementation. Participants recruited at-pandemic provided oral informed consent.

Both pre- and at-pandemic

Interested individuals contacted the study by phone call, email, or text to be screened for potential eligibility by a bilingual (English/Spanish) research assistant. Eligible individuals were scheduled for a baseline interview, where informed consent was obtained from all individual participants included in the study. Flexible times and days for appointments were available; completion by phone was an option. At the completion of the baseline interview, participants were randomized to a group via simple probability sampling. Random numbers were generated using Microsoft Excel within the range of 0–1, and at the time of assignment, if the subsequent number fell at or below 0.5, the participant was assigned to the control group. If the number was greater than or equal to 0.5, the participant was assigned to the intervention group according to their heritage (i.e., intervention for Caribbeans or intervention for non-Caribbeans). Participants were compensated for their time up to $65, such that they received $25 at baseline, and $20 at each remaining visit through physical gift cards pre-pandemic, and electronic gift cards or physical gift cards sent via certified mail at-pandemic. Reimbursement for transportation was available upon request during pre-pandemic.

To assist with attendance and retention, participants were contacted up to five times to schedule or remind them of the appointments using their preferred method of communication. Three points of contact were recorded to reach participants if not responsive. To assist with data completion, participants were allowed to pause the interviews at any time and resume them within the subsequent 14 days; they were contacted up to five times

to remind them to complete the pending questions. Process evaluation (i.e., reach of texts; fidelity of texting delivery and receipt; rates of recruitment, rescheduling, retention, adverse events, data quality checks, etc.) was monitored bi-weekly and adjustments were implemented as needed.

Data collection

Research assistants were trained and re-trained on questionnaire implementation, uniform data collection and processing, cultural sensitivity, treatment fidelity, and confidentiality. All personnel in contact with participants was blinded to group allocation, except for one research assistant who exclusively sent text messages and mailed letters with information on the group-dependent website. To assist with double blinding, participants were informed that they would receive messages on healthy eating, without further details on the type of messages.

Pre-pandemic

Data collection and procedures were conducted in a single private room in the partner clinics or at Harvard TH Chan School of Public Health by bilingual research assistants. When scheduling an interview, participants were instructed to wear light clothing for the body measurements. At each visit, the research assistant measured the participant's waist and hip circumference to the nearest 0.1 cm using a stretch-resistant measuring tape, and weight to the nearest 0.1 kg using a Detecto SlimTalkXL scale (Detecto, Webb City, MO) following standard procedures. After sitting for a 5-min rest, the participant was measured for blood pressure at either arm using an Omron 10 Series Upper Arm Blood Pressure Monitor (Omron, Kyoto, Japan). Instruments were tested and calibrated before and during the study. Measurements were repeated thrice, and an average value was calculated across all three measurements. Height was self-reported. A letter with these values was sent to the participant upon request.

At each visit, a research assistant administered a questionnaire in the participant's preferred language. Answers were entered using the real-time web-based electronic data capture tool, "Research Electronic Data Capture" (REDCap) (23). Participants received a light, healthy snack, and water.

The questionnaire included sections to assess our primary and secondary outcomes (described below), as well as single-item question on age, sex-at-birth, education, income, work history, health care, medical diagnoses, food security and assistance, smoking, alcohol use, physical activity, and sleep quantity and quality. The questionnaire also included psychosocial measures previously validated among Spanish speakers: a 10-item perceived stress scale (24), a 3-item loneliness scale (25), the 20-item Center for Epidemiologic Studies Depression Scale (26), and the Interpersonal Support Evaluation List-12 for social support (27).

The primary outcomes were changes in dietary intake (i.e., quality) and behaviors, at 2-months and 4-months. Diet quality was measured using an adapted brief diet quality screener that probed frequency of intake of 18 major food groups and has been validated against 24-h recalls ($r = 0.61$) and various nutrients (28). Briefly, standard portions are described to the participant, who is then asked to report the consumption in the past month of one daily portion of bread, vegetables, fruit, milk/yogurt, rice/pasta, oils (corn, sunflower or olive), or breakfast cereal; 4–6 portions per week of meat, sausage, cheese, sweets/desserts, butter/fat, other oils, or fast food; and 2–3 portions per week of fish, legumes (e.g., beans), or nuts. Intake in the indicated frequency for each of these foods is allocated 2 points; intake at a higher frequency is given 3 points, and at a lower frequency is given 1 point; except for meat, sausage, cheese, sweets/desserts, butter/fat, other oils, or fast food that are reverse-coded. Daily consumption of one alcoholic drink is scored as 3; lower and higher intakes are scored 1. The food items are added for a total possible score range of 18–54.

The dietary behaviors measured were food consumption away from home, mealtime habits with the family, cooking practices (such as portion or nutrient control), and nutrition awareness (such as knowledge of the USDA My Plate or nutrition facts label). Food consumption away from home was probed using a questionnaire administered in the Hispanic Community Health Study/Study of Latinos (29). The remaining constructs were measured via questions adapted from the Food Attitudes and Behaviors Survey of the National Cancer Institute (Cronbach's α coefficient ≥ 0.68) (30, 31)and a validated dietary behaviors questionnaire for Latinos (Cronbach's α coefficients 0.47–0.48) (32). The questions have been subsequently applied in studies with participants of Latino heritage (33, 34).

Secondary outcomes included changes in the 45-item Diet Satisfaction Questionnaire to assess healthy lifestyle, cost, convenience, family dynamics, preoccupation with food, negative aspects, and planning and preparation (35); cultural dietary attitudes and perceptions from the survey developed during formative research (17); emotional, uncontrolled and restrictive eating behaviors using the Three-Factor Eating Questionnaire (36); and an adapted Fulkerson home food inventory (37). Additionally, we evaluated program satisfaction and engagement by asking participants whether they agreed or disagreed with various statements regarding the program components and implementation.

At-pandemic

Interviews shifted to the IRB-approved password-protected online video platforms (i.e., Zoom or Microsoft Teams). Phone calls were also available via a password protected Google Voice account. Participants were asked the same questions as pre-pandemic. They were mailed detailed instructions, with diagrams, on how to take their waist and hip circumference and blood pressure at home as used in the pre-pandemic protocols. We mailed a measuring tape and a wrist blood pressure monitor [G.LAB md1520/2222/2231 (Fremont, CA) or LifeSource UB-521 (Mississauga, ON)] directly to the participant's home. Participants kept these instruments after the program ended. The research assistant guided the participant on how to use the instruments and visually confirmed the measurements by showing the instrument or a picture during the video call or texting a picture or the values if not using video platforms. Sending weight scales was not viable at the time of protocol changes, thus, participants were asked to self-report their weight.

Text messages and website access

Text messaging was chosen given its high acceptability and feasibility among Latinos, and efficacy of previous interventions for healthy eating in this population (38–40). Texting also broadens access for populations without a smartphone or internet. Daily text messages (56 in total, over 2 months) were delivered to participants in each assigned group in their preferred language throughout the initial 2

months (delivery phase). After the delivery phase, an unblinded research assistant provided a letter to the participant with detailed instructions on how to log into a password-protected Harvard University-hosted website that contained all the text messages specific to the participant's assigned group. Because prior research has demonstrated periodic reminders may be effective in diet behavior interventions (41), we designed a reinforcement phase where participants received the same 56 text messages during the subsequent 2 months.

The fee-based automated Short Message Servicing (SMS) platform EZTexting was initially selected to deliver the text messages, but because of its limited Spanish language capabilities at the time of the study (e.g., accents), the team promptly switched to Google Voice (an SMS platform free at the time of the study) to send messages in both Spanish and English. Participants had the opportunity to send messages with questions or comments to the study using Google Voice. These messages were answered by a research assistant; consultation with the team was sought if needed.

Sample size and projected analysis

The projected sample size was 75 participants based on estimates for pilot studies, with a 0.05 Type I error, 80% power, and assumed 20% dropout rate based on previous projects in this population (42, 43). Primary analysis will be based on intention-to-treat. Per protocol analysis will also be done. We will use repeated measure analyses to test differences in mean change in 2-mo and 4-mo (from baseline) in primary outcomes for control vs. intervention groups, adjusting for baseline score, and any characteristic that was not randomly allocated. Secondary analyses will test similar changes by Caribbean vs. non-Caribbean heritage, and for secondary outcomes. Data analysis will follow the Consolidated Standards of Reporting Trials (CONSORT) guidelines (44).

Results

The March 2020 emergency of COVID-19 triggered protocol changes that imparted lessons on study implementation. At-pandemic, the video platforms approved by IRB for interviews were unfamiliar or unavailable to several participants and sometimes required registration or a fee; participants, instead, often requested video calls through popular free social media platforms or apps that they already used for casual communication, such as FaceTime, WhatsApp, or Facebook Messenger. Limited access to internet connectivity (reliable or at all), or to a computer with video capability, was also commonly mentioned by participants, who preferred phone-based options. Despite this preference and need, IRB declined approval of the more familiar online video platforms.

Because the measurement instruments were mailed directly to the participant's home, the study personnel could not test or calibrate them before use. The additional steps in guiding the participant on how to set up and use the instruments during the video call, lengthened the duration of the interview. Mailing letters, gift cards, and materials increased costs—by approximately US$10 (letters and gift cards) to US$30 (materials) per participant—and delayed the protocol timeline by 5–10 days per participant. Several deliveries were lost, and 7 wrist monitors were reported defective and re-sent, which further delayed the interviews and increased costs.

General lessons were also learned throughout the whole study period, especially relevant for studies delivered digitally. After the text delivery phase, nearly all participants needed help with the process of accessing the password-protected website that contained all the text messages specific to their assigned group. As the institutional website was cumbersome to access and the password was difficult to remember and could not be changed; this guidance required extra time and effort from the interviewers and participants. Another technological challenge was that Google Voice was not automatized. Therefore, an unblinded research assistant needed to manually send messages to each participant daily, which was time consuming and prone to lapses to fidelity of protocol. Pictures or long texts (e.g., recipes) sent through Multimedia Messaging Service (MMS) were received as small and unclear on some cellphones, and sometimes were received in the wrong order, even when sent correctly, confusing the participants. Thus, MMS had to be limited and recipes were instead sent in multiple text messages or as a link, which was cumbersome and may have excluded access for those without internet connection.

Discussion

LUCHA demonstrates that creating deep-structure culturally tailored nutrition messages to specific Latino ethnic heritages is feasible and valuable. Although gaps remain in methodological approaches to create such messages, recent interest from the Dietary Guideline for Americans in encouraging culturally appropriate healthy diets should pave the way for more and better designed deep-structure dietary programs and interventions, especially for underserved ethnic groups. Such endeavors are starting to emerge and should be emulated, including the deep-structure modifications made to the culturally adapted version of the "Coping with Stress Course" (into the Resilient in spite of Stressful Events) for Black adolescents in a low-income urban community, and the self-help program "Step-by-Step" for psychological distress for Albanian-speaking immigrants in Switzerland and Germany (45, 46).

We learned several key lessons while adapting and implementing LUCHA, which has encouraged us to propose recommendations for future research and practice (Figure 3). First, formative research, especially those employing mixed-methods design (47), is essential in informing cultural adaptations. Quantitative data may help collect metrics of outcomes generalizable to the intended population while qualitative data may help contextualize such data in a meaningful manner. During the adaptation process, researchers should apply an evidence-based behavioral theory that aligns with their research question, include both surface and deep-structure components, and record their process using reporting guidelines. Additional time, budget, and contingency plans should also be prepared in case of delayed or defective instruments mailed to participants, or the unexpected onset of public health emergencies (i.e., COVID-19). We also faced institutional barriers with IRB that required password-protected professional platforms for the online video interviews and the website where materials were

- Conduct and use formative research to inform adaptation; mixed methods provide thorough interpretations
- Frame adaptation with behavioral theory
- Adapt both surface (superficial) and deep-structure (embedded) components
- Use reporting guidelines or frameworks before, during, and after the adaptation process
- Account for additional time if physical materials or instruments are mailed directly to participants as these may be delayed or defective
- Allow a buffer on timeline and budget, as well as contingency plans, for unanticipated public health emergencies
- Work with IRB offices to expand coverage of online video platforms to those that are familiar, user-friendly, free, and accessible to minority populations, rather than paid or professional platforms
- Share educational material online in easily-accessible websites; if IRB requires password-protection, allow for participants to set their own rather than using institutional passwords
- Avoid using large pictures in text messages as some text messaging platforms are unable to send them and some phones receive low-quality pictures; switch to simple figures or text only
- Select text messaging platforms that have special characters (e.g., accents, punctuation marks) and technical assistance in the language of the served population
- Provide technical support to participants, and incorporate this during study design and budget
- Explore options to instruct participants to take their own clinical measurements at home using standardized instructions

FIGURE 3
Recommendations for cultural adaptation of text-message-based behavioral programs for ethnic groups.

shared, limiting access to participants who were unfamiliar or unable to open such. Latinos continue to be underrepresented in research and several strategies have been identified to prioritize and facilitate their recruitment and retention in biomedical studies. To overcome obstacles that would hinder their representation, IRB offices should consider alternatives for familiar, free, and user-friendly online platforms, especially in a post-COVID-19 era that has shifted many research protocols online. Providing technical support to participants should be part of the study planning and budgeting. Researchers and practitioners delivering text-based health interventions should opt for content quality over intricate visuals for ease of delivery and select text messaging platforms with services in the language of the served population. Updated and new platforms should solve these barriers. Lastly, researchers may consider instructing participants to measure their own clinical values at home using standardized protocols and guided via video; doing so may help empower participants and bolster health behaviors, as has been previously shown with improvements in blood pressure control, self-care, and self-efficacy (48).

