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Nutrition and sustainable development goal 4: Quality education

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Nutrition and sustainable development goal 4: Quality education

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Editorial: Nutrition and sustainable development goal 4: quality education

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Editorial on the Research Topic
Nutrition and sustainable development goal 4: quality education

Nutrition sits at the center of the sustainable development goals (SDGs) because of its multisectoral nature and multidimensional contribution. In addition to achieving "Zero Hunger" (SDG2), improvements in nutrition are critical to both achieve and reap the benefits of all the 17 SDGs. Good nutrition comes with improved health and wellbeing (SDG3), enhanced educational and work productivity (SDGs 4 and 8), less poverty (SDG1), and reduced inequalities (SDGs 5 and 10). On the other hand, improved food security and nutrition will result in stronger and more sustainable environment, communities, and technologies (SDGs 6, 7, 9, 11–17). This Evidence Research Topic, *Nutrition and sustainable development goal 4: quality education*, is part of an innovative collection showcasing nutrition in the context of the SDGs. The Research Topic provides up-to-date evidence on the role and impact of nutrition in relation to educational outcomes, as well as a selection of activities that have been utilized to promote education and capacity building for youth and health workers.

Nutrition education plays an important role in supporting the acquisition of knowledge, skills and behaviors needed for healthy and sustainable food behaviors. Food literacy is defined as "*the scaffolding that empowers individuals, households, communities or nations to protect diet quality through change and strengthen dietary resilience over time. It is composed of a collection of inter-related knowledge, skills and behaviors required to plan, manage, select, prepare and eat food to meet needs and determine intake*" [(1), p. 54]. In this Research Topic, Groufh-Jacobsen and Medin present *Food literacy competencies in youth—a mini-review*. This review concluded there is a lack of agreement about effective measurement of youth food literacy and that current tools to measure food literacy in youth are inadequate. The authors urge continued effort to achieve consensus on how to measure food literacy.

Nutrition education can be utilized to support positive behavior change. In the study by Wakwoya et al., positive outcomes of an intensive nutrition education and counseling program in pregnant women in East Shoa Zone, Ethiopia are described. The authors describe an educational program including counseling sessions, take-home brochures (in local language) and short text messages, and how this was effective in reducing

undernutrition and improving overall nutrition status among pregnant women. They propose this be part of regular antenatal care in this setting. Mekonnen et al., present an evaluation of a school-based pulse crop focused nutrition education strategy. Based on inadequate intake of protein-source foods, especially animal-origin foods, the authors evaluated effectiveness of pulses crop focused nutrition education in reducing thinness among school adolescent girls. The nutrition education did not significantly reduce magnitude of thinness, however, does provide an opportunity to consider further activities and that small, but positive changes in pulse crop consumption behavior may still occur.

It is important to understand the preferences of individuals when considering the development and delivery of nutrition education. Soam et al. highlights the importance of exploring dietary patterns to guide meal planning and preparation to reduce food waste. The authors assessed food preferences of individuals attending training programs at several higher education institutions in India, using a food and nutrition survey. The authors argue that there is a clear pattern in food preference modulated by age, gender, and region of residence/origin. Based on the findings the authors recommend on innovations in meal planning, based on preferences, to reduce food waste. In another study authored by Szczepanski et al., the authors explored 6th- and 10th-grade students' conceptions of the production of cow's milk to provide evidence for the development of effective teaching and learning opportunities. The study focused on the importance of students' conceptions to promote sustainable food production and consumption. It highlighted key factors that influence students' conceptualization and their significance while identifying varying degrees of maturity in students' conceptualizations. The authors recommend curriculum in the context of Education for Sustainable Development.

School is the common setting for formal educational activities. School food environments, school feeding programs, and/or nutrition education can impact school attendance, diet quality, nutritional status, and educational indicators. In the study by Mohammed et al., the authors report on the nutritional impact of the school feeding program in Ethiopia. The authors used BMI-for-age, measured by body mass index for age *z*-score (BAZ) and a food frequency questionnaire to develop a dietary diversity score. The authors recommend continued investment in the human capital development of children, and further studies to examine sustainability and long-term impact.

Education for sustainable development, economic growth, environment, and health has the potential to impact poverty and food and nutrition security, especially so in vulnerable children. Adeoya et al. outline a study that involved utilizing interactive teaching methods with grade 4 and 5 students to develop a disaster preparedness nutrition curriculum. The goal was the implementation of continuous nutrition education to empower children to make healthy food choices in daily life and reduce the risk of disaster-nutrition-related morbidity and mortality. In addition, Gajardo-Araya et al., describe how a higher level of general physical fitness, particularly cardiorespiratory fitness, plays an important role in mediating the influence of fatness on the academic achievement of Chilean adolescents. The authors conclude that physical fitness plays an important role in academic achievement and health and should be supported in educational settings.

Nutrition education and professional development for health professionals is important in moving toward achievement of SDG2, as these health cadres are often relied upon to deliver nutrition information. Fresán et al., discuss an example of assessing knowledge and attitudes regarding sustainable diets among health professionals in Spain. The authors identify the need for capacity building among Spanish health workers to promote healthy diets and call for greater efforts in training to build this capacity. This is similar to the findings from Ayande et al.'s study on the knowledge, attitudes, and practices of registered dietitians and nutritionists in Ghana, in the context of enteral and parenteral nutrition support. The authors found that there was limited training and exposure, impacting self-efficacy, and that there was a need to develop professional training programs for this audience.

The depth and diversity of the research included in this Research Topic highlights the value and potential of considering nutrition alongside Sustainable Development Goal 4: Quality education. It is clear that good nutrition can enhance academic outcomes, and that education is needed to enhance nutrition outcomes, underscoring the value of, and need to, consider these side-by-side. The evidence presented in this Research Topic highlights presence of gaps in terms of tools to measure food literacy and in our understanding of effective nutrition education, but that there are strategies that are being used successfully. For health workers, the need for nutrition literacy focused professional development programs has also been indicated to equip them for effective implementation of nutrition awareness activities.

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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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Physical fitness mediates the inverse association between fatness indicators and academic achievement, despite the school vulnerability of adolescents—The Cogni-Action Project

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Objective: This study aims to determine the mediating role of physical fitness in the relationship between fatness indicators and academic achievement, exploring the influence of school vulnerability.

Methods: A total of 1,296 Chilean adolescents (aged 10 to 14 years; 50% girls) participated in this study. The global fitness score (GFS) was obtained by adding the three main components of the ALPHA fitness test: cardiorespiratory fitness (CRF), muscular fitness (MF), and speed/agility fitness (SAF). CRF was evaluated through the 20 m shuttle run test; MF by upper and lower limb strength tests; and SAF by the 4 × 10 shuttle run test. BMIz and WHtR were evaluated as general (unspecific) and central (specific) fatness indicators. Academic achievement was established through grades in math, language, and science and their average scores. Multiple mediation analyses were performed according to two models, adjusted for sex, maturity, and schools (model 1), and in model 2, the school vulnerability index (SVI) was added. The SVI is an important proxy of socioeconomic status at the school level, and it was categorized as high-, mid-, or low-SVI. Mediation percentages were calculated, and confidence intervals (bootstrapping) were used to establish significant findings.