This study has some limitations. Creating materials for LUCHA was specific to the Latino population in Massachusetts and may not be generalizable to other sites in the US or globally. Messages were designed for Caribbean vs. non-Caribbean groups that may be homogenous in some ways, but the content may not reflect cultural nuances of distinct ethnic groups by country of origin. Future formative research and interventions should consider these intricacies. However, the same cultural tailoring methodology utilized in this study may be applied in other settings and for different ethnic groups. Furthermore, this study was completed during the height of the COVID-19 pandemic, which created a unique environment that may not be replicated in other studies. However, the pandemic granted an opportunity to redesign the project and, subsequently, learn useful lessons for future research.

LUCHA supports the tailoring of nutrition programs with deep-structure cultural messages as an essential step when promoting healthy diets in Latinos of diverse ethnic heritages. Recommendations from our adaptation and implementation process can inform similar programs for other ethnic groups.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Institutional Review Board of Harvard TH Chan School of Public Health. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JM: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing, Formal analysis. AC-G: Data curation, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. AM-R: Data curation, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing, Methodology. AZ: Data curation, Writing – review & editing, Methodology. HJO'N: Data curation, Formal analysis, Visualization, Writing – review & editing, Methodology.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Maternal periconception food insecurity and postpartum parenting stress and bonding outcomes

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Food insecurity during pregnancy is associated with various adverse pregnancy outcomes for the mother and infant, but less is known about the role of periconception food insecurity and its links to maternal and child wellbeing in the postpartum period. In a sample of 115 diverse (41% white) and predominately low-income mothers, results of hierarchical regression analyses showed that periconception food insecurity was positively associated with parenting stress at 2months postpartum. A negative association between food insecurity and maternal–infant bonding at 6months postpartum was mediated after controlling for prenatal depression, social support, and demographic factors. Findings highlight the need for maternal linkage to effective food security programs, such as United States-based Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), for women during their childbearing years due to the critical importance of food security for maternal and infant well-being.

KEYWORDS

food insecurity, first 1000 days, pregnancy, maternal, parenting stress, bonding

Introduction

Approximately 11% of households in the U.S. report food insecurity (1), defined as a limited availability of nutritionally adequate and safe foods or the ability to acquire such foods in a socially acceptable way (2). Food insecurity during pregnancy is associated with many negative health outcomes for the mother and infant (3), including increased maternal stress and depression (4, 5), as well as iron deficiency which potentially could lead to developmental concerns in the neonate (6). Food insecurity during pregnancy has also been associated with increased risk of birth defects (7) and poor health outcomes for the infant in the short term as well as throughout childhood (3, 8, 9). As a result of these, and other studies, the American Academy of Pediatrics (10) issued a policy statement endorsing food insecurity screening in routine clinical practice. Less is known, however, about the role of food insecurity during the periconception period on future maternal-child indicators of wellbeing, which has important implications for future policy guidance for reducing risk prior to conception.

The consequences of periconception food insecurity for maternal and infant adverse pregnancy outcomes due to nutritional deficiencies are well-known (11). Existing programs such as the federal food program offered through the Special Supplemental Nutrition Program

for Women, Infants, and Children (WIC) target the reduction of maternal food insecurity during pregnancy in an effort to ameliorate the adverse nutritional impacts of food insecurity on maternal and infant health well-being. Food insecurity also has the potential to influence maternal and infant health and well-being as it is stressor that has been linked to a variety of adverse mental and behavioral health outcomes (12, 13). In an adaptation of the Family Stress Model (14), Ashiabi and O'Neal (15) proposed that food insecurity adversely affects children's outcomes through compromised parenting associated with elevations in parental stress and mental health problems. The maternal–infant relationship begins to form early in pregnancy and continues to develop through the pregnancy, during the immediate postpartum period, and throughout early infancy and childhood (16). Maternal–infant bonding is vital for the health and well-being of both the mother and infant (17–19). Parenting stress, on the other hand, arises when mothers report difficulties adapting to the demands of parenting (20) and is considered a key determinant of subsequent parenting quality and behaviors and as well as adverse child developmental outcomes (21). Although the nutritional consequences of perinatal food insecurity are well-known, there is a lack of data examining causal stressor-related impacts of maternal food insecurity. Understanding the implications of periconception maternal food insecurity for key aspects of the maternal–infant relationship—parenting stress and bonding—is critical. Food insecurity is modifiable by interventions through programs aimed at easing this burden for families, and as such makes periconception food insecurity a potential target for such interventions. The current study fills a gap in the literature by exploring the association between periconception food insecurity and parenting stress at 2 months postpartum and the mother-infant bond at 6 months postpartum. Depressive symptoms are included in the study as a control variable due to the strong associations between depression and a variety of parenting outcomes including stress and bonding (22). Social support is included as a control variable as well because prior studies indicate it can mediate early pregnancy stressors on maternal–infant wellbeing in the postpartum period (23). We expect to find that reported food insecurity in the year preceding the first prenatal appointment will be associated with worse mother-infant relational outcomes in the postpartum period. We also expect to find that psychosocial factors of maternal depression and social support will mediate the association between periconception food insecurity and postpartum parenting stress and bonding outcomes.

Methods

Sample

Data for the present study were collected as part of a clinic-based longitudinal cohort study. The cohort study included 177 pregnant women (ages 16–38) that were recruited at their first prenatal appointment during 2017 and 2018 from two urban perinatal clinics in a south-central U.S. state. IRB approval was obtained prior to data collection. Nurses screened potential participants, and research team members reviewed the study procedures and ensured written informed consent/assent was collected before study participation could begin. To be eligible for the study, participants had to be able to participate in English or Spanish and had to be planning to give birth and parent the child (i.e., participants were not eligible if they planned to have an abortion or place the baby for adoption as a goal of the study was to follow participants and their children into the postpartum period). Recruitment sites serve a racially diverse and primarily socioeconomically disadvantaged patient population; approximately 90% of study participants reported receiving public insurance and the majority of participants (59%) reported racial/ethnic minority group identity. The present study included 115 of the original 177 participants who responded from the first trimester of pregnancy through the sixth wave of data collection, occurring at 6 months postpartum.

Measures

Parenting stress was measured using the 4-item Parenting Stress Index (PSI) (24) at approximately 2 months postpartum, with higher values indicating greater stress, with a range of 4 through 19 and Cronbach's alpha of 0.71, indicating acceptable reliability. At the six-month postpartum assessment, postpartum bonding was measured using the 24-item Postpartum Bonding Questionnaire (PBQ) (25). Responses were coded from 0 to 5 such that higher values indicated greater bonding, with a range of 58 to 129 and Cronbach's alpha of 0.91 in the current sample, indicating high reliability.

At the first assessment, food insecurity over the previous 12 months was measured using the United States Department of Agriculture (USDA) 6-item short form, and participants were categorized into four groups: high food secure (0 points), marginal food secure (1 point), low food secure (2–4 points), and very low food secure (5–6 points) (26). Maternal depressive symptoms were assessed in the third trimester using the 20-item Center for Epidemiologic Studies Depression (CES-D) scale (27) and coded and summed to create a scale with a range of 0–47 and Cronbach's alpha reliability of 0.89 in the current sample. Social support was measured using the Multidimensional Scale of Perceived Social Support (28) and coded and summed to create a scale with a range of 12–84 and Cronbach's alpha reliability of 0.96 in this sample. Demographic variables included in the study were race/ethnicity coded into dummy variables using the Census priority coding scheme for White, Black, Hispanic, American Indian, and "others." Education was included as a continuous variable for years, living in a married or cohabiting union was included as a dichotomous variable, and parity was included as a continuous variable ranging from 0 to 9 or more children.

Analysis

Descriptive statistics were calculated for the study. Hierarchical linear regression conducted in Statistical Package for the Social Sciences (SPSS v27.0) was used to examine the associations between study variables, adjusting for demographic characteristics. Model 1 includes food insecurity categories with "high food security" as the reference category. Model 2 includes psychosocial factors of depressive symptoms and social support, as well as sociodemographic covariates, including race, education status, married or cohabiting union status, and parity. Materials and analysis code for this study are available by emailing the corresponding author.

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Results

See Table 1 for affirmative responses to each item of the food insecurity assessment. Nearly half of participants (49%) reported high food security, with 18% reporting marginal food security, 21% reporting low food security, and 12% reporting very low food security in the year preceding pregnancy (see Table 2 for descriptive statistics of study variables). The mean value of parenting stress measured at 2 months postpartum fell near the midpoint of the scale ($M = 9.12$, $SD = 3.31$), whereas the average bonding score reported at 6 months postpartum was closer to the higher end of the scale range ($M = 122.70$, $SD = 10.34$).

TABLE 1 Affirmative responses to food insecurity measure.[a]

In the past 12 months	%
The food I bought did not last, and I did not have money to buy more.	38%
I could not afford to eat balanced meals.	34%
I cut the size of my meals or skipped meals because there wasn't enough money for food.	17%
How often did this happen?[b]	13%
I ate less than I felt I should because there wasn't enough money for food.	14%
I was hungry but did not eat because there wasn't money for food.	15%

[a]Six-item short form of the USDA Food Security Survey; [b]Item only asked of participants who affirmatively responded to prior question; almost every month or some months but not every month = 1.

TABLE 2 Descriptive statistics of study variables ($N = 115$).

Variables	*M* or %	SD
Food insecurity (1st trimester)		
High food security	49%	
Marginal food security	18%	
Low food security	21%	
Very low food security	12%	
Outcome variables		
Parenting stress (2 mo. postpartum)	9.12	3.31
Bonding (6 mo. postpartum)	122.70	10.34
Psychosocial variables		
Depressive symptoms (3rd trimester)	14.96	9.85
Social support (2nd trimester)	65.46	18.59
Sociodemographic control variables		
Race/ethnicity		
White (reference)	41%	
Black	27%	
Hispanic	13%	
American Indian	18%	
Other race	1%	
Education (in years)	12.98	1.95
Married or cohabiting	61%	
Parity	1.30	1.49

To examine the association between food insecurity in the 12 months prior to the participants' first prenatal visit, parenting stress 2 months after giving birth, and self-reported postpartum bonding approximately 6 months after giving birth, hierarchical regression analyses were conducted (see Table 3). Results showed that having very low food security during the first trimester predicted parenting stress at 2 months postpartum ($B = 3.69$; $p < 0.01$) and that the association remained significant after controlling for depressive symptoms ($B = 0.09$, $p < 0.05$), social support ($B = -0.04$, $p < 0.05$) and sociodemographic variables. We also found that periconception food insecurity was associated with lower self-reported postpartum bonding at the 6-month postpartum assessment in Model 1; low food security ($B = -7.85$, $p < 0.01$) and very low food security ($B = -7.35$, $p < 0.05$) predicted maternal–infant bonding at 6 months postpartum. After controlling for psychosocial and sociodemographic factors in Model 2, however, the association between food insecurity and bonding was no longer significant, suggesting a mediating effort of social support ($B = 0.17$, $p < 0.01$).

Discussion

The results of the present study suggest that food insecurity during the periconception period has the potential to impact the maternal–infant relationship in the short and long-term postpartum period. In particular, participants with very low food security reported significantly greater parenting stress and lower levels of maternal–infant bonding as compared to participants with high food security. The current study therefore provides support for Ashiabi and O'Neal's (15) adaptation of the Family Stress Model and suggests that these negative impacts on parental well-being and the parent–child relationship can emerge very early in the infant's life, setting the stage for long-term developmental risk (16). On the other hand, the findings also reveal that perceived social support during pregnancy can mediate the adverse effects of food insecurity for postpartum maternal–infant bonding, though we did not find a similar buffering effect for parenting stress. Future research should explore which aspects of social support are most beneficial for pregnant women who have experienced food insecurity; perhaps greater instrumental support is associated with the ability to increase food security.

Limitations of the current study include a small sample size and a predominately low-income and diverse sample, which limit the generalizability of study findings. Despite limitations, these findings provide evidence that the harms of food insecurity can endure over time, such that periconception food insecurity is associated with postpartum parental functioning. Given some evidence of the mediating role of social support, these associations may also reflect persistent food insecurity that parents continue to face postpartum, particularly when they do not have a supportive social network to draw upon.

It is beyond the scope of this study to examine change in food insecurity across the perinatal period, but additional research examining change in food security status is needed to determine

TABLE 3 Hierarchical regression analysis of maternal parenting stress (2 months) and postpartum bonding (6 months) by pre-pregnancy food insecurity, depressive symptoms, and demographic characteristics ($N = 115$).

	Parenting stress				*Postpartum bonding*			
	Model 1		Model 2		Model 1		Model 2	
Variables	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*
Food insecurity								
High food security (ref)								
Marginal food security	−0.57	0.92	−1.07	0.95	−1.85	2.80	−0.86	2.89
Low food security	0.67	0.82	−0.45	0.88	−7.85**	2.49	−3.96	2.68
Very low food security	3.69**	1.10	3.27**	1.12	−7.35*	3.36	−5.18	3.41
Psychosocial variables								
Depressive symptoms[a]			0.09*	0.03			−0.16	0.11
Social support[b]			−0.04*	0.02			0.17**	0.06
Race/ethnicity								
White (reference)								
Black			−0.33	0.79			−1.84	2.41
Hispanic			0.90	0.93			−0.63	2.83
American Indian			−0.65	0.89			1.51	2.71
Other race			−0.70	2.23			4.02	6.81
Education (in years)			0.24	0.17			−0.42	0.53
Married or cohabiting			0.66	0.73			−5.31*	2.22
Parity			−0.28	0.21			−0.76	0.63
Constant	8.51***	0.46	6.83*	2.88	125.85***	1.41	125.60***	8.80
Adj. R^2	0.10		0.21		0.09		0.20	

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$. [a]Measured in the 3rd trimester; [b]measured in the 2nd trimester. Food insecurity and socio-demographic variables were measured in the 1st trimester.

whether food insecurity has long term effects (29). It is important to note that both earlier and concurrent food insecurity are associated with suboptimal parenting practices across infancy to age five (30), suggesting that it is critical to prevent any food insecurity to support parent and child well-being. The findings of this study highlight the need for maternal linkages to effective food security programs, such as WIC, during childbearing years due to the critical importance of food security for maternal and infant health and well-being as well as the early mother-infant relationship.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Oklahoma State University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

KS: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. CD: Writing – original draft, Writing – review & editing. LC: Writing – review & editing. MW: Formal analysis, Writing – review & editing. JC: Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Enhancing dietary adherence among African-American adolescents: the role of parenting styles and food-related practices

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Introduction: Parenting styles (PSs) and food-related parenting practices (FPPs) play a crucial role in shaping adolescent eating behavior. This study aimed to investigate the relationship between the different PSs and FPPs of African-American families and the frequency of consumption of MyPlate food items by adolescents based on recommendations from the Dietary Guidelines for Americans (DGA).

Methods: This study used a cross-sectional design. Data collection was conducted using Qualtrics through an online survey of 211 African-American parents and their adolescents aged 10–17-year-old. Adolescents completed the Youth and Adolescent Food Frequency Questionnaire to assess their dietary behavior, while parents filled out the survey to identify the degree of PSs (i.e., authoritative, authoritarian, setting rules, and neglecting) and FPPs (i.e., monitoring, reasoning, copying, and modeling). Spearman's rank correlation coefficient, Wilcoxon rank-sum test, and stepwise logistic regression were performed to determine the answers to the research questions.

Results: For fruit consumption, authoritative parenting significantly reduced the likelihood of adherence to DGA, while authoritarian, monitoring, and reasoning practices increased it. Female adolescents were more likely to meet fruit intake recommendations, with a similar positive impact observed for those whose parents had above high school education. In vegetable intake, authoritarian and monitoring practices positively impact on adherence to DGA, whereas setting rules had a detrimental impact. Being in a married household also increased vegetable intake DGA adherence. For grain consumption, reasoning was a significant positive predictor, while setting rules negatively impacted adherence. Dairy DGA adherence was positively impacted by monitoring and copying practices, but negatively impacted by female gender. Protein intake showed a positive association with reasoning and parental education.

Discussion: Our findings confirm the importance of parenting in developing desired eating behaviors among African-American adolescents. The results of this study can be used to develop culture-based nutritional education programs for parents and youth.

KEYWORDS

parenting styles, food-related parenting practices, MyPlate, African-American, parent-adolescent dyads, dietary guidelines for Americans

1 Introduction

Adolescence is a vital period for adopting healthy eating behaviors and a balanced diet, key for acquiring essential nutrients required for the physical and mental development of adolescents. This stage also sets the foundation for sustaining dietary preference into adulthood (1). Currently, there is a significant concern regarding adherence of adolescents to the daily minimum amount (DMA) of MyPlate food groups, based on the Dietary Guidelines for Americans (DGA) (2). Designed by the United States Department of Agriculture (USDA), MyPlate provides a comprehensive healthy eating habit guide for five major food groups, i.e., fruits, vegetables, grains, dairy, and protein (3). The DGA provides information about dietary pattern and reports the recommended DMA for each MyPlate item based on age and sex.

Although adolescents have become more independent in their food choices owing to the influence of their peers, the impact of the family environment is significant (4). Parenting styles (PSs) and food-related parenting practices (FPPs) affect the development and improvement of dietary habits (5–7). Developmental psychologists identify different PSs, including authoritative, authoritarian, permissive, and neglectful styles. These styles are classified based on the degree of parental responsiveness and demandingness, which affect the regulation of norms and behaviors of adolescents (8, 9). In addition, FPPs are considered separate constructs derived from PSs, and are goal-oriented behavioral strategies that parents use during different eating situations, such as meal or snack times, which can impact the diet and weight status of their children (10). These FPPs, which encompass a variety of approaches, including availability, accessibility, responsibility, monitoring, modeling, encouragement, restriction, mealtime structures, setting rules and expectations, and pressuring to eat, play a crucial role in shaping adolescents' dietary behaviors (7, 11, 12).

Notably, research has shown that the adoption of higher monitoring and modeling FPPs is associated with increased consumption of fruits and vegetables among adolescents from diverse racial backgrounds (13). Higher-reasoning FPPs and authoritative parenting styles have been shown to decrease the consumption of unhealthy snacks, while setting numerous rules has been linked to increased consumption of unhealthy snacks due to the perceived threat to adolescents' autonomy (13). Parents' eating habits and FPPs directly impact their adolescents' eating habits, with parents who encouraged fruit and vegetable consumption tending to have adolescents who consumed more items from these groups. However, parents who exert control to limit junk food and sugary drink consumption may inadvertently contribute to the increased consumption of unhealthy foods among adolescents (14). Furthermore, research has demonstrated that autonomy-supportive and intrinsic motivational practices of parents are associated with improved fruit and vegetable intake and reduced consumption of sugar-sweetened beverages among boys. Structured parenting practices showed positive effects on dietary behaviors for both sexes, whereas controlling and autonomy-supportive practices had indirect effects on boys' dietary behaviors through motivation (15). The present study extends this existing body of knowledge by specifically investigating the influence of PSs and FPPs on the comprehensive dietary patterns of African-American adolescents, a focus that is notably absent from current literature. The impact of PSs and FPPs may vary across races and ethnicities, particularly among minority groups. For instance, among African-American families, an authoritarian parenting style characterized by rigidity and restriction has been identified as a hindrance to adolescents' self-efficacy and healthy eating habits (16, 17). A study with a small sample size of 14 participants found that African Americans predominantly utilized modeling practices and setting rule styles as their dominant PSs and FPPs (18). Furthermore, monitoring practices have been shown to positively influence the consumption of fruit and vegetable by African-American adolescents (13). However, limiting the consumption of unhealthy foods among African-American adolescent boys has been associated with a higher risk of being overweight or obese (19). While previous studies have explored the impact of specific PSs and FPPs on limited food items or food groups, the current study aims to expand this investigation by considering all of MyPlate food items consumption. This study also intends to comprehensively examine four PSs (authoritative, authoritarian, setting rules, and neglecting) and four FPPs (monitoring, reasoning, copying, and modeling). Monitoring and reasoning are direct, communicative strategies that encourage awareness and understanding of healthy eating choices (10). Copying and modeling leverage parental behavior as a template for healthy eating, promoting learning through observation and imitation (7).

Two theoretical frameworks, the Social Cognitive Theory (SCT) and Family System Theory (FST), are foundational to our understanding of the relationships between PS, FPP, and eating habits among adolescents. These two frameworks offer valuable insights into the complex interplay among family dynamics, individual cognition, and sociodemographic factors that shape dietary behaviors. SCT focuses on the reciprocal influence of individual experiences, behaviors, the actions of others, and environmental factors on individual health behaviors (20). SCT has also been frequently used to evaluate the effects of influential factors such as FPPs, PSs, and demographic characteristics on the eating behaviors of adolescents (21). Self-efficacy as a construct of SCT can help us understand how we can enforce healthy behaviors among adolescents by applying PS and FPPs (22). By enhancing adolescents' self-efficacy through positive reinforcement, parents can increase the likelihood of their children engaging in healthy behaviors and making healthy food choices. In addition, FST highlights the importance of the family system in explaining individual behavior (23). Based on FST, the functionality and behavior of individuals are related to their interactions with family members, with each individual in a family playing a defined role in interactions with other family members (24). Consequently, any change in the family structure, or even in one of the family members, can change the behavior of other family members (25). For instance, a warm and supportive PS is correlated with improved adolescent eating behavior (17, 26).

The number of studies examining the effect of the family environment on the eating habits of adolescents, especially among minorities such as African-American adolescents, is limited. This study not only assesses the impact of various PSs and FPPs on the consumption of DGA-recommended DMA for all MyPlate items but also aims to explore differences in eating habits between adolescents who meet and those who do not meet the guideline. The findings of this study will help specialists develop interventions or educational sessions to improve the eating habits of African-American adolescents.

2 Methods

2.1 Research design, participants, and procedure

Prior to data collection, the Institutional Review Board responsible for overseeing human subject research at the University of the District of Columbia approved this study. This study was designed as a cross-sectional investigation in which data were collected from 211 African-American parent-adolescent dyads. Participants were recruited through email invitations sent via Qualtrics. Participants were provided with a link to an online survey that included both parental consent and adolescent assent forms. Each parent and his/her adolescent completed the survey through a single integrated survey link. The adolescents completed the first part of the survey, which focused on their dietary habits, and their parents completed the second part, which focused on their PSs and FPPs. The inclusion criteria required participants to (1) self-identify as African American, (2) be parents or legal guardians of adolescents aged 10–17 years, and (3) reside in the United States at the time of the study. The exclusion criteria disqualified potential participants if they: (1) did not identify as African-American, (2) did not have children or legal guardianship of children within the specified age range, or (3) resided outside the United States. If participants did not meet the inclusion criteria, the survey was automatically terminated.

2.2 Survey

The survey used various tools for gathering comprehensive data. For this study, we focused on a specific portion of the collected data that pertained to participants' responses regarding sociodemographic attributes, consumption of various MyPlate food items (as reported by adolescents), and assessment of PSs and FPPs (as reported by parents).

2.2.1 Demographic characteristics

The study collected demographic characteristics of the participants, including the age and sex of the adolescents, as well as the age and sex of their parents. Education level, household income, marital status, and the relationship between adult and adolescent participants were also recorded. Descriptive statistics, such as percentages, means, and standard deviations, were calculated to summarize demographic characteristics.

2.2.2 MyPlate food item consumption

To assess adolescent food consumption, the 2012 Youth Adolescent Food Frequency Questionnaire (YAQ FFQ/FFQ) was administrated, detailing the type, frequency of intake, and portion size of each food (27), which was subsequently analyzed to obtain data regarding various MyPlate food items. These items were selected because they reflected the recommended dietary guidelines for a healthy and balanced diet (27, 28). Adolescents reported their consumption retrospectively for over the past year. The specific procedures used to retrieve MyPlate food items from the FFQ reports are detailed in Table 1. Furthermore, to identify whether adolescents met the recommended DMA for each MyPlate food item, we referred to the guidelines provided by the DGA and the USDA handbook (28). These guidelines specify the recommended DMA for each food item based on the age and sex of the adolescents. By comparing the reported consumption of each MyPlate item with the corresponding DMA, we determined which adolescents met the recommended intake and those who fell short of it.

According to the DGA, DMA is assessed separately for two age groups: 9–13 years old and 14–18 years old. For fruit consumption, DMA is recommended at 1 ½ cups for both girls and boys aged 9–13 years old, and 2 cups for boys aged 14–18 years old. In terms of vegetable intake, the DMA is 1 ½ cups for girls and boys aged 9–13 years old, and 2 ½ cups for both sexes in the 14–18 age group. For grain consumption, DMA was set at 5 ounce equivalents for all adolescents aged 9–13 years old, and 6 ounce equivalents for those aged 14–18 years old. The DMA for dairy is consistent, at three cups for adolescents of all ages. Finally, the DMA for protein varies with sex and age: two serving sizes for girls aged 9–13 years old, 2.5 serving sizes for girls aged 14–18 years old and for boys aged 9–13 years old, and two ¾ serving sizes for boys aged 14–18 years old (28). Table 1 summarizes the DMA by the age and sex of the adolescents.

2.2.3 PSs and FPPs

The FPP questions were used from Monroe-Lord et al. (13), who explored the impact of FPP on the eating behavior of adolescents among African-American families (18). In addition, the 85-item Comprehensive General Parenting Questionnaire was used to identify PSs (29). Further details about the parent part of the survey are available in a study by Gunther et al. (30). Responses were collected using a 5-point Likert scale ranging from "strongly disagree" to "strongly agree" with "sometimes" as the mid-point or from "never" to "always" featuring "neutral" as its mid-point. Specifically, the FPPs measured in this study included monitoring, reasoning, copying, and role-modeling. Monitoring is defined as parent consistently overseeing their children's food intake, with a focus on the type and quantities of food consumed. Reasoning is defined as parents imparting knowledge to their children about the benefits of nutritious foods and guiding them toward establishing healthy eating habits. Copying is defined as when parents intentionally or unintentionally lead their children to mimic their eating habits. Modeling is defined as parents actively demonstrating healthy eating habits to inspire their children to adopt similar behavior through observational learning. PSs were categorized as authoritative, authoritarian, setting rules/expectations, and neglecting. Authoritative is defined as when parenting combines attentive, empathetic engagement with consistent, fair guidance and support for a child's autonomy. Authoritarian is characterized by strict enforcement of rules, limited emotional responsiveness, and a strong emphasis on obedience and control over a child's actions and feelings. Setting rules is defined as a parenting approach focused on setting clear expectations and rules, with an emphasis on obedience and the parent's authority in the family dynamic. Neglecting style is defined as characterized by inconsistency in enforcing discipline and a lack of follow-through on consequences. The more details of how the FPPs and PSs were identified and named are reported in our earlier study (31). Each parent was assigned a score for FPP and PS based on their responses to the survey questions.