Results: CRF, SAF, and GFS mediate the relationship between fatness indicators and academic achievement, both partially and totally (ranging from 12.7 to 59.2%). However, MF did not show any mediation effect. After controlling for SVI, CRF, and GFS, mediation changed from partial to total

in the associations between math and science with WHtR. Although SAF contributed to GFS mediation, CRF seems to have the most significant mediation role for all academic achievements, regardless of SVI and the fat indicator studied.

Conclusion: A higher level of general physical fitness, especially CRF, significantly mediates the detrimental influence of fatness on the academic achievement of schoolchildren. This study suggests that physical fitness plays a relevant role in academic and public health, considering the high prevalence and detrimental influence of obesity and school vulnerability in children and adolescents.

KEYWORDS

mediating factor, exercise, abdominal obesity, poverty, socioeconomic factor

Introduction

The detrimental impact of obesity on a variety of metabolic and brain health indicators in childhood is being widely addressed (e.g., cardiometabolic disease, cognitive functioning, brain health) (1, 2), and, simultaneously, it has been related to other important collateral indicators, such as academic achievement (3). For instance, some studies have shown differences in gray and white matter brain regions according to children's weight status (4), which might affect their cognitive and, in turn, academic achievement (5–7).

In general, evidence has established the inverse relationship between fatness indicators and academic achievement (8–12). Most studies in this research discipline have evaluated fatness using body mass index (BMI), a valuable, easy, and fast method to determine nutritional status (13). However, this is a non-specific method related to fat distribution. The location of adiposity in the body (i.e., peripheral or central) is essential due to its impact on low-grade inflammation (14). In this sense, an indicator of central adiposities, such as the waist-to-height ratio (WHtR), is related to a higher level of inflammation markers, which, in turn, are associated with neurodegeneration and cognitive impairment (15, 16). Therefore, BMI and WHtR might differ in the way they are related to academic achievement. Indeed, a large-scale cross-sectional study of schoolchildren showed that WHtR was more closely related to academic achievement than BMI (14).

Promoting regular physical activity is essential to counteract the impact of fatness on health. This is a low-cost strategy that contributes to the control of childhood overweight and obesity and can improve several parameters of physical fitness, such as cardiorespiratory fitness (CRF), muscular fitness (MF), and speed-agility fitness (SAF), related to brain health and academic achievement (17–19). Regarding the latter, a recent systematic review concluded that adolescents with higher physical fitness levels (mainly CRF and MF) presented better academic achievement (20); however, findings in this field of study are heterogeneous, especially with MF (21) and SAF (22).

Mediation analysis plays a relevant role in finding a suitable statistical approach to study the relationship between fatness, fitness, and academic achievement, particularly the influence of fitness on this relationship. To date, some studies have shown that CRF, MF, and SAF positively mediate the inverse association between fatness and academic achievement (9, 23). However, as the socioeconomic status (SES) background of young people is a root problem linked to inequalities in health (24), brain development (25), and academic achievements (26), exploring the influence of SES background on future mediation approaches seems to be necessary for at least two key reasons. First, most studies adjust their analyses for confounding by SES (i.e., parental education, income, occupational class, and others); however, evidence shows that they are not interchangeable in social epidemiology. Thus, it is strongly recommended to use a more complex indicator of SES (27, 28), such as the school vulnerability index (SVI), a complex indicator involving several social factors based on Chilean school clusters. Second, by 2030, 63% of children worldwide will live in lower-middle-income countries, which presents growing economic difficulties, widening the educational gap between SES groups and nations (29). This way, data and evidence-based on regional contexts (a programmatic approach from UNICEF) are necessary to deal with this global learning crisis that prepares children and adolescents for life, work, and active citizenship.

Therefore, the present study aimed to determine the mediating role of several physical fitness variables in the association between fatness indicators and several academic achievements in adolescents, exploring the influence of school vulnerability.

Materials and methods

Study design

This study is part of the Cogni-Action Project (from March 2017 to October 2019), which establishes associations between physical fitness, physical activity, and sedentary life with academic achievement, cognitive performance, and brain structure and function in Chilean schoolchildren (30). This project was retrospectively registered (8/July/2020) with the Research Registry (ID: researchregistry5791) and was approved by the Ethics Committee of the Pontificia Universidad Católica de Valparaíso (BIOEPUCV-H103–2016). This study was prepared according to the STROBE guidelines for cross-sectional studies (31) and the AGReMA Statement for Reporting mediation analyses (32). Before participation, written consent was obtained from the school principal, parents, and participants.

Study population

The Cogni-Action Project collected information on 1,296 girls and boys (1:1) between 5th and 8th grade (aged 10–14 years) from public, subsidized, and private schools in Valparaiso, Chile. A total of 19 schools participated in the project. More information on the Cogni-Action Project is provided in Solis-Urra et al. (30). It is important to note that this project and study adhere to the definition of adolescence, which is established as a period between 10 and 24 years of age (33). The inclusion criteria for this project were schoolchildren from 5^{th} to 8^{th} grade, while exclusion criteria for this study were based on a lack of data for the following variables: body mass index Z-score (BMIz), WHtR, CRF, MF, SAF, GFS, math, language (Lang), science (Sci), academic achievement average (AAA), and SVI. Finally, a range of 920–951 school children was included based on the mediation analysis.

The total sample size and power calculations were based on the total enrolment of schoolchildren in the Valparaiso region (5th to 8th grades) indicated by the Chilean Ministry of Education in the year 2016 (universe N = 951,962). It was considered an alpha error of 5%, a confidence interval of 99%, heterogeneity of 50%, and a 20% dropout. Hence, a total of 797 participants was necessary to reach a representative sample size from the second most populated region in Chile.

Measurements

School children were evaluated at the school in two four-hour sessions, separated by eight days. Anthropometric measurements (body weight, height, and waist circumference) were evaluated in the first session, and physical fitness was assessed in the second session. Trained instructors from our research team evaluated all measurements. Academic achievement variables were obtained from each student's school.

Fatness indicators

The general and unspecific adiposity indicators (i.e., BMIz) were calculated using the World Health Organization's 2007 growth reference for school-aged children (34). Height was measured using a SECA 213 portable stadiometer (Hamburg, Germany), with the head in the Frankfort plane with a precision of 0.1 cm, and weight was measured with an OMRON (HN-289-LA, Kyoto, Japan) digital scale with a precision of 0.1 kg.

The central adiposity indicator (i.e., WHtR) was obtained by measuring the waist circumference with an inextensible tape (Lufkin, Apex, NC, USA) at the mid-axillary line, at the midpoint between the costal margin and the iliac crest. The result was divided by height to obtain the waist-to-height ratio (waist[cm]/height [cm]).