2.3 Statistical analysis

All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, United States). In this study, the independent

TABLE 1 The DMA and composition of MyPlate food item for adolescents by age and gender.

Fruit			
Female		Male	
9–13 years old	14–18 years old	9–13 years old	14–18 years old
1½ cups	1½ cups	1½ cups	2 cups
Bananas; apples; grapes; applesauce; cantaloupe, melon; watermelon; oranges; strawberries; blueberries; pear; peaches, grapefruit; plums, apricots; pineapple; apple juice; orange juice; and other 100% fruit juices; raisins; mixed dried fruit/trail mix.			

Vegetable			
Female		Male	
9–13 years old	14–18 years old	9–13 years old	14–18 years old
1½ cups	2 ½ cups	2 cups	2 ½ cups
Tomatoes; tomato juice; broccoli; green beans; cauliflower; peas; mixed vegetables; corn; spinach, raw as in salad; collard greens/kale/cooked spinach; yam/sweet potatoes; zucchini, summer squash; eggplant; green/red/yellow peppers; carrots, cooked; carrots, raw; lettuce/tossed salad; celery; coleslaw; onion rings, cabbage; okra; cooked onion, or onion soup.			

Grain			
Female		Male	
9–13 years old	14–18 years old	9–13 years old	14–18 years old
5 ounce equivalents	6 ounce equivalents	5 ounce equivalents	6 ounce equivalents
Cold breakfast cereal; oatmeal, including instant; other cooked breakfast cereal (e.g., cream of wheat, grits); white bread, pita bread, including toast (not in sandwich); whole wheat or whole grain bread, including toast (not in sandwich); muffin or cornbread; English muffins, bagels, or rolls (include breakfast sandwich); croissant; white rice; brown rice; biscuit; quesadilla not tacos or burritos; corn or flour tortilla- no filling, e.g., pancakes or waffles; French toast; potatoes-baked or boiled mashed.			

Dairy			
Female		Male	
9–13 years old	14–18 years old	9–13 years old	14–18 years old
3 cups	3 cups	3 cups	3 cups
Milk, chocolate, or other flavored milk; instant breakfast drink; plain/low-calorie yogurt; regular yogurt sweetened with fruit or other flavoring cheese, cream cheese, cottage or ricotta cheese.			

Protein			
Female		Male	
9–13 years old	14–18 years old	9–13 years old	14–18 years old
2 serving size	2.5 serving size	2.5 serving size	2.75 serving size
Cheeseburger; tofu, soy burger, hamburger or Sloppy Joe; miso, edamame, or other soy dish; veggie burger; tacos; pizza; burritos; chicken nuggets; beef or pork hot dogs (include corndogs); chicken or turkey hot dogs or sausage; chicken or turkey as a mixed dish (e.g., stir fry or soup); chicken or turkey as main dish; fish sticks, fish cakes or fish sandwich; dark meat fish as main dish, e.g., tuna steak, salmon sardines, swordfish; other fish as main dish, e.g., cod, haddock, halibut; shrimp, lobster, scallops; beef, pork or lamb as a mixed dish (e.g., stir fry or stew); beef (steak, roast) or lamb as main dish; liver; pork, ribs, or ham as main dish; meatballs or meatloaf; eggs; sausage (beef/pork); peanut butter sandwich, chicken or turkey sandwich, roast beef sandwich; salami, bologna, ham or other deli meat; beans or lentils (include baked beans); tuna sandwich; peanut; other nuts.			

variables considered were PSs and FPPs, whereas the dependent variable was meeting the DGA criteria. Meeting the DGA were evaluated based on the frequency of consumption of MyPlate items, measured as serving size per week. Three statistical tests were used: Spearman's correlation coefficient, Wilcoxon rank-sum test, and stepwise logistic regression analysis. Spearman's correlation coefficient was used to assess the strength and direction of the relationships between PSs, FPPs, and eating habits. The Wilcoxon rank-sum test, a non-parametric test, was used to compare the differences in eating habits between the two groups of adolescents: those who met or did not meet the DGA criteria for each food item. Because we examined the relationship of each food group with the four PSs and four FPPs, we have indicated the adjusted *p*-value (Bonferroni adjustment, α/8) significance in Tables 2, 3. Five separate stepwise logistic regression models (one for each food group) were used to identify the predictors of meeting the DGA criteria (Yes/No). The potential covariates included FPPs and PSs as well as the following dyad demographic parameters: family income (under $45,000/ $45,000 and above), parent and adolescent sex (Female/Male), parent age (under35 years/ 35 years and above), adolescent age, marital status (married/not

TABLE 2 Demographic characteristics for the African American parent-adolescents dyads.

Characteristic	*N* (%)
Adolescent sex	
Male	87 (41.23)
Female	124 (58.77)
Parent sex	
Male	63 (29.87)
Female	148 (70.14)
Adolescent age	
10–13	82 (38.86)
14–17	129 (61.14)
Parent age	
18–25	42 (19.91)
26–34	66 (31.28)
35–54	98 (46.45)
55–64	3 (1.42)
≥65	2 (0.95)
Parent education	
Not completed high school	80 (37.91)
High school diploma or GED	12 (5.69)
Some/4-year college, technical school, or advanced degree	119 (56.40)
Household income (USD)	
0–$44,999	85 (40.28)
$45,000–$84,999	70 (33.18)
$85,000 or more	49 (23.22)
Prefer not to answer	7 (3.23)
Marital status	
Married	102 (48.34)
Single (includes divorced, never married, and widowed)	109 (51.67)
Relationship with adolescent	
Parent (includes step/foster parent)	173 (81.99)
Other caregivers	38 (18.01)

married), and parent education (high school graduate or not). Stepwise regression parameters were set so that a p-value of 0.10 was required to stay in the model. Results were considered statistically significant if the p-values were < 0.05.

3 Results

3.1 Demographic analysis

A total of 211 adolescents participated in the study, with a mean age of 14.28 years (SD = 2.32). Among them, 129 (61.14%) were between 14 and 17 years old and 124 (58.77%) were female. For the parents' characteristics, the age distribution was as follows: 42 (19.91%) were between 18 and 25 years old, 66 (31.28%) were between 26 and 34 years old, 98 (46.45%) were between 35 and 54 years old, 3 (1.42%) were–55-64 years old, and 2 (0.95%) were 65 years or older. Most parents were female, accounting for 148 (70.14%) participants. in term of parents' education, more than half of participants 119 (56.40) were in Some/4-year college, technical school, or advanced degree category. Regarding household income, 85 (40.28%) of families earned less than $45,000 annually. Considering marital status, 109 (51.67%) participants reported being single. The majority of participants (173 (81.99%)) had a parent–child relationship, which included biological, step-, or foster parents. A detailed summary of the sample characteristics can be found in Table 2.

3.2 PSs, FPPs, and frequency of consumption of MyPlate food items

Associations between the consumption of different MyPlate food items, PSs, and FPPs were examined. The authoritarian PS alone was significantly positively correlated with the consumption of all MyPlate food items (fruit: $r = 0.21$, $p = 0.0017$; vegetable: $r = 0.28$, $p < 0.0001$; grain: $r = 0.23$, $p = 0.0005$; dairy: $r = 0.18$, $p = 0.0078$; and protein: $r = 0.29$, $p < 0.0001$). Setting rules and neglecting PSs were positively correlated with dairy consumption ($r = 0.14$, $p = 0.0381$ for both PSs). Neglecting PS was significantly correlated with protein consumption ($r = 0.13$, $p = 0.0496$). Authoritative PS did not correlate with any of the MyPlate food items consumed.

Monitoring (fruit: $r = 0.26$, $p = 0.0001$; vegetable: $r = 0.18$, $p = 0.008$; grain: $r = 0.20$, $p = 0.003$; dairy: $r = 0.27$, $p < 0.0001$; and protein: $r = 0.17$, $p = 0.011$), reasoning (fruit: $r = 0.36$, $p < 0.0001$; vegetable: $r = 0.26$, $p < 0.001$; grain: $r = 0.26$, $p = 0.0001$; dairy: $r = 0.28$, $p < 0.0001$; and protein: $r = 0.24$, $p = 0.0005$), and copying FPPs (fruit: $r = 0.25$, $p = 0.0002$; vegetable: $r = 0.23$, $p = 0.0006$; grain: $r = 0.25$, $p = 0.0002$; dairy: $r = 0.23$, $p = 0.0006$; and protein: $r = 0.25$, $p = 0.0003$) were significantly correlated with the consumption of all MyPlate food items. The correlation coefficients between the three FPPs and all MyPlate food items were positive. Moreover, role modeling was significantly and positively correlated with the consumption of two MyPlate food items: fruit and dairy ($r = 0.23$, $p = 0.0006$ and $r = 0.24$, $p = 0.0005$, respectively) (Table 3).

3.3 PSs, FPPs, and DGA for the frequency of consumption of MyPlate food items

The relationships between PSs and FPPs and whether adolescents met the DGA recommendations for the consumption of different MyPlate food items were examined. Table 4 shows a comparison of PSs and FPPs between adolescents who did and did not meet the recommended DGA for the consumption of different MyPlate food items. Overall, the percentages of African-American adolescents who met the DGA for the consumption of different MyPlate food items were 81% (protein), 65% (fruit), 56% (vegetables), 40% (grains), and 32% (dairy).

There were no statistically significant differences in the mean scores of the authoritative factors related to meeting the DGA for any food category ($p > 0.05$). When examining authoritativeness, significant differences were observed between adolescents who met the DGA criteria and those who did not. Specifically, adolescents who met the DGA had higher scores for authoritarian parenting than those

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TABLE 3 Relationships between the consumption of different MyPlate food items and PSs and FPPs.

	Fruit		Vegetable		Grain		Dairy		Protein	
	r^a	p-value	r^a	p-value	r^a	p-value	r^a	p-value	r^a	p-value
Parenting styles										
Authoritative	0.04	0.528	−0.02	0.773	−0.01	0.919	−0.10	0.119	0.010	0.887
Authoritarian	0.21	**0.0017**[b]	0.28	**<0.0001**[b]	0.23	**0.0005**[b]	0.18	**0.0078**[b]	0.29	**<0.0001**[b]
Setting rules	0.03	0.6439	−0.06	0.3172	0.66	0.3385	0.14	**0.0381**	−0.07	0.2867
Neglecting	0.07	0.2639	0.08	0.1993	0.08	0.2364	0.14	**0.0381**	0.13	**0.0496**
Food-related parenting practices										
Monitoring	0.26	**0.0001**[b]	0.18	**0.008**	0.20	**0.003**[b]	0.27	**<0.0001**[b]	0.17	**0.011**
Reasoning	0.36	**<0.0001**[b]	0.26	**<0.0001**[b]	0.26	**0.0001**[b]	0.28	**<0.0001**[b]	0.24	**0.0005**[b]
Copying	0.25	**0.0002**[b]	0.23	**0.0006**[b]	0.25	**0.0002**[b]	0.23	**0.0006**[b]	0.25	**0.0003**[b]
Modeling	0.23	**0.0006**[b]	0.11	0.11	0.11	0.11	0.24	**0.0005**[b]	0.11	0.09

[a]Correlation coefficient.
[b]Bonferroni adjusted p-value is significant.
FPPs, Food-related parenting practices; PS, parenting styles.

who did not, indicating a positive association between authoritarian parenting and adherence to the DGA. This pattern was consistent across all five food items: fruit ($p = 0.0013$), vegetable ($p = 0.0101$), grain ($p = 0.0158$), dairy ($p = 0.0016$), and protein ($p = 0.0305$). In contrast, no significant differences were found in PSs scores related to setting rules and neglecting, except for dairy consumption, where adolescents who completed the DGA had higher scores for setting rules ($p = 0.0293$) and neglect ($p = 0.0325$) than those who did not.

Adolescents who met the DGA had higher monitoring scores than those who did not, indicating that parental monitoring was associated with better adherence to the guidelines. This trend was also observed for fruit ($p = 0.0095$), vegetable ($p = 0.0311$), grain ($p = 0.0083$), and dairy ($p = 0.0003$). In addition, adolescents who met the DGA criteria had higher scores on reasoning and copying FPPs than those who did not meet the DGA criteria for all MyPlate items, except vegetables (fruit: $p = 0.0006$ and $p = 0.0247$; grain: $p = 0.0008$ and $p = 0.0059$; dairy: $p = 0.0009$ and $p = 0.0004$; protein: $p = 0.0184$ and $p = 0.0467$, respectively for reasoning and copying). Adolescents who met the DGA exhibited higher modeling scores for fruit and dairy consumption than those who did not meet the DGA (fruit: $p = 0.0222$; dairy: $p = 0.0007$).