Physical fitness assessment

Cardiorespiratory fitness

CRF was evaluated through the 20-m shuttle run test (35). Briefly, children ran 20 m from one line to the next for an audio signal, and the intervals between audio signals were reduced each minute. The test ended when children were unable to reach the line twice or felt fatigued. As recommended, the number of completed stages and total time (in seconds) were registered (36). The total time (seconds) was based on age and sex to create a normalized Z-score CRF. Appropriate sportswear was suggested to perform this test, and it was held during the morning (between 9:30 and 12:00) in an indoor gym or sports field. The instructors gave verbal instructions about how to perform the test and a brief demonstration of the technique to ensure correct test execution. Adolescents could practice the test and begin when they felt confident.

Muscular fitness

MF was obtained after considering upper and lower limb strength. The maximum result of the handgrip strength test was used to determine upper limb strength using a dynamometer (Jamar Plus + Digital Hand Dynamometer, Sammons Preston, USA). The instrument allowed 0 to 90 kg measurements with a 0.1 kg precision and was adjusted to the schoolchildren's hand size. The procedure to evaluate it was to stand up with the elbow completely extended; the instrument should be pressed firmly with one hand and then with the opposite hand, two attempts per hand, and the maximum score would be registered. The score (kg) was divided by body weight to create a relative measure of this indicator.

A standing long jump test was used to assess lower limb strength. The test consists of standing behind a previously marked line. The instructors give a verbal signal, and the schoolchildren must jump as far as possible and use both feet. This test was performed twice, resting for at least one minute between them. The maximum score was registered in centimeters (cm). The MF score was calculated by adding the standardized *Z*-scores of both tests (adjusted for age and sex).

Speed, agility, fitness

Speed, Agility Fitness was evaluated using the 4 × 10 shuttle run test. Movement, agility, and coordination were involved in this test. The application of this test is obtained by demarcating two lines (five meters long) separated by 10 m; additionally, two cones were positioned on each line. Each participant was asked to run as fast as possible from the first line, pick up a piece of cloth located ∼50 cm after the first line, and carry it to the following line. Then they had to leave the cloth, pick up another one, and run to the opposite line. Each schoolchild had two chances to perform the test; the best performance was used, registered in seconds, and multiplied by −1. The SAF *Z*-score was adjusted for age and sex.

Global fitness score

The global fitness score (GFS) was obtained by calculating the three main components of the ALPHA fitness test (i.e., CRF, MF, and SAF) (35). Each component was standardized (*Z*-score), and all scores were adjusted for sex and age, with all three added. The procedure for each test is detailed as follows.

Academic achievement

According to the school records, academic achievement was established through three school subjects (i.e., Math, Lang, and Sci) at the end of the school year. In Chile, the grade scoring range is between 1 and 7 points, and the three subjects are the main subjects included in the Chilean education quality agency evaluation system (SIMCE) and the Programme for International Student Assessment (PISA) by the Organization for Economic Cooperation and Development (OECD). Grades are expressed on a national scale, ranging from 1 to 7. An average of these three subjects was also computed.

Confounders

In this study, we sought to reduce bias by adjusting the analyses to relevant confounders, such as sex, peak height velocity (PHV), participants' schools, and SVI. Sex is considered an important moderator in this discipline because visceral fat may affect girls more than boys (37). PHV is a maturity status indicator calculated by subtracting PHV age from chronological age (38). Thus, the maturity offset value is determined by the years of difference between them. Socioeconomic status is also a powerful predictor of various domains, such as academic and neurocognitive performance (39); however, in Latin American countries, a scholar indicator seems to be a better predictor of school achievement than a family SES factor (40). Therefore, we used the SVI, an indicator that measures the socioeconomic vulnerability of students in public/subsidized schools. It ranges from 0 to 100%, with the higher value implying a higher school's vulnerability. Private schools have a value of 0. SVI is calculated by the Chilean National Board of School Aid and Scholarships (JUNAEB) annually, and it integrates both personal and family indicators (educational level of parents-guardians, SES, students' health status, physical and emotional well-being, and the school's geographic location) (41). Finally, the participants' school was included as a confounder because we assume that each school has certain differences in grading its students.

Statistical analysis

Table 1 presents the participant characteristics as the mean and standard deviations (SD). The following parametric tests (independent t-student, correlations, and mediations) were used in this study according to the central limit theorem for sample sizes of over 500 participants (42). Simultaneously, a Q-Q plot (quantile-quantile plot) was used to check normality visually. A correlation matrix between fatness, fitness variables, and academic achievements was performed using Pearson's correlation (**Table 2**). In addition, multicollinearity was checked before performing mediation analyses (VIF ranged from 1.027 to 1.254), and due to the high rate of participation and representativeness, missing data were not imputed.

The mediation effect of fitness indicators on the association between BMIz and WHtR with academic achievements was analyzed using the PROCESS SPSS script (43) through linear regression analysis with bootstrapping (5,000 samples) (44). The theoretical approach and general mediation model are presented in **Figure 1**. The original four steps proposed originally by Baron and Kenny (45) were considered, step (1) the predictor must significantly predict the outcome variable; step (2) the predictor must significantly predict the mediator; step (3) the mediator must significantly predict the outcome variable, and step (4) the predictor variable must predict the outcome variable less strongly in equation c' than in equation c. Overall, mediation analysis was performed considering predictors (fatness: BMIz and WHtR), mediators (fitness: CRF, MF, SAF, or GFS), outcome (academic achievements: Math, Lang, Sci, and AAA), and two models (confounding). The general mediation model was structured as follows: equation (a) consisted of the predictor by the mediator; equation (b) was defined as a mediator by

TABLE 1 Participant characteristics by sex.

	All		Boys		Girls			
	N	Mean ± SD	*N*	Mean ± SD	*n*	Mean ± SD	*P*-value	Effect size
Age (years)	1,296	11.89 ± 1.19	648	11.83 ± 1.17	648	11.94 ± 1.21	0.089	0.09
Body Weight (kg)	1,280	50.90 ± 12.04	644	50.03 ± 12.23	636	51.79 ± 11.79	**0.009**	0.15
Height (cm)	1,280	153.04 ± 9.35	644	152.99 ± 10.43	636	153.09 ± 8.13	0.845	0.01
BMI (*Z*-score)	1,280	1.02 ± 1.07	644	1.05 ± 1.11	636	0.99 ± 1.02	0.315	0.06
WHtR	1,250	0.46 ± 0.06	628	0.46 ± 0.05	622	0.45 ± 0.05	< **0.001**	0.23
CRF (*Z*-score)	1,040	0.00 ± 1.00	526	0.00 ± 1.00	514	−0.00 ± 1.00	0.999	0.00
MF (*Z*-score)	1,049	0.03 ± 1.68	521	0.03 ± 1.73	528	0.02 ± 1.62	0.919	0.01
SA-F (*Z*-score)	1,052	0.00 ± 1.00	525	0.00 ± 1.00	527	0.00 ± 1.00	1.000	0.00
GFS	979	0.01 ± 3.10	490	0.01 ± 3.22	489	0.02 ± 2.99	0.951	0.00
Math (grade)	1,275	5.36 ± 0.96	641	5.31 ± 0.95	634	5.41 ± 0.96	0.067	0.10
Language (grade)	1,276	5.40 ± 0.79	641	5.27 ± 0.79	635	5.54 ± 0.77	< **0.001**	0.35
Science (grade)	1,274	5.45 ± 0.84	640	5.32 ± 0.83	634	5.58 ± 0.82	< **0.001**	0.31
AAA	1,276	5.40 ± 0.76	641	5.30 ± 0.75	635	5.51 ± 0.76	< **0.001**	0.28
PHV	1,280	−0.42 ± 1.27	644	−1.17 ± 1.00	636	0.35 ± 1.04	< **0.001**	1.49
SVI	1,296	55.11 ± 35.35	648	57.21 ± 34.17	648	53.02 ± 36.40	**0.033**	0.12

SD: standard deviation; BMI: body mass index; WHtR: waist-to-height ratio; CRF: cardiorespiratory fitness; MF: muscular fitness; SAF: speed-agility fitness; GFS: global fitness score; AAA: academic achievement average; PHV: peak height velocity; SVI: school vulnerability index. Bold values indicate statistical significance. Effect size: Cohen's d.