Next, a stepwise logistic regression was performed for each MyPlate food item to examine the relationship between meeting the DGA-recommended DMA of food item consumption and PSs and FPPs scores, while controlling for confounders. Details of the analyses are presented in Table 5.

The results revealed that authoritative ($p = 0.0001$), authoritarian ($p = 0.0054$), monitoring ($p = 0.0091$), reasoning ($p = 0.0055$), adolescent sex ($p = 0.0031$), and parental education ($p = 0.0167$) were significantly correlated with the consumption of the DGA-recommended DMA of fruit among adolescents. For every one score increase in authoritarian PS, monitoring and reasoning FPP, adolescents were approximately 1.7, 2.1, and 2.2 times more likely to consume the DGA-recommended DMA of fruits, respectively. However, for every one-score increase on the authoritative PS, African-American adolescents were 71% less likely to consume the DGA-recommended DMA of fruits. Female adolescents were 2.8 times more likely to consume the DGA-recommended DMA of fruit than male adolescents. Moreover, adolescents with parents with an educational attainment of high school or higher were 2.4 times more likely to consume the DGA-recommended DMA of fruit.

The analysis of vegetable consumption revealed that authoritarian ($p = 0.0117$), setting rules ($p = 0.0019$), monitoring ($p = 0.0027$), and marital status ($p = 0.0394$) were significantly correlated with consuming the DGA-recommended DMA of vegetables among African-American adolescents. African-American adolescents with one higher score in the setting rules style were 50% less likely to consume the DGA-recommended DMA of vegetables. However, for every one-score increase in authoritarian PS and monitoring FPP, adolescents were approximately 1.5 and 1.9 times more likely to consume the DGA-recommended DMA of vegetables. In addition, adolescents living in households with both parents were 1.9 times more likely to consume the DGA-recommended DMA of vegetables.

The results of the regression analysis for grain consumption revealed that the setting rules PS ($p = 0.0134$) and reasoning FPP ($p = 0.0008$) were significantly correlated with the consumption of the DGA-recommended DMA of grains. Based on these results, for every one-score increase in reasoning, adolescents were approximately 2.1 times more likely to consume the DGA-recommended DMA of grains, whereas adolescents with one score higher in setting rules were approximately 44% less likely to consume the recommended amount.

The results of the regression analysis for dairy consumption showed that monitoring ($p = 0.0193$), copying FPP ($p = 0.0260$), and sex ($p = 0.321$) were significantly correlated with the consumption of the DGA-recommended DMA of dairy among adolescents. Based on these results, for every one-score increase in monitoring and copying FPPs, adolescents were approximately 1.6 and 1.7 times more likely to consume the DGA-recommended DMA of dairy, respectively. Furthermore, females were 53% less likely than males to meet the DGA for this food group.

The results of the regression analysis for protein consumption showed that reasoning ($p = 0.0249$) and parental education ($p = 0.0363$) were significantly correlated with consumption of the DGA-recommended DMA of protein among adolescents. For every one-score increase in reasoning and having parents with educational attainment of high school or higher, adolescents were 1.8 and 2.4

TABLE 4 Comparison of PS and FPPs among adolescents who did and did not consume the DGA-recommended amounts of all MyPlate food items.

	Mean (SD)				
	Fruit	Vegetable	Grain	Dairy	Protein
Authoritative					
Not met DGA	4.13 (0.82)	4.12 (0.74)	4.07 (0.79)	4.04 (0.78)	4.08 (0.75)
Met DGA	4.07 (0.77)	4.07 (0.82)	4.13 (0.78)	4.21 (0.79)	4.09 (0.80)
p value	0.4551	0.8779	0.6031	0.1209	0.8093
Authoritarian					
Not met DGA	3.15 (0.97)	3.27 (0.92)	3.31 (0.93)	3.30 (0.88)	3.17 (0.89)
Met DGA	3.60 (0.89)	3.57 (0.94)	3.63 (0.92)	3.74 (1.00)	3.50 (0.94)
p value	**0.0013**[a]	**0.0101**[a]	**0.0158**[a]	**0.0016**[a]	**0.0305**[a]
Setting rules					
Not met DGA	4.09 (0.88)	4.14 (0.79)	4.09 (0.87)	4.02 (0.81)	4.14 (0.79)
Met DGA	4.09 (0.79)	4.05 (0.84)	4.08 (0.76)	4.25 (0.82)	4.08 (0.83)
p value	0.7409	0.4162	0.6053	**0.0293**[a]	0.6704
Neglecting					
Not met DGA	3.42 (1.23)	3.58 (1.11)	3.54 (1.17)	3.49 (1.13)	3.47 (1.09)
Met DGA	3.68 (1.10)	3.60 (1.19)	3.66 (1.13)	3.81 (1.19)	3.62 (1.17)
p value	0.1453	0.7459	0.4992	**0.0325**[a]	0.3750
Monitoring					
Not met DGA	3.18 (0.95)	3.25 (0.92)	3.29 (0.85)	3.28 (0.84)	3.36 (0.77)
Met DGA	3.56 (0.77)	3.57 (0.78)	3.63 (0.84)	3.74 (0.80)	3.44 (0.88)
p value	**0.0095**[a]	**0.0311**[a]	**0.0083**[a]	**0.0003**[a]	0.4644
Reasoning					
Not met DGA	3.17 (0.93)	3.32 (0.93)	3.29 (0.86)	3.32 (0.88)	3.16 (0.96)
Met DGA	3.61 (0.79)	3.56 (0.80)	3.70 (0.82)	3.74 (0.77)	3.52 (0.83)
p value	**0.0006**[a]	0.0577	**0.0008**[a]	**0.0009**[a]	**0.0184**[a]
Copying					
Not met DGA	3.24 (0.73)	3.32 (0.75)	3.29 (0.77)	3.27 (0.78)	3.21 (0.62)
Met DGA	3.50 (0.85)	3.49 (0.86)	3.60 (0.85)	3.71 (0.81)	3.46 (0.85)
p value	**0.0247**[a]	0.0779	**0.0059**[a]	**0.0004**[a]	**0.0467**[a]
Modeling					
Not met DGA	3.45 (0.48)	3.62 (0.81)	3.55 (0.83)	3.51 (0.80)	3.48 (0.73)
Met DGA	3.71(0.79)	3.62 (0.83)	3.72 (0.80)	3.86 (0.82)	3.65 (0.84)
p value	**0.0222**[a]	0.6560	0.0979	**0.0007**[a]	0.1315

[a]Bonferroni adjusted *p*-value is significant.
DGA, Dietary Guidelines for Americans; FPPs, food-related parenting practices; PS, parenting styles; SD, standard deviation.

times more likely to consume the DGA-recommended DMA of protein, respectively.

4 Discussion

The aim of this study was to assess the impact of PSs and FPPs on the adherence of African-American adolescents to the DGA. Specifically, we focused on determining which PSs and FPPs impact the consumption of recommended DMA across various MyPlate food categories. In relation to different PSs, an authoritative PS has been reported as an effective strategy to raise children with healthy eating habits and normal weight status (17, 29, 32). However, we found that adolescents with an authoritative PS did not consume the DGA-recommended DMA of MyPlate food items. This discrepancy can be attributed to the differences in the race/ethnicity of the samples in the studies, underscoring the necessity for culturally tailored parenting strategies. According to our study, African-American adolescents with an authoritative PS were less likely to consume the DGA-recommended DMA of fruit. This indicates that a higher score on authoritative PS is not a suitable tactic for increasing fruit consumption to the DMA among African-American adolescents. Setting rules plays a role similar to that of the authoritative style in ensuring the consumption of

TABLE 5 Relationship between meeting the DGA-recommended DMA of the frequency of consumption of MyPlate food items and PSs and FPPs while controlling for cofounders.

	Reference	Estimate (SE)	Odd Ratio (95% CI)	*p*-value
Fruit				
Authoritative		−1.24 (0.32)	0.29 (0.15–0.54)	0.0001
Authoritarian		0.55 (0.20)	1.73 (1.77–2.54)	0.0054
Monitoring		0.75 (0.29)	2.12 (1.20–3.73)	0.0091
Reasoning		0.77 (0.28)	2.16 (1.20–3.73)	0.0055
Sex	Female[1]	0.51 (0.17)	2.76 (1.41–5.41)	0.0031
Education	Above high school[2]	0.44 (0.18)	2.40 (1.17–4.92)	0.0167
Vegetable				
Authoritarian		0.43 (0.17)	1.54 (1.10–2.15)	0.0117
Setting rules		−0.69 (0.22)	0.50 (0.32–0.78)	0.0019
Monitoring		0.63 (0.21)	1.87 (1.24–2.82)	0.0027
Marital status	Married[3]	0.31 (0.15)	1.87 (1.03–3.38)	0.0394
Grain				
Authoritarian		0.31 (0.17)	1.36 (0.97–1.91)	0.0743
Setting rules		−0.57 (0.23)	0.56 (0.36–0.89)	0.0134
Reasoning		0.75 (0.22)	2.13 (1.37–3.31)	0.0008
Dairy	Reference	Estimate (SE)	Odd Ratio (95% CI)	*p*-value
Monitoring		0.49 (0.22)	1.63 (1.06–2.50)	0.0193
Copying		0.51 (0.24)	1.66 (1.04–2.65)	0.0260
Sex	Female	−0.38 (0.16)	0.47 (0.25–0.88)	0.0321
Protein	Reference	Estimate (SE)	Odd Ratio (95% CI)	*p*-value
Authoritarian		0.36 (0.21)	1.43 (0.94–2.17)	0.0912
Setting rules		−0.47 (0.26)	0.62 (0.37–1.04)	0.0706
Reasoning		0.57 (0.25)	1.77 (1.07–2.92)	0.0249
Education	Above high school	0.40 (0.19)	2.24 (1.05–4.75)	0.0363

1. Female vs male; 2. Above high school vs below high school; and 3. Married vs single.
CI, confidence interval; DGA, Dietary Guidelines for Americans; DMA, Daily Minimum Amount; FPPs, food-related parenting practices; PS, parenting style.

DGA-recommended amounts of vegetables and grains. This is consistent with the results of a previous study revealing that rules can have a negative impact on children's inability to regulate their food intake (33). However, setting at least one health-oriented food rule at home is directly associated with healthy, independent eating choices among early adolescents (30). Setting rules may be a good strategy for younger adolescents, but plays a negative role in threatening the autonomy of older adolescents. However, although the authoritarian style is characterized by extreme control and obedience, it plays a positive role in ensuring the consumption of DGA-recommended DMA in fruits and dairy. The findings of our study indicate that, among African-American adolescents, those who experienced a higher degree of authoritarian parenting were more likely to meet the DGA recommendations for fruit and vegetable consumption. This suggests that strict rules and discipline associated with authoritarian parenting may play a positive role in promoting healthier eating habits in this population. It is worth noting that previous studies examining parenting styles and dietary behaviors have mostly been conducted in the general population, which may explain the inconsistencies between our findings and those of previous research. By focusing specifically on African-American adolescents, our study provides valuable insights into the unique influences on dietary behaviors within this demographic group.

Among the four FPPs, monitoring and reasoning emerged as strategies that parents could adopt to ensure their adolescents consume the DGA-recommended DMA for at least three MyPlate food items. Adolescents who experienced monitoring FPP met the DGA for fruit, vegetables, and dairy, while adolescents with higher reasoning FPP met the DGA for fruit, grain, and protein consumption. Monitoring FPP had the largest positive impact on fruit consumption and the smallest on dairy, according to the DGA. Our previous study, which involved a smaller sample size, examined the same PSs and FPPs also confirmed a positive correlation between monitoring FPP and an increase in fruit and vegetable consumption and a decrease in unhealthy snack consumption among African-American adolescents (13, 18). Beckers et al. reported a curvilinear relationship between monitoring and adolescent eating behavior, indicating that monitoring can promote healthy eating to a certain extent; however, extreme monitoring has a negative role in the evolution of an unhealthy diet among adolescents (34). Thus, considering the level of age-suitable independence is important to adjust the optimal level of FPP

monitoring. Furthermore, reasoning FPP had the largest positive impact on meeting the DGA for fruit consumption and the smallest positive impact on meeting the DGA for protein consumption. Reasoning practice is defined as a tool used to convince adolescents to adopt better eating behaviors by transmitting nutritional knowledge (35). Enhancing this kind of knowledge promotes autonomy among adolescents, which can impact their self-efficacy regarding the foods they consume. Additionally, copying emerged as another FPP in which parents encouraged their children to imitate their own eating behaviors, intentionally or unintentionally (30). The findings of this study suggest that copying behavior also influences whether adolescents meet the recommended guidelines for dairy consumption. Recognizing the role of copying can help develop strategies to promote positive parental behaviors and foster healthier dairy consumption habits among adolescents.

Furthermore, along with PSs and FPPs, specific demographic factors influenced the attainment of the DGA-recommended DMA for MyPlate food items. Sex plays a significant role in meeting the DGA for fruit consumption, with females having a higher likelihood of meeting the DGA-recommended amounts than males. However, females were less likely to meet the DGA for dairy consumption than males. This can be attributed to various factors, including differences in taste preferences, dietary choices, and cultural norms. Moreover, residing in educated African-American households was associated with an increased probability of consuming DGA-recommended amounts of fruit and protein. Higher levels of education among parents or caregivers may lead to greater awareness and understanding of nutrition, thereby promoting healthier food choices for adolescents. Education serves as a pathway for acquiring knowledge about the impact of nutrition on health, empowering individuals to make informed decisions about their diet. Moreover, our study revealed that adolescents living in married households were more likely to meet the DGA-recommended vegetable consumption. This finding suggests that a stable marital environment creates a supportive atmosphere that encourages healthy dietary habits among adolescents. Shared mealtime practices and a family environment that values and promotes vegetable consumption may contribute to an increased likelihood of meeting the DGA guidelines.

One strength of this study was the use of all five MyPlate food groups, whereas previous studies considered only one or two food groups to examine the impact of PSs/FPPs. By including all five MyPlate food items, our study offers a comprehensive evaluation of dietary patterns, providing a holistic view of the impact of studied parenting on dietary adherence among African-American family. In this study, PSs and FPPs were considered together to determine which among them plays an important role in the diet of African-American adolescents. To our knowledge, this is the first study to use information on the consumption of the DGA-recommended DMA to determine the effectiveness of PSs and FPPs in eliciting behaviors toward the consumption of different food items. The participation of the parent–adolescent dyad is another strength of this study, which reduced the bias from collecting data from just one participant. Additionally, we focused on a minority group, African-Americans, who have been less studied.

However, this study had certain limitations. The data collection to assess dietary habits was based on the FFQ, which, while practical and widely used, is subject to recall bias, as it relies on the participant's memory of their dietary intake. Additionally, the fixed list of food items may not capture the full diversity of the adolescents' diet, especially for those with unique eating habits. This can lead also to under- or over-reporting of data, which can directly impact the results. Future studies should use 24 h recalls combined with an FFQ survey to increase the accuracy of dietary intake data collection. Moreover, additional FPPs, such as the availability and accessibility of food, rules, and expectations, as well as pressure-to-eat or the effect of parenting styles, including permissive and neglectful styles, can be included in future studies to comprehensively analyze parenting practices. Finally, studies on macro- and micronutrient components can be included in the food consumption analysis. In this study, we considered the total grain (refined and whole grains) consumption. Therefore, these results can be attributed to a higher proportion of refined grains than whole grains. Most Americans consume adequate amounts of total grain food, whereas few consume adequate amounts of whole grains (36). Future studies should consider these two types of grains separately to obtain more detailed results.

Finally, this study highlights the significant role of PSs and FPPs in shaping the dietary behaviors of African-American adolescents. This underscores the importance of PSs and FPPs in meeting the DGA recommendations, particularly for different food categories. These findings suggest that specific PSs, FPPs, and certain demographic factors are associated with increased or decreased odds of meeting DGA criteria for various food items. These insights contribute to a better understanding of suitable parenting approaches within a cultural context and can positively influence the eating behaviors of adolescents, ultimately improving the health of families and communities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This research study was approved by the Institutional Review Board at the University of the District of Columbia (IRB#878591-2) on 16 February 2021. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

AA: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. LM-L: Conceptualization, Funding acquisition, Writing – original draft, Writing – review & editing. DW: Formal analysis, Methodology, Validation, Writing – review & editing. CC: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Predictors of time to recovery from uncomplicated severe acute malnutrition among children in eastern Ethiopia

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Background: Managing severe acute malnutrition (SAM) involves an outpatient therapeutic program (OTP), targeting more than 80% of SAM children where the quality of primary healthcare remains poor. Treatment success and recovery from SAM remain poor and could be affected by many factors, where such evidence is limited in East Hararghe. This study assessed the predictors of time to recovery from SAM in eastern Ethiopia.

Methods: A retrospective cohort study was conducted on 402 records of SAM children under 5 years of age enrolled on OTP at 12 health posts retrieved from 2020 to 2021. We used the Kaplan–Meir estimate along with the *p*-value of the log-rank test and the survival curve to compare the time to recovery across categories. A multivariable Cox proportional hazard model was fitted to identify predictors of time to recovery from SAM. A *p*-value below 0.05 was used to declare statistical significance.

Results: A total of 402 records were reviewed, and the cure rate from SAM was 89.6% [95% confidence interval (CI), 87–93]. Moreover, a death rate of 0.7%, a default rate of 9.5%, and a non-responder rate of 0.2% were obtained with a median length of stay of 7 weeks. The median time to recovery was significantly shorter for children from shorter distances from OTP sites with edema, amoxicillin, ($p < 0.05$). Edema at admission [adjusted hazard ratio (AHR) = 1.74; 95% CI: 1.33–2.29], without diarrhea (AHR = 1.51; 95% CI: 1.18–1.94), taking amoxicillin (AHR = 1.55; 95% CI: 1.19–2.02), shorter travel time to the OTP site (AHR = 1.44; 95% CI: 1.13–1.85), breastfeeding (AHR = 1.60; 95% CI: 1.27–2.02), adequacy of ready-to-use therapeutic food (RUTF) (AHR = 1.22; 95% CI: 0.90–1.65), and new admission (AHR = 1.62; 95% CI: 0.84–3.10) were important predictors of recovery from SAM.

Conclusion: Recovery from SAM was found to be acceptable in comparison with the Sphere Standards and is predicted by edema, diarrhea, distance from the OTP site, amoxicillin, and RUTF adequacy. These allow for focused interventions that address the identified factors for better recovery from SAM.

KEYWORDS

outpatient therapeutic program, time to recovery, severe acute malnutrition, treatment outcome, Ethiopia

Introduction

Acute malnutrition develops over a short period of time in response to inadequate dietary intake and infections (1), which is graded as moderate and severe acute malnutrition (SAM). SAM is defined as a mid-upper arm circumference < 115 mm, or a weight-for-height/length < −3 Z-score of the World Health Organization (WHO) child growth standards medians, or bilateral pitting edema (2). Every year, approximately 45.5 million children are affected by acute malnutrition, and 13 million are severely malnourished (3). In Africa, almost 13.8 million under-five children were acutely malnourished (4). Moreover, it leads to 1.7 million child deaths annually in sub-Saharan Africa (2), increasing the risk of mortality by nine-fold (5, 6). These figures have increased by 6.7 million due to the current COVID-19 pandemic in recent years (7, 8). In particular in developing countries, more than 2% of children are severely malnourished (9). The recent national survey of Ethiopia has also shown that 11% of children were wasted in Ethiopia, and the prevalence was 9% in the Oromia region (10), indicating a rise in recent years.

Malnutrition is a major cause of morbidity, mortality, and long-term developmental deficits. For instance, approximately 45 percent of children under the age of five die as a result of malnutrition (8), and children who are wasted are at risk for long-term developmental deficits (2). Compared to the global target to reduce wasting below 5%, there is an alarming rate of wasting aggravated by natural and man-made disasters. Ethiopia has been hit by a series of natural and manmade disasters, most notably the cyclic drought, which has had a severe influence on the efforts of the country to reduce acute malnutrition (11, 12). Despite the fact that the magnitude of wasting has declined from 13 to 7% from 2016 to 2019, the burden of SAM in the country is increasing alarmingly, coupled with the prevailing civil war, rising food prices, and others (13). Hence, acute malnutrition contributes to a total loss of US $230 million and up to 64% of the economic burden (14).

The Community Management of Acute Malnutrition (CMAM) is found to be effective for the rapid recovery of SAM children and the prevention of future crises. However, the coverage is still approximately 56%, as reported in 2020, where a significant number of SAM children are being missed (15). The outpatient therapeutic program (OTP) had a higher coverage (79–95% of SAM children) for children suffering from uncomplicated SAM to recover (16), although treatment success is limited by various factors that need to be investigated. A study showed a high recovery rate of 92%, low mortality of 0.1%, and acceptable default rates (7.5%) among SAM children. The implementation of CMAM has increased access to malnutrition care closer to home and significantly reduced deaths. However, only approximately 20% of children with SAM receive treatment at a facility (17), where the OTP makes it easier to treat children at home with maximum coverage. The program targets SAM children above 6 months without medical complications or transfer outs from inpatient care for better coverage and treatment success (18, 19). The results of treatment are categorized as cured, defaulted, died, and non-respondent to treatment, which are used as indicators for treatment success (20).

The Sphere Humanitarian Standards is a widely recognized set of guidelines and principles for humanitarian response in emergency settings. These standards provide a framework for improving the quality, effectiveness, and accountability of humanitarian interventions. In the context of recovery from severe acute malnutrition (SAM), adherence to the Sphere Humanitarian Standards becomes crucial in ensuring that interventions meet minimum benchmarks and prioritize the wellbeing and rights of affected individuals (21, 22). This allows us to understand the specific needs and challenges associated with SAM recovery, leading to more effective and coordinated interventions. The standard sets more than 75% recovery, less than 10% death, and less than 15% default rates (21).

Although poor treatment outcomes could be lower and previous studies focused on inpatient care, there is limited evidence to elucidate treatment success and potential factors limiting optimal treatment outcomes. In addition, the OTP targets 80% of the SAM children, where evaluation of program success is vital for policy decisions (5, 23). East Hararghe faces numerous nutritional challenges, worsened by high fertility rates and low agricultural productivity. However, there is a lack of evidence for understanding the factors influencing the time it takes for individuals to recover from SAM, which is crucial for addressing the existing situation. This study aimed to fill this knowledge gap by providing valuable evidence specific to the context of East Hararghe, where SAM occurrence is prevalent but such evidence is lacking. The objective of this study was to assess the significant factors that predict the time to recovery from uncomplicated SAM in the context of the OTP in eastern Ethiopia.

Materials and methods

Study area and period

East Hararghe zone is one of the 20 Zones in the Oromia region, located in the eastern part of Ethiopia. The zone has 20 rural and 4 urban woredas with 543 kebeles (the least administrative). East Hararghe zone is located 510 km to the east of Addis Ababa, Ethiopia. The zone has a total population of 4.04 million. The zone has 557 health posts, 121 health centers, and 8 hospitals; these facilities make up the health service coverage of the zone (24). From the total population, under 5-year-old children were 682,796 and the zone has approximately 650 OTP sites. It is one of the most populous zones in the region. In addition, it is among the chronically food-insecure areas of the country that face recurrent drought and poverty. The data were collected from 20 May 2022 to 20 June 2022 whereas the retrieval period was from 2020 to 2022.

Study design and population

An institution-based retrospective cohort study was employed among SAM children in the OTP program via chart review. The current study targeted records of uncomplicated SAM children aged from 6 to 59 months who were on OTP treatment between 8 July 2020

Abbreviations: AM, Acute malnutrition; AHR, Adjusted hazard ratio; CMAM, Community-Based Management of Acute Malnutrition; CTC, Community Therapeutic Care; EDHS, Ethiopian Demographic Health Survey; IMCI, Integrated Management of Childhood Illness; MOH, Ministry of Health; MUAC, Mid-upper arm circumference; OTP, Outpatient therapeutic program; PPS, Proportion to population size; RUTF, Ready-to-use therapeutic food; SAM, Severe acute malnutrition; SRS, Simple random sampling; SPHERE, Social and Public Health Economics Research Group; TFC, Therapeutic feeding centers; UNICEF, United Nations Children's Fund.

and 7 July 2021. Those children admitted according to the recent national SAM protocol were included (MUAC value 11.5 cm or bilateral pitting nutritional edema, good appetite test, and no medical complications). Records of SAM children referred for inpatient care against medical advice were excluded. In addition, records of children with incomplete outcome variables and missing more than 50% of the independent variables were dropped.

Sample size determination and sampling methods

A two-population proportion sample size estimation formula was employed in Epi Info software. We considered 95% confidence level, 80% power, 5% margin of error, a ratio of unexposed to exposed of 1:1, the proportion of children with diarrhea who were recovered (exposed group) = 47.4%, and the proportion of children without diarrhea who were recovered (non-exposed group) = 65.9% (25). Furthermore, we assumed a design effect of 1.5 to account for heterogeneity and a 10% card withdrawal rate; a total of 402 SAM records were required for this study.

We employed stratified random sampling with proportional allocation to select samples for four selected districts of the eastern Hararghe zone. Then, three OTP sites were randomly selected from each district, for a total of 12 OTP sites. Finally, the individual SAM records from each selected OTP site were selected using systematic random sampling at each sample interval based on their unique medical record number and/or SAM registration number. The number of medical records from each of the OTP sites was selected proportionally to the total number of SAM records at each OTP site. Then, the allocated number of SAM records was known, and each medical record was selected at every sampling interval. The starting sample record was selected randomly, and the sample at each sample interval was selected accordingly (26). Children aged 6–59 months on OTP from 8 July 2020 to 7 July 2021 in four woredas were 8,850. These numbers were allocated according to their population size. Hence, 143 (35.6%) of the sample was from Fadis, 114 (28.4%) from Kersa, 98 (24.4%) from Haramaya, and 47 (11.7%) from Kombolcha districts.

Variables of the study

The outcome variable was time to recovery from SAM as defined as recovery from acute malnutrition as per the national and WHO SAM protocols. Recovery from SAM is determined based on significant weight gain, improvement in anthropometric measurements (MUAC in centimeters), resolution of nutritional edema, WFH percentage of the median above 80% and clinical improvement with the absence of edema, improved appetite, and overall enhancement of health and wellbeing (5). This has been tracked from the SAM register and/or the medical chart of children, which is being implemented as per the national SAM guideline, which is a very valid means.