TABLE 2 Correlation matrix between fatness, fitness, and academic achievement variables.

	BMIz	WHtR	CRF	MF	SAF	GFS	Maths	Lang	Sci	AAA
WHtR	0.830***									
CRF	−0.344***	−0.357***								
MF	−0.458***	−0.517***	0.565***							
SAF	−0.217***	−0.257***	0.497***	0.559***						
GFS	−0.430***	−0.477***	0.790***	0.909***	0.787***					
Maths	−0.130***	−0.120***	0.196***	0.106***	0.107***	0.158***				
Lang	−0.102***	−0.122***	0.146***	0.059	0.022	0.085**	0.659***			
Sci	−0.093***	−0.109***	0.181***	0.105***	0.100**	0.148***	0.688**	0.656***		
AAA	−0.123***	−0.130***	0.198***	0.104***	0.086**	0.148***	0.900***	0.864***	0.883***	
SVI	0.121***	0.181***	−0.178***	−0.231***	−0.129***	−0.225***	−0.116***	−0.098***	−0.126***	−0.129***

BMIz: body mass index (*Z*-score); WHtR: waist-to-height ratio; CRF: cardiorespiratory fitness; MF: muscular fitness; SAF: speed-agility fitness; GFS: global fitness score; Maths; Lang: language; Sci: science; AAA: academic achievement average; SVI: school vulnerability index.
$^{**}p < 0.01$, $^{***}p < 0.001$ indicate statistical significance.

the outcome; equation (c) consisted of the predictor by the outcome; and finally, equation (c') consisted of the predictor and mediator by the outcome. Two models were performed to test our objectives: Model 1: adjusted for sex, PHV, and schools; and Model 2: adjusted for sex, PHV, schools, and SVI. The latter was established to explore the influence of SVI on the central model.

The indirect effects (equation a by equation b) and confidence interval (CI) were established to define a mediation effect (CI not including zero). The percentage of mediation was estimated as 1- (equation c'/equation c). A detailed set of findings (equation a, b, c, c',% mediation, and category) is presented as Supplementary material (**Supplementary Tables 1, 2**). The mediation was classified, according to Nitzl et al. (46), as (a) "indirect-only" (full mediation): the indirect effect only exists through the mediator, which means the indirect effect exists but has no direct effect; (b) "complementary" (Partial mediation): a portion of the effect of the predictor on the outcome variable is mediated through the mediator, whereas the predictor still explains a portion of the outcome variable that is independent of a mediator, which means that the indirect and direct effects exist and point in the same direction; (c) "Competitive" (Partial mediation): the same as the complementary classification, both the indirect and direct effects exist but point in different directions; (d) "direct-only" (no mediation): the direct effect exists, but there is no indirect effect, and (e) "no effect"

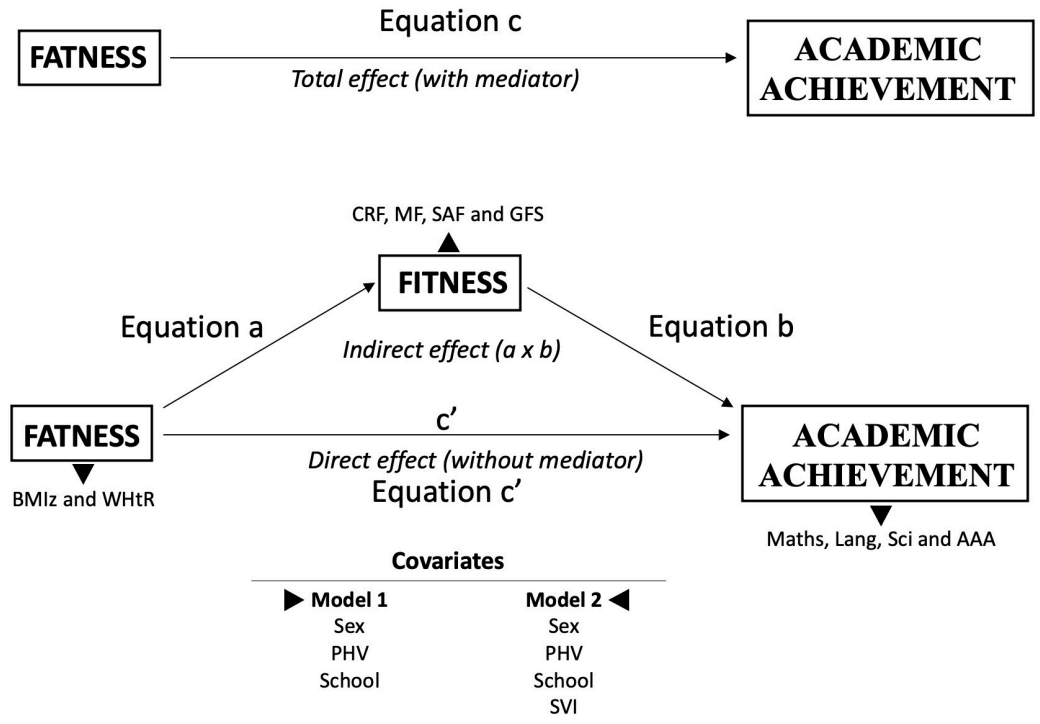

FIGURE 1
Theoretical approach and general mediation model. BMIz, body mass index (*Z*-score); WHtR, waist-to-height ratio; CRF, cardiorespiratory fitness; MF, muscular fitness; SAF: speed-agility fitness; GFS, global fitness score; sex; PHV, peak height velocity; school; SVI, school vulnerability index.

(no mediation): neither the direct nor indirect effect exists (47). For all analyses, the significance level was set at $p < 0.05$.

Results

The characteristics of participating adolescents and differences by sex are summarized in Table 1. Overall, significant differences between boys and girls were observed in body weight, PHV, WHtR, SVI, Lang, Sci, and AAA. However, no interaction by sex was observed (sex*fatness $p = 0.603$ and sex*fitness $p = 0.138$).

The correlation matrix between all study variables is presented in Table 2. Overall, fatness indicators were negatively correlated with fitness indicators. Academic achievement scores were positively associated with fitness indicators and negatively associated with fatness. Almost all correlations were statistically significant ($p < 0.05$), except for Lang, with MF and SAF ($p = 0.058$ and $p = 0.472$, respectively).

Table 3 shows a summary of all mediation analyses. Overall, it is possible to observe variations in each meditation percentage and some changes in the mediation classification according to models 1 and 2 (without/with SVI as a confounding factor, respectively).

Overall, a mediation role of CRF, SAF, and GFS is observed, but not of MF. Additionally, the SVI inclusion in the model (model 2) generates significant variations in the mediation percentage and classification.

In particular, the association between BMIz and math, CRF, SAF, and GFS presented "complementary" mediation (models 1 and 2). For Lang, only CRF showed a complementary mediation (models 1 and 2); no mediation was observed for MF, SAF, and GFS. For Sci, only SAF presents a "complementary" mediation (models 1 and 2). Finally, AAA, CRF, and GFS showed "complementary" mediation (models 1 and 2), but SAF lost its mediation role in model 2. In general, no mediation role was observed for MF, and the percentage of mediations ranged from 12.7 to 42.4%, where CRF was the strongest mediator between BMIz and academic achievements.

For the association between WHtR and math, CRF, SAF, and GFS presented "complementary" mediation in model 1; only SAF maintained its mediation after adjusting for SVI (model 2). For Lang, only CRF showed a complementary mediation (models 1 and 2); no mediation was observed for MF, SAF, and GFS (models 1 and 2). With Sci, both CRF and GFS presented an "indirect only" mediation (full mediation, even after adjusting to SVI), and SAF showed a "complementary" mediation role (models 1 and 2). Finally, AAA, CRF, and GFS showed "complementary" mediation

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TABLE 3 Findings summary concerning the direct and indirect effects according to both models. Percentage of mediation and classification.

		Maths	Language	Science	AAA
CRF	**BMIz**	**39.1%* → 38.4%* = Δ −0.7** Complementary → Complementary (n = 1,022)	**37.9%* → 37.2%* = Δ −0.7** Complementary → Complementary (n = 1,022)	**51.5% → 52.7% = Δ + 1.2** Direct Only → Direct Only (n = 1,021)	**42.4%* → 42.1%* = Δ −0.3** Complementary → Complementary (n = 1,022)
	WHtR	**46.7%* → 48.6%* = Δ + 1.8** Complementary → Indirect Only (n = 1,001)	**30.4%* → 30.2%* = Δ −0.2** Complementary → Complementary (n = 1,001)	**49.7%* → 53.5%* = Δ + 3.8** Complementary → Indirect Only (n = 1,000)	**42.7%* → 44.3%* = Δ + 1.6** Complementary → Complementary (n = 1,001)
MF	**BMIz**	**19.7% → 14.6% = Δ −5.2** Direct Only → Direct Only (n = 1,036)	**8.8% → 3.6% = Δ −5.2** Direct Only → Direct Only (n = 1,036)	**34.9%* → 29.7 = Δ −5.2** Indirect Only → No Effect (n = 1,034)	**21.8% → 16.4% = Δ −5.5** No Effect → Direct Only (n = 1,036)
	WHtR	**20.8% → 16.3% = Δ −4.5** Direct Only → Direct Only (n = 1,015)	**−0.8% → −6.3% = Δ + 5.5** Direct Only → Direct Only (n = 1,015)	**30.4% → 26.8% = Δ −3.6** Direct Only → No Effect (n = 1,013)	**17.8% → 12.8% = Δ −5.0** Direct Only → Direct Only (n = 1,015)
SAF	**BMIz**	**13.7%* → 12.7* = Δ −1.1** Complementary → Complementary (n = 1,032)	**1.6% → −0.3% = Δ −1.9** Direct Only → Direct Only (n = 1,032)	**18.7%* → 17.9%* = Δ −0.8** Complementary → Complementary (n = 1,030)	**11.3%* → 10.2% = Δ −1.2** Complementary → Direct Only (n = 1,032)
	WHtR	**15.6%* → 15.6%* = Δ 0.0** Complementary → Complementary (n = 1,011)	**−0.5% → −2.1% = Δ −1.6** Direct Only → Direct Only (n = 1,011)	**18.2%* → 18.7%* = Δ + 0.6** Complementary → Complementary (n = 1,009)	**10.8% → 10.1% = Δ −0.7** Direct Only → Direct Only (n = 1,011)
GFS	**BMIz**	**38.5%* → 35.4%* = Δ −3.2** Complementary → Complementary (n = 967)	**23.6% → 19.4% = Δ −4.2** Direct Only → Direct Only (n = 967)	**58.5% → 57.1% = Δ −1.5** Direct Only → Direct Only (n = 966)	**40.0%* → 36.7%* = Δ −3.3** Complementary → Complementary (n = 967)
	WHtR	**45.6%* → 45.4%* = Δ −0.1** Complementary → Indirect Only (n = 947)	**13.1% → 9.1% = Δ −4.0** Direct Only → Direct Only (n = 947)	**56.5%* → 59.2%* = Δ + 2.7** Indirect Only → Indirect Only (n = 946)	**38.1%* → 36.9%* = Δ −1.3** Complementary → Complementary (n = 947)

General scheme: Model 1 → Model 2 = Variation on mediation (%); Model 1: Adjusted to sex, PHV and school; Model 2: Adjusted model 1 + SVI. BMIz: body mass index SD; WHtR: waist-to-height ratio; CRF: cardiorespiratory fitness; MF: muscular fitness; SAF: speed-agility fitness; GFS: global fitness score; Math; Language; Science; AAA: academic achievement average. Mediation and non-mediation type: (a) "Complementary" (mediation): indirect and direct effect exists and points in the same direction; (b) "Competitive" (mediation): indirect and direct effect exists, but in opposite directions; (c) "Indirect-only" (mediation): indirect effect exists, but no direct effect; (e) "Direct-only" (non-mediation): direct effect exists, but no indirect effect; and (f) "No effect" (non-mediation): neither direct nor indirect effect exists.

(models 1 and 2). In general, no mediation role was observed for MF, and the percentage of mediations ranged from 15.6 to 59.2%, where CRF was the strongest mediator between WHtR and academic achievements. A complete description of all mediation indicators (equations a, b, c, and c', and others) is available as Supplementary material (**Supplementary Tables 1, 2**).

Discussion

This study aimed to determine the mediating role of fitness indicators (CRF, MF, SAF, and GFS) between two fatness indicators related to fat distribution (BMIz and WHtR) and main academic achievements at the national and international levels (math, language, science, and average), as well as to explore the influence of a strong SES factor, such as SVI.

The primary finding confirmed the significant mediating role of fitness in the relationship between fatness and academic achievement. The secondary results showed that (a) CRF, SAF, and GFS had a significant mediation role in the inverse association between fatness and academic achievement, but MF did not; (b) CRF seems to be the most relevant mediator; (c) differences between fatness indicators were observed, in which WHtR obtained the highest percentage of mediation by fitness indicators; and (d) SVI was able to significantly modify both percentages and mediation classifications.

Differences in fitness component mediations

Presently, the positive association between physical fitness and academic achievement is well established in the literature

(21, 48, 49). In this sense, the present findings confirm the evidence indicating that all fitness components (MF, CRF, and SAF) play a certain role in higher academic achievement (21, 48, 50) and that CRF seems to be associated more strongly with educational outcomes than with the other fitness components (49, 50). Indeed, our results align with mediation approaches evidencing the mediation role of CRF in reducing the negative association between fatness and academic achievement (9, 23). However, contrary to some evidence indicating that MF would positively correlate with academic achievement (50, 51), our findings did not display any MF mediation influence on academic achievement according to BMIz and WHtR predictors.

In particular, several studies have shown the short- and long-term effects of aerobic exercise and its physiological marker (CRF) on brain health indicators (i.e., cognitive performance, structural and functional brain activity, the release of brain-derived neurotrophic factor, mood, etc.) (52). However, there are few experimental studies on MF in children's brains, and the evidence is inconclusive (18). Thus, based on the current evidence, CRF may play a central role in this research area. Supporting this idea and the high degree of interdependence between fitness components, a study in overweight and obese children found that the significant association of MF and SAF with academic achievements weakened after controlling for CRF (50).

Transferring these findings to the educational and public health arenas, we have shown several interventions that have shown the positive impact that physical activity has on the academic achievement of schoolchildren (53, 54) and, likewise, on their cognitive performance (55). Moreover, considering the time children spend in schools, systematic and meta-analytic reviews showed that physical activity at school and physical education classes is positively associated with academic achievement, classroom behavior, and skills related to math and reading, among others (56, 57). Therefore, the recurrent strategy of reducing physical education class time to increase time for math and language subjects could negatively affect adolescent health and educational outcomes (58). Thus, it is recommended to maintain or increase an active lifestyle and, in particular, CRF in schoolchildren to improve factors contributing to academic achievement.

Differences in fatness indicators related to fat distribution

A key contribution of the present study is to have studied a general adiposity indicator (BMIz) and a central adiposity indicator (WHtR) to establish their differential association with academic achievement when mediated by physical fitness. Our findings showed that WHtR seems more sensitive than BMIz and is affected significantly by physical fitness indicators, mainly CRF. Thus, our results support the importance of studying fatness indicators related to its distribution because the mediation role of fitness would depend on them (14).

In this sense, our findings displayed a differential association between the two fat indicators analyzed in this study. This could be because BMIz is considered a surrogate and unspecific obesity marker (it does not differentiate between peripheral and central obesity), while WHtR seems more specific and more substantially related to inflammation and cognitive functioning (14, 16). The main rationale behind the above is that excess adiposity in childhood has been linked to higher low-level inflammation, which has been associated with the development of neurodegeneration in adulthood (16, 59). Thus, children and adolescents living with obesity have shown reduced gray matter in the prefrontal cortex, lower cognitive performance, and reduced academic achievement (2). Therefore, preventing fat storage in more specific zones related to higher inflammation markers throughout the body is crucial to promoting healthy development in childhood.

To achieve this goal, physical activity and improved physical fitness are fundamental. For instance, in children and adolescents with obesity, exercise is more effective than diet alone or in combination with diet and exercise to reduce visceral fat (60, 61). In turn, a cross-sectional and longitudinal analysis showed that children with or improving their CRF showed lower inflammation levels (high-sensitivity C-reactive protein), regardless of their body composition (62). In addition, a network meta-analysis showed that high-intensity interval training and aerobic exercise were the most effective strategies to reduce visceral fat compared to strength exercise (63). In this way, the mediation role of CRF, SAF, and GFS in this study could be related mainly to the influence or shared participation of CRF on these fitness components and the global indicator. The main reason for speculating this is that CRF has been deemed the primary predictor of maximal fat oxidation (64).

Exploring the influence of an school vulnerability index

A novel approach in this study was to explore a complex SES indicator related to adolescents' vulnerability in school and establish its implications in the relationship between fatness, fitness, and academic achievement. It is pertinent to carry out this type of methodology because most of the academic differences among schoolchildren can be explained by their social background (27, 65). Thus, including this SES variable in a second statistical model gives us an overview of a) the influence of SES on this set of mediation analyses and b) the relevance of fitness as a mediator if it keeps its statistical significance, even after controlling for SVI.

Overall, we found that SVI showed a differential influence according to the model analyzed, generating greater variation (percentages and classification mediations) in WHtR than BMIz. This scenario supports our study aim due to this statistical approach's higher specificity of WHtR than BMIz. In addition, it reinforces that both CRF and GFS play a relevant role regardless of adolescents' school vulnerability influence.

These findings become significant if we consider two main points. First is the high dependence of fatness, fitness, and academic achievement on SES (65–67). Second, the worldwide prevalence of fatness; the secular trend indicating a reduction in physical fitness in children and adolescents; the global concern for educational achievement in low- and middle-income countries; and the health, economic, and educational effects of the COVID-19 pandemic (68–70). In this sense, and addressing a close area linked to academic achievement, a recent study has shown that adolescents from schools with a high vulnerability index and a high fitness level present better cognitive performance than their unfit peers (41). In addition, this fit group had no statistical differences compared to their unfit peers from schools with a lower vulnerability index (41). Therefore, the present study supports the current literature in this field (14, 41), suggesting that having better physical fitness could act as a social protective factor related to bridging the gap at the academic level derived from school vulnerability. Experimental and longitudinal studies are needed to corroborate this assumption.

Limitations and strengths

The main limitation of the present study is its cross-sectional design, which reduces the possibility of determining causality among variables. In addition, fitness and fatness indicators were evaluated by field-based and indirect tests, respectively, which could increase methodological biases; nonetheless, it is feasible to implement these measurements in school settings. Finally, the academic evaluation depends on the school's increasing biases.

The main strengths are the large sample size of adolescents from a Latin American country and the inclusion of several fatness and fitness indicators, improving understanding in this research area. Moreover, we analyzed the three main subjects evaluated internationally (PISA). Finally, we explored the influence of a powerful SES indicator, such as the SVI, which allowed us to determine a novel finding concerning the mediator role of fitness, regardless of the adolescents' social background profile.

Conclusion

In conclusion, a higher level of global physical fitness, but mainly CRF, mediates the detrimental influence of fatness on adolescent academic achievement. This favorable influence was shown to be constant, even for a central fatness indicator such as WHtR and a critical socioeconomic factor. Indeed, our findings reinforce the relevant role of CRF and GFS, regardless of adolescents' school vulnerability influence. This is crucial at a public health level, considering the strong relationship between obesity and adolescent socioeconomic background. Thus, these findings become essential if we consider the current high rate of obesity, low educational and fitness performance in childhood, and the increasing poverty rate globally in low- to middle-income countries. Therefore, governments should create public policies that encourage physical activity, focusing on enhancing adolescents' physical fitness. Experimental and longitudinal studies in this research area are warranted.

Data availability statement

The datasets presented in this article are not readily available because of ethical restrictions. Requests to access the datasets should be directed to carlos.cristi.montero@gmail.com.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of the Pontificia Universidad Católica de Valparaíso (BIOEPUCV-H103–2016). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

CC-M contributed to the design of the project. CC-M and GG-A conceptualized the design of the study, analyzed the data, and wrote the concept version of the manuscript. SH-J, JO-A, GF, and PD-F critically reviewed the manuscript and edited the article. All authors have given final approval of the manuscript and agreed to be accountable for the accuracy and integrity of any part of the work.

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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.2022.904831/full#supplementary-material

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Effect of school feeding program on body mass index of primary school adolescents in Addis Ababa, Ethiopia: A prospective cohort study

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Background: Governments and developmental organizations are encouraged to devote adequate resources to the establishment of free school meals to low-income children in developing countries. In Ethiopia, the school feeding program (SFP) is implemented in a few regions including the capital, Addis Ababa. However, the nutritional benefit of the program was not monitored and reported thus far. In this study, we evaluated the effect of the SFP on the body mass index (BMI) of primary school adolescents in Addis Ababa, Central Ethiopia.

Method: A prospective cohort study was employed to collect data from 644 SFP-beneficiary adolescents (n = 322) and non-SFP (n = 322). Nutritional outcomes were measured following 6 months of follow-up. WHO Anthroplus were used to convert anthropometric data into body-mass-index-for-age Z scores. The independent effect of school feeding is analyzed through a multivariable linear regression model.

Result: In linear regression, unadjusted model (Model 1), compared with the non-school-fed adolescents, the mean difference in difference of BAZ-score of school-fed adolescent was higher by 0.36 (β 0.36, 95% CI 0.17, 0.55). The beta coefficient remained positive after adjusted for age and sex (Model 2: β 0.35, 95% CI 0.16, 0.54) and sociodemographic variable (Model 3: β 0.35, 95% CI 0.16, 0.54). In the final model, adjusted for model four, lifestyle and health status there was a significant difference in favor of school-fed adolescents on BAZ-score indices (Model 4: β 0.4, 95% CI 0.18–0.62). On the contrary, for a unit increase in family size, the BAZ score will decrease by 0.06 (β 0.06, 95% CI −0.12–−0.01). Similarly, adolescents with a middle tertile wealth index decreased their BAZ score by 0.30 (β 0.30, 95% CI −0.55–−0.05) as compared to the higher tertile wealth index.

Conclusion: School feeding was positively associated with a change in BAZ score whereas family size and middle tertile wealth index were negatively associated. This implies that school feeding can serve as an optimal strategy for addressing the nutrition needs of adolescents.

KEYWORDS

school feeding program, body mass index, adolescents, BAZ, school

Introduction

According to UNICEF, adolescence encompasses children of age group between 10 and 19 years (1). The Global estimate of the adolescent population is 1.2 billion (16 percent of the total population), while the sub-Saharan African region is known to have the greatest proportion (23%). In Ethiopia, about a quarter of the general population is estimated to be adolescents (2, 3). Adolescence is the second rapid growth period and psychosocial development which can determine the upcoming adult health conditions (4). Unmet nutritional requirements sub-optimal dietary diversity and inadequacies are the major threats during this period. Moreover, psychosocial factors play a major role in adolescent health and dietary decisions (5–7).

Stunting or wasting are affecting more than 200 million children in low- and middle-income countries (8). Likewise, as many almost twice suffer from essential micronutrient deficiencies. On the other hand, the number of overweight and obese children is on the rise, bringing a dual burden of malnutrition on the frail health care system (9). In East and Central Africa, nearly one-third of all boys were underweight while the corresponding figure for girls ranged from 15.52 percent in Rwanda to 22 percent in Ethiopia (8). According to the global burden of disease recent estimate, in Ethiopia, protein-energy malnutrition prevalence among adolescents aged 10 to 14 and 15 to 19 was 33 and 38% respectively (10).

Child health, growth, and development are outcomes of direct and indirect linked multi-layered factors (2). The UNICEF global conceptual framework depicts the causes of malnutrition in terms of immediate, underlying, and enabling. The immediate determinants are diets and health, which also influence each other. In the adolescent context, their mental wellbeing also plays a significant influence on their dietary intake and physical activity. Mental health conditions may affect mood and desire to eat, disrupt the ability to digest food or absorb nutrients, and cause a person to neglect their wellbeing and forget to eat (11, 12).

The underlying determinants are the food practices, and services available to children and women in their communities. The last enabling determinants are the financial, political, cultural, social, and environmental conditions (13).

There exist a wide array of interest by several global organizations including WHO, FAO, and UNICEF in addressing the nutrition need of adolescents where schools were used as an optimal setting for interventions (1, 14, 15). Several interventions focused on promoting nutrition education, provision of food, improving quality of diets in schools and beyond, promoting healthy food environments, promoting healthy dietary practices, providing micronutrient supplementation, promotion of exercise, and deworming are known to have been delivered in the school environment (1).

School feeding programs are kind of interventions designed to provide good quality nutrient foods to children and adolescents attending school (16, 17). It is a component of national social protection systems for many countries including those with a low prevalence of undernutrition (17). Most countries had some form of a school feeding program for adolescents like daily snacks or meals (18). However, the design and implementation modality of school feeding varies significantly (19). Novel approaches, such as school farming for school feeding, agroforestry projects relating to school feeding, home grew school feeding have been receiving attention (20, 21). The nutritional benefits of the school feeding program were also anticipated to serve as a tool to improve the educational capabilities of children (22). Alleviating hunger, reducing malnutrition, Improving school attendance and enrollment, improving academic and cognitive achievements, and contributing educational gender equity are reported benefits of school feeding (23–25).

Poverty eradication, nutrition, health, and education, continue to be pillars of sustainable development. holistic school meal programs can make an adequate, sustainable positive impact on these determinants of development through various pathways (26). The National School Health and the Nutrition Strategy and National Nutrition Program of Ethiopia have identified a key nutrition-sensitive intervention by promotion of home-grown SFP to combat malnutrition (27). World Food Program-funded SFP was began in Ethiopia in 1994 (28). Later, in 2016 drought-affected areas were involved to address more than a million children in the program while in 2020 the SFP expand to some urban cities including Addis Ababa (26, 27). Addis Ababa City government provides a school feeding program for about three hundred thousand students aiming at

reducing absenteeism and increasing enrollment among school children (29).

Although the school feeding program is initiated in some parts of Ethiopia, the extent of its nutritional benefit among adolescents was not explored enough thus far. In this we hypothesized that school fed children will have improved nutritional status as compared to non-school fed children. Hence, this study was designed to investigate the effect of school feeding on the body-mass-index for z-score of primary school adolescents.

Methods and materials

Study area

A prospective cohort study design was conducted among primary school adolescents' in Addis Ababa and Adama, Central Ethiopia. Addis Ababa is the capital city of Ethiopia with great diversity, and homes of almost all ethnicities found in the country. According to the 2018 report of the Addis Ababa City Government Educational Bureau, there are 806 primary schools. In all these schools, there are a total of 504,205 students. Of the total number of schools, 223 (27.66%) are governmental and 583 (72.33%) are private (30). Adama town, central Ethiopia, is found 99 km southeast of Addis Ababa. According to ACAEO statistics records in Adama, there are 11 governmental, 3 public, 6 religious, and 13 local private schools. According to the Adama city administration office, the total number of primary school students are 38,503 (31).

Populations

Adolescents aged between 10 and 19 in Addis Ababa and Adama enrolled in the primary school for the 2020/2021 academic years who were attending their regular classes were included. Addis Ababa (Exposed group) and Adama (Unexposed group) are two neighboring cities that are found in the central part of Ethiopia. The school feeding program schools (Exposed group) are given to all the government primary schools found in Addis Ababa and it was considered our source population. The Non-school feeding program schools (unexposed group) were taken from the neighboring town, Adama. Regarding the characterization of exposed and unexposed, we have been going through an independent *t*-test to check sociodemographic characteristics and it is insignificant which shows the two groups have similar sociodemographic characteristics.

Sample size determination

The sample size was calculated using G*Power 3.1 program (32) assuming that the primary outcomes would be compared within the two groups using a one-tailed mean difference test. The sample size was calculated with a 95% confidence level, 80% power, medium effect size (d = 0·4), one-to-one allocation ratio between the two groups, and design effect of 2. Further, 5% compensation for possible dropout was added. Ultimately, the sample size of 676 (338 SFP beneficiaries and 338 non-beneficiaries) was determined (33).

Sampling technique and procedures

A stratified multi-stage sampling procedure was employed to select the study units. In the two cities, there are 223 governmental primary schools in Addis Ababa and 11 in Adama. Sixty-seven and three governmental primary schools were selected by simple random sampling from Addis Ababa and Adama respectively. The total sample size was allocated for each selected primary school proportionally to the number of students within each SFP beneficiaries in Addis Ababa and Non-SFP beneficiaries in Adama primary schools. Finally, study participants were selected by a simple random sampling method from a student list of each section.

Measurement

Anthropometric measurements

Body weight was measured on an electronic digital scale to the nearest 0.1 kg with minimum clothing and baring foot. and height was measured using a measuring instrument (Stadiometer, CE 0123, Germany,) to the nearest 0.1 cm by looking straight ahead with Frankfurt plane horizontal, shoulders relaxed, arms at sides, legs straight and knees together feet flat and with heels almost together. The shoulder blades, buttocks, and heels touch the measurement board. WHO recommend BMI-for-age to assess thinness/wasting in registered school-aged children. Overweight ($>+1$SD BMI-for-age z score), obesity ($>+2$SD BMI-for-age z score), thinness/ wasting (<-2SD of BMI-for-age z score), stunting (<-2SD of height-for-age (HAZ) z score) were defined according to the WHO references (34, 35).

DDS

Food frequency questionnaire containing 28 food items was used to assess dietary diversity score that are commonly consumed in the study area. Wide-ranging interview of key informants from the study area who knew the culture and language were used to develop the list of food items. The food frequency questionnaire was refined based on the result of the pretest on 14 adolescents' responses by observing patterns of week days of common food consumption. Cronbach's alpha result was 0.79 during the pretest. Adolescents were considered as "consumers" of a food item if they had consumed the food item at least once per week. As there is no Ethiopian

classification of food groups, the 28 food items of the food frequency questionnaire were grouped into nine groups (36). For instance, an adolescent who consumed one item from each of the food groups at least once during the week would have a maximum DDS of 9, and those who did not consume per week scored 0 for all food groups (37).

Physical inactivity

WHO Global Physical Activity Questionnaire (GPAQ) (38) was used to assess the physical activity and sedentary behavior of adolescents. The questionnaire includes items that require participants to indicate the kinds of physical activities that they do as part of their daily activities. The participants were asked on the time spent being physically active in the last 7 days, based on work-related activities, yard work, domestic chores, and activities related to commuting from one place to another, and those undertaken in exercise, sport, or during pastime. The study subject was also asked to think about all the vigorous and moderate activities that they did in the last 7 days. Vigorous physical activities were those that require hard physical effort and make participants breathe much harder than normal. Moderate activities were those that demand moderate physical effort and make them breathe somewhat harder than usual, while low physical activities were those involving walking and being sedentary at least 7 times a week for a minimum of 10 min. In the GPAQ only sessions which lasted 10 min or more were analyzed. All types of physical activities related to occupation, transportation, household chores, and leisure time were also included. Based on the GPAQ scores, their physical activity levels were categorized as follows: Low = METs scores of <500, Moderate = METs scores of between 500 and 1,499 and Vigorous = METs>1500.

Mental health

Mental health status (common mental disorders) were assessed using Self-Reporting Questionnaire (SRQ-20). The SRQ is a 20-item with yes/no answers that measure psychiatric symptomatology which developed by the World Health Organization (39, 40). The SRQ includes both somatic items (e.g., headaches, loss of appetite) and psychological items (e.g., feeling unhappy, nervous, and worthless). It is implemented throughout low-and middle-income countries, including Ethiopia and many other African settings (40–43).

Difference-in-differences estimation

We used difference-in-difference (DiD) estimators to compares the changes in outcomes from baseline to end line in SFP and non-SFP:

$$\Delta DID = E[(Y_1^T - Y_0^T) - (Y_1^C - Y_0{}^C)]$$

TABLE 1 Demographic and socio-economic characteristics of a cohort of primary school adolescents at baseline in Addis Ababa and Adama, Central Ethiopia in 2020/2021.

Variables	SFP	Non-SFP	*P*-value
Mean (SD) age in year	14.9 (1.86)	15.04 (1.67)	0.33
Mean (SD) family size	5.47 (1.57)	5.59 (1.77)	0.34
Sex (%)			
Male	166 (51.6)	160 (49.7)	0.63
Female	156 (48.4)	162 (50.3)	
Wealth index (%)			
Low	135 (41.9)	134 (41.6)	0.73
Middle	108 (33.5)	101 (31.4)	
Higher	79 (24.5)	87 (27.0)	
Household head (%)			
Male	241 (74.8)	244 (75.8)	0.78
Female	81 (25.2)	78 (24.2)	
Paternal education (%)			
Formal education	261 (81.1)	246 (76.4)	0.15
No formal education	61 (18.9)	76 (23.6)	
Maternal education (%)			
Formal education	187 (58.1)	183 (56.8)	0.75
No formal education	135 (41.9)	139 (43.2)	
Paternal occupation (%)			
Employed	181 (56.2%)	175 (54.3%)	0.63
Unemployed	141 (43.8%)	147 (45.7%)	
Maternal occupation (%)			
Employed	117 (36.3%)	111 (34.5%)	0.62
Unemployed	205 (63.7%)	211 (65.5%)	

Chi-square, independent t-test.

where Y_0 and Y_1 denote outcomes at baseline and end line respectively, and T and C denote treatment (SFP) and control (non-SFP).

Formally, our DiD specification is

$$Yivt = \beta 0 + \beta 1 SF + \beta 2^{*} Round2 + \beta 3^{*} SF