Recovery was coded as recovered and not recovered. The length of time (in days) was extracted from the day of admission and the last recorded follow-up period. Moreover, default is declared when the child is lost to follow-up, and death is recorded when the child dies during the follow-up period (23). Discharge from the OTP program refers to children with SAM who exit the program through cure, death, default, or being non-responders. Cure or recovery was when MUAC was 12.5 cm and the child had no edema for at least 2 weeks, while death was when the child reported death during treatment in outpatient care (1, 5, 27). Default is defined as being absent for two consecutive visits (2 weeks), and non-responders are when the child did not recover after 4 months (16 weeks) of standard OTP care. Finally, transferred-out is when the condition of the child has deteriorated or is not responding to treatment and is referred for treatment in inpatient care or to another OTP facility.

The outcomes were measured as follows;

$$Recovery\ rate\,(\%) = \frac{number\ of\ SAM\ children\ recovered\ or\ cured}{total\ number\ of\ SAM\ children\ on\ follow\ up} * 100$$

$$Defaulter\ rate\,(\%) = \frac{number\ of\ SAM\ children\ defaulted}{totalumber\ of\ SAM\ children\ on\ follow\ up} * 100$$

$$Death\ rate\,(\%) = \frac{number\ of\ SAM\ children\ died}{totalumber\ of\ SAM\ children\ on\ follow\ up} * 100$$

$$Average\ length\ of\ stay\ in\ days = Date\ ofdischarge\ or\ outcome - date\ of\ admission$$

The independent variables included age in months, sex, time taken from OTP sites to the child's home (in minutes), type of malnutrition, breastfeeding, and provision of amoxicillin at admission; an appetite test at admission; admission weight in kilogram; MUAC on admission in centimeter; edema; and routine medication intakes.

Data collection procedures

To capture the data, we designed a structured abstraction checklist from the OTP card and nutrition registration logbook by four trained health professionals. We checked the tool on a random sample of 10 records, and the necessary changes were made before data collection. A pretest was conducted on 20 SAM records before implementing the study on a large scale. Extensive and practical training was given to data collectors on the practical ways of extracting and cross-validating data sources. The completed questionnaire and the corresponding patient card were collected daily using an offline data collection tool named Open Data Kit (ODK) and checked for completeness and consistency. Cleaning was done on a daily basis, and data collectors received daily supervision with on-the-spot feedback.

Data management and analyses

The captured data were checked and cleaned for any inconsistencies and analyzed in SPSS version 20 (28). The data were described and summarized using frequency, percent, and a measure of central tendency. The outcome variable was dichotomized as "cured" and "censored" for the final survival and Cox regression analysis, where the outcome was ascertained at discharge or discharge against medical

TABLE 1 Socio-demographic and admission characteristics of SAM children on treatment at OTP, East Hararghe zone, Oromia Ethiopia, from 8 July 2020 to 7 July 2021 ($n = 402$).

Child characteristics	Category	Frequency	Percent
Sex	Male	191	47.5
	Female	211	52.5
Age	<24 months	288	71.6
	24–59 months	114	28.4
Breastfeeding status	Yes	214	53.2
	No	188	46.8
Admission status	New	390	97.0
	Readmission	3	0.8
	Return after default	9	2.2
Distance (time of travel in minutes)	< 30 min	256	63.7
	> = 30 min	146	36.3
Selected districts	Haramaya	98	24.4
	Fadis	143	35.6
	Kersa	114	28.4
	Kombolcha	47	11.7

advice. We employed a life table to explain the patterns of recovery among SAM children. Relevant hazards and survival curves were plotted and interpreted, along with mean or median survival times. To compare survival time among different categories, a log-rank test with its corresponding *p*-value was reported. The time to development of the outcome (cure vs. censor) was calculated from the date of discharge or outcome and the date of admission to the OTP program and expressed in days. We used bivariable and multivariable Cox proportional hazard models to identify factors predicting time to recovery from uncomplicated SAM. The proportional hazard assumption for the Cox proportional hazard model was validated by plotting the log-minus-log survival plot against time by categorical variables and performing a global test using Stata software under the null hypothesis of proportional hazards. Predictors with a *p*-value below 0.25 in bivariable analysis and biologically plausible predictors from previous studies were candidates for the final model (29). Hence, we have considered edema, referral system, and chest indrawing as potentially plausible risk factors for recovery from SAM and considered them for the final model. Adjusted hazard ratios (AHR) with a 95% confidence interval were reported, at which statistical significance was declared at a *p*-value less than 0.05. Interaction and multicollinearity effects were also explored using appropriate statistical approaches.

Ethical considerations

Formal ethical approval was obtained from the Ethical Review Committee of Addis Ababa Medical and Business College (AAMBC), faculty of postgraduate studies with reference no. of AMBC/stu/10746/14 and dated 26/07/2014EC. A formal support letter was written to the Oromia Health Bureau to facilitate the conduct of the study. The bureau rechecked the ethical compatibility, and the study was implemented. We have obtained written consent from each health facility, and no personal identifiers were collected for this study. As the current study was based on a secondary chart review, obtaining consent from a mother or caregiver was not feasible. In addition, the collected data were kept private with the investigators and will be shared anonymously.

Results

Baseline characteristics of SAM children

A total of 402 records of SAM children were included in this study. Approximately 211 (52.5%) were female children, and 288 (71.6%) of them were under 2 years of age. A total of 214 (53.2%) of them were breastfeeding, and 256 (63.7%) of the children took less than 30 min to reach health facilities, whereas 146 (36.3%) took more than 30 min. Almost all 390 (97%) of them were new admissions to the OTP program (Table 1).

Regarding admission characteristics, children were mainly admitted due to MUAC (66.2%) and edema (31.6%). On the other hand, 275 (68.4%) and 113 (28.1%) of children had marasmus and kwashiorkor at admission, respectively. With regard to common co-morbidities, 148 (37%) had at least one medical comorbidity, of which diarrhea (36.8%) and cough (2%) were common. We found that ready-to-use therapeutic food (RUTF) was administered according to the weight of children, and 338 (84.1%) got the recommended RUTF as per the national SAM protocol. Routine medications were also provided at OTP for children in the OTP program. Approximately 298 (74.1%) children have taken amoxicillin, and 310 (77.1%) children have had deworming (Table 2).

Treatment outcomes of SAM children

Of 402 SAM children on OTP service delivery sites, 360 (89.6%) were recovered or cured. In addition, 38 (9.5%) were defaulters, 3 (0.7%) died, and 1 (0.2%) were non-responders among the study participants. The median length of stay at OTP was approximately

TABLE 2 Forms of malnutrition and major comorbidities at admission among SAM children attended OTP service in East Hararghe Zone from 8 July 2020 to 7 July 2021 ($n = 402$).

Variables	Categories	Frequencies	%
Type of malnutrition	Marasmus	275	68.4
	Kwashiorkor	113	28.1
	Marasmic kwashiorkor	14	3.5
Presence of Edema	Yes	127	31.4
	No	275	68.6
Adequacy of RUTF	Adequate	338	84.1
	Not adequate	64	15.9
Presence of diarrhea	Yes	148	36.8
	No	254	63.2
Presence of Cough	Yes	8	2.0
	No	394	98.0
Appetite test done	Good	367	91.3
	Poor	35	8.7
Mebendazole/Albendazole on second visits at admission	Yes	310	77.1
	No	92	22.9
Provision of Amoxicillin at admission	Yes	298	74.1
	No	104	25.9

TABLE 3 Performance indicators of OTP and comparison to the Sphere Standards for treatment success among children in East Hararghe Zone, Ethiopia ($n = 402$).

Performance indicators	Frequency of indicators	International sphere standards reference	
		Acceptable	Alarming
Recovery rate (%)	89.6% ($n = 360$)	>75%	<50%
Defaulter rate (%)	9.5% ($n = 38$)	<15%	>25%
Death rate (%)	0.7% ($n = 3$)	<10%	>15%
Average length of stay in weeks		<4 weeks	>6 weeks
<4 weeks	3 (0.7%)	Acceptable	
4–6 weeks	183 (45.5)	Long	
>6 week	216 (53.8%)		Alarming

7 weeks. Yet, this standard is mainly for emergency settings where further moves are expected to improve good treatment outcomes. More importantly, the median length of stay at the hospital was relatively longer (>6 weeks) (Table 3).

Time to recovery from SAM

Approximately 89.6% of SAM children recovered from SAM, with a median time to recovery of 49 days (IQR: 35–63), or 7 weeks. The majority of the recoveries occurred within 4–6 weeks of starting OTP care, which is considered a longer stay for children under OTP care in comparison with the SPHERE minimum references. The majority of recoveries were experienced after 4 weeks of admission as indicated by the major increase in the number of recovered children between 4 and 7 weeks (Figure 1).

Upon Kaplan–Meir analysis, the recovery rate was substantially lower among children residing within >30 min of the health facility, on antibiotics, and non-breastfeeding children. Furthermore, there was a significant difference in survival time to recovery due to diarrhea, the presence of edema, and the absence of edema in children who took amoxicillin drugs as compared to those who were not on routine drugs. Using the log-rank test, we have checked for the significance of the observed differences in recovery rates among the categorical factors (Figure 1 and Table 4).

The average time to recovery from SAM was relatively longer among children with lower admission weight (7 kg) and children coming from distant places from health posts (p-value of the log-rank test = 0.0001). Similarly, the time to recovery from SAM was significantly shorter among SAM children who were breastfed, had edema, received adequate RUTF based on their weight, took amoxicillin, and were dewormed as compared to their counterparts. Hence, children with these admission characteristics and treatment options had a better recovery time as compared to those without these attributes (Table 4).

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Predictors of time to recovery from uncomplicated SAM

We have checked the proportional hazard assumption before fitting the covariates into the regression model. Hence, all of the predictor variables did not violate the proportional hazards' assumptions ($p > 0.05$), making the data suitable for the Cox proportional regression analysis. In the bivariable Cox regression model, the age of the child, MUAC and weight category, edema, taking amoxicillin, breastfeeding status, vaccination status, clinical forms of SAM, deworming, distance to a health facility, and having adequate RUTF were important predictors of cure from SAM in the crude model ($p < 0.05$).

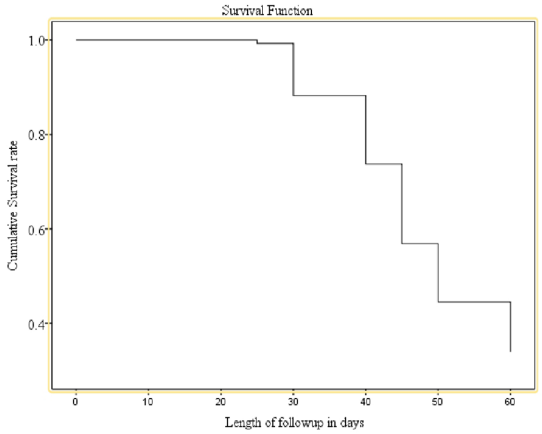

FIGURE 1
Cumulative survival curve for time to recovery from uncomplicated SAM, in eastern Ethiopia.

In the adjusted model, distance from the OTP site to home, presence of edema and diarrhea on admission, breastfeeding status, source of referral, measles vaccination status, amoxicillin, and the adequacy of the prescribed RUTF amount were independent predictors of time-to-nutritional recovery from uncomplicated SAM. Children residing >30 min from a health post had a 44% higher probability of having a shorter recovery (AHR = 1.44; 95% CI: 1.13–1.85). In addition, children who took amoxicillin (AHR = 1.55; 95% CI: 1.19–2.02) and without measles vaccination [AHR = 1.46 (1.04–2.03)] were 55 and 46% more likely to have shorter recovery from SAM, respectively (Table 5).

The time to recovery was better among children without diarrhea (AHR = 1.51; 95% CI: 1.18–1.94), with edema (AHR = 1.74; 95% CI: 1.33–2.29) at admission, and new admissions to the OTP (AHR = 1.62; 95% CI: 0.84–3.91) than counterparts. Self-referred children had a significantly longer time to recover from uncomplicated SAM as compared to those referred from inpatient care or community outreach. Furthermore, the time to recovery was significantly shorter for children diagnosed with marasmic kwashiorkor and kwashiorkor than those children with marasmus. More importantly, administering adequate RUTF in accordance with the SAM protocol could improve the time to recovery (AHR = 1.22; 95% CI: 0.90–1.65) (Table 5).

TABLE 4 Comparison of the median survival time to recovery from SAM by categorical predictors among children in eastern Ethiopia.

Variable	Options	Median survival time with 95% CI	X^2	*p*-value of log-rank test
Admission weight category	<7 kg	62.3 (51.3–60.7)	42.1	0.0001
	>7 kg	47.5 (38.9–45.2)		
Distance from home to HP	< 30 min	49.0 (46.4–51.6)	12.8	0.0001
	> = 30 min	56.0 (50.4–61.6)		
Breastfeeding	Yes	56.0 (51.9–60.1)	47.8	0.0001
	No	42.0 (39.8–44.2)		
Type of SAM	Marasmus	56.0 (52.2–59.8)	30.0	0.0001
	Kwashiorkor	42.0 (38.7–45.3)		
Edema	Yes	42.0 (39.3–44.7)	42.4	0.0001
	No	56.0 (52.4–59.6)	30.0	
Diarrhea	Yes	56.0 (50.9–61.1)	11.9	0.001
	No	49.0 (46.1–51.9)		
Amoxicillin	Yes	49.0 (46.5–51.5)	29.2	0.0001
	No	63.0 (56.9–69.1)		
Deworming	Yes	42.0 (39.4–44.6)	14.2	0.0001
	No	56.0 (52.7–59.3)		
Edema	No	56.0 (52.4–59.6)	42.4	0.0001
	Yes	42.0 (39.3–44.7)		
Adequate RUTF	Not adequate	63.0 (56.8–69.3)	11.5	0.001
	Adequate	49.0 (46.5–51.5)		

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TABLE 5 Bivariable and multivariable Cox regression output for factors determining time to recovery from SAM children at OTP in East Hararghe Zone, Ethiopia ($n = 402$).

Variable	Options	Treatment outcome		CHR 95% CI	AHR with 95% CI	*p*-value
		Cured	Censored			
Sex	Male	173	18	1.04 (0.845–1.279)		
	Female	187	24	1		
Age in months	<24	257	31	1.49 (1.18–1.88)*		
	24–59	103	11	1		
Referral system	Self-referred	121	13	1	1	
	Community volunteer and campaign	221	26	1.13 (0.90–1.41)	1.15 (0.90–1.45)	0.261
	From stabilization center and Other OTP	18	3	1.15 (0.70–1.89)	1.70 (1.02–2.84)	0.041
MUAC	<11.5	240	38	1		
	11.5–12.5	55	3	1.67 (1.24–2.24)*		
	>12.5	65	1	2.282 (1.73–3.01)*		
Admission weight category	<7 kg	170	33	1		
	>7 kg	190	9	1.85 (1.50–2.28)*		
Distance to health facility	<30 min	256	1	1.44 (1.15–1.81)*	1.44 (1.13–1.85)	0.004
	> = 30 min	104	41	1	1	
Breastfeeding	Yes	184	30	1	1	
	No	176	12	1.92 (1.56–2.38)**	1.60 (1.27–2.02)	0.000
Vaccination	Yes	235	25	1.15 (0.93–1.43)		
	No	125	17	1		
Type of SAM	Marasmus	239	36	1		
	Kwashiorkor	111	2	1.91 (1.5–2.40)**		
	Marasmic kwashiorkor	10	4	2.09 (1.10–3.96)*		
Diarrhea	Yes	111	37	1		
	No	249	5	1.42 (1.13–1.77)*	1.51 (1.18–1.94)	0.001
Amoxicillin	Yes	280	18	1.83 (1.42–2.35)*	1.55 (1.19–2.02)	0.001
	No	80	24	1	1	
Deworming	Yes	86	6	1		
	No	274	36	1.51 (1.19–1.93)*		
Measles	Yes	42	3	1		0.027
	No	318	39	1.15 (0.84–1.59)	1.46 (1.04–2.03)	
Chest indrawing	No	354	42	1.92 (0.84–4.37)		
	Yes	6	0	1		
Edema	No	239	36	1	1	
	Yes	121	6	1.92 (1.54–2.40)*	1.74 (1.33–2.29)	0.000
Admission type	New admission	350	40	1.49 (0.79–2.80)	1.62 (0.84–3.10)	0.148
	Readmission	10	2	1	1	
Adequate RUTF	Not adequate	55	9	1	1	
	Adequate	305	33	1.55 (1.16–2.07)*	1.22 (0.90–1.65)	0.206

The asterisks indicate statistically significant predictors of time to recovery from SAM at a *p*-value below 0.05 (*) and 0.001 (**).

Discussion

The current study was to identify the potential factors predicting time to recovery from SAM in low-income settings, in eastern Ethiopia. The findings of this study showed that 89.6, 9.5, 0.7, and 0.2% were recovered, defaulted, dead, and non-respondents, respectively. All indicators met the minimum performance indicator and were within the Sphere Standard range, which is above 75% (21). The Sphere Standards are a set of guidelines and principles for humanitarian response. It establishes minimum standards and

principles in areas such as water, sanitation, shelter, health, and protection, with a focus on promoting accountability and the wellbeing of affected populations. Adhering to these standards helps ensure effective and coordinated humanitarian assistance while prioritizing the rights and dignity of those in need (21).

On the other hand, the average length of stay within the program was in an alarming range, where a child could stay for more than 7 weeks. The current study showed a better cure rate than studies conducted in different parts of the globe, which range from 10.2 to 77.9% (30). Comparable cure rates were reported from Afar (83.2%) (31), southern Ethiopia (85%) (25), and Tigray (87%) (32), which are above the Sphere Standards. However, due to the curable nature of SAM, expanded interventions in the home environment and care at OTP sites could improve timely recovery. Through this, full recovery can be achieved by reducing a significant number of child deaths. It should also be noted that the Sphere Standards are mainly for humanitarian settings, where basic livelihoods are severely affected.

Both the death and default rates were within the acceptable range of the International Sphere Humanitarian Standard reference, which is 10 and 15%, respectively (21). The study also showed a default rate of 9.5%, which is below the standard reference point and lower than studies conducted in Yemen, where 80.2% of SAM had defaulted and only 10.2% had recovered (33), which could be related to the emerging disasters and poor service delivery in Yemen. It is worse than studies conducted in the Afar region (6.3%) (25), the Tigray region (2.2%) (34), and Kenya (2.9%) (32). The reported death rate in our study is lower than studies from the Afar region (4.9%) (33), and Yemen (3.3%) (32). In this study, the median length of stay at the OTP site was 7 weeks, considered alarming and not acceptable compared to the minimum international standard of 4 weeks, yet it is acceptable based on the national SAM protocol (16 weeks) (23). It is also consistent with other studies in southern Ethiopia showing 6.7–8.7 weeks (25, 35, 36), which is lower than previous studies (9–10 weeks) (7, 32, 33). These discrepancies could be linked to service quality, adherence to care, the practice of sharing RUTF, suitable home environments, and the severity of SAM at admission.

Children coming from a nearby health post (less than 30 min) had 44% higher odds of having rapid recovery from SAM as compared to children from farther locations. A study from the Kamba district showed that residents from distant areas could affect recovery from SAM, but it was not statistically significant (35). These could be due to poor physical access to weekly OTP follow-up and poor treatment adherence as compared to those from near the facility.

Children who received amoxicillin therapy had a 55% higher probability of recovery than their counterparts. The finding is consistent with the finding from Tigray Region (20) and clinical trials in antibiotics are a crucial part of SAM treatment in India (37), which had the potential to reverse hidden infections such as pneumonia or bowel bacterial overgrowth (23). On the other hand, those children who did not get measles at admission usually had the vaccination already, making them protected.

More importantly, time to recovery was better for children with edema, including kwashiorkor and marasmic kwashiorkor. As opposed to the fact that edematous malnutrition is associated with many complications and is usually treated in inpatient care, these children might have been referred to a stabilization center (SC) or have a better nutritional index. These would shorten the recovery period. Previous studies conducted in Ethiopia (25, 32) and Ghana (38) showed that children admitted with kwashiorkor had a rapid recovery compared to marasmic children. Another study from Ethiopia did not indicate these associations (35). This could be explained by the concurrent presence of other medical morbidities that would reduce recovery and provide better care for kwashiorkor children (19). In contrast, OTP implementation is challenged by many factors, including the sharing of RUTF among family members (2, 39), which is usually associated with poor knowledge and limited household food access (40). Thus, the perceived severity of kwashiorkor might influence caregivers' decisions not to share the RUTF (41).

Medical comorbidities were associated with a longer recovery from SAM, specifically the presence of diarrhea. The likelihood of timely recovery was 51% higher among those without diarrhea. This finding was consistent with a study conducted in the southern part of Ethiopia (26) and northern Ethiopia (7). This could be explained by the vicious cycle of diarrhea and SAM affecting recovery time mainly due to metabolic disturbances, fluid and electrolyte losses, and dehydration (5). This evidence is also in line with the fact that a multitude of studies implied diarrhea as a major determinant predicting time to recovery from uncomplicated SAM (32, 42).

Those children who were not breastfed have limited options for food and are more likely to consume the prescribed RUTF, leading to rapid recovery. Due to overreliance on breastfeeding, adherence to RUTF might be limited, increasing the risk of sharing. This scenario can occur when infants are less likely to take the full dose of RUTF as it may be less palatable and have less acceptable textures compared to breast milk. Furthermore, sharing RUTF among household members could reduce cure rates (7) and average weight gain (43). Arguably, sharing of RUTF is more likely with older siblings of a breastfeeding infant than their counterparts because the mother can provide better nutritional care to the affected child along with breast milk. Hence, strong adherence counseling should be in place for those who on breastfeed although breastfeeding is growth-promoting for children.

While a few studies depicting the link between breast-feeding and time to recovery from SAM found none (44, 45); however, neither study did a sub-analysis for children under 2 years or explored the link between breast-feeding and improvement in MUAC. The small weekly increase in MUAC among breast-feeding children below 2 years of age was unexpected and needs careful consideration. Beyond the first 6 months, breastfeeding without adequate complementary feeding is inadequate for meeting the growing needs of children (46). Hence, providing RUTF serves to improve recovery from SAM as a short-term intervention.

Those children who get adequate RUTF according to their weight have a better time recovering from SAM. A study showed that a reduced dose of RUTF could significantly reduce weight, which was pronounced among infants under 1 year (47). In addition, alternative ready-to-use foods were found to be inferior to the standard RUTF in Ghana (48).

The study provides valuable insights into the context-specific predictors of severe acute malnutrition (SAM) and the effectiveness of management practices. It highlights the potential benefits of utilizing extended packages for managing uncomplicated SAM through trained community health workers or health extension workers (49, 50). This approach has shown promise in reducing the adverse impacts of SAM at an early stage as demonstrated by previous

studies (8, 22, 51). By leveraging the expertise and accessibility of community-based healthcare providers, there is an opportunity to improve the timeliness and effectiveness of interventions, ultimately leading to better outcomes for individuals affected by SAM. These findings contribute to the existing body of knowledge and support the importance of community-based approaches in addressing SAM effectively.

Limitations of the study

Although this study generated valuable evidence, data on RUTF sharing practices, selling behaviors, and food security status are frequently reported as risk factors for recovery (51). However, due to the retrospective design of the study, these pieces of data were not captured, limiting the interpretation of this study. Moreover, the presence of some missing data could also further limit the conclusions derived from this study. The lack of data on poverty or family income due to the secondary nature of the data could limit the interpretability of the study findings.

Conclusion

Overall, the recovery rate from SAM among children on OTP was found to be optimal in accordance with the Sphere Standards, yet there is a need for further improvements. In addition, this is below the universal target to cure all children from SAM. The proximity of the health posts to the patient's house, the occurrence of diarrhea, the kind of malnutrition, and the availability of amoxicillin were all associated with time to recovery. Comorbid diseases must also be properly treated in order to improve the cure rate. Health extension workers counsel the mother if the child is breastfeeding, offer breast milk on demand, and feed RUTF according to the guidelines, but need to follow up with the child to ensure the prescribed RUTF is consumed properly. Enhanced health education packages and community engagement could improve early recovery. Prospective studies quantifying the food security situation and RUTF-sharing practices could generate valuable evidence for targeted interventions. Therefore, the conclusions of the study may help current SAM treatments identify high-risk kids who have a bad prognosis and target them with additional care and therapies.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Addis Ababa Medical and Business College. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because it is secondary data review where informed consent was not applicable.

Author contributions

SY: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Writing – original draft, Writing – review & editing. TT: Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing. TN: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. BH: Conceptualization, Investigation, Methodology, Resources, Writing – review & editing. AK: Conceptualization, Investigation, Supervision, Validation, Writing – review & editing. AM: Investigation, Methodology, Resources, Validation, Writing – review & editing. DA: Data curation, Investigation, Resources, Software, Writing – review & editing. AO: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. KR: Conceptualization, Data curation, Investigation, Methodology, Resources, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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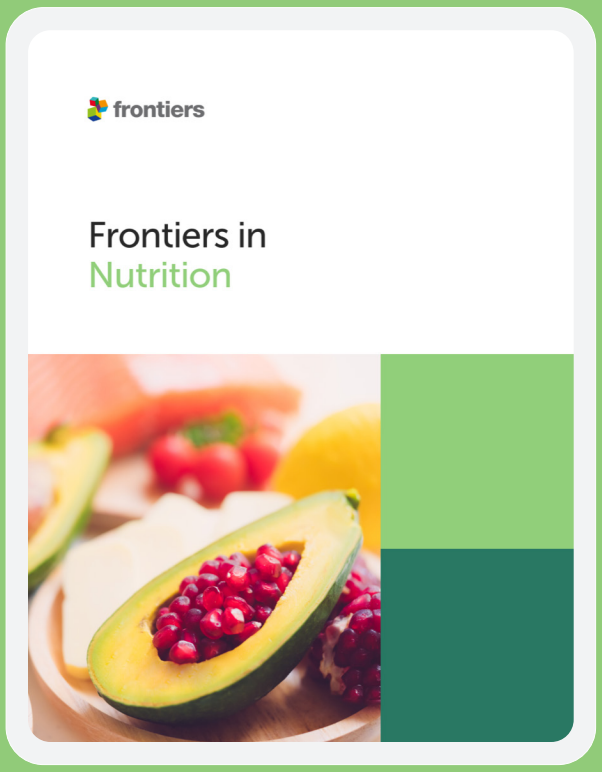

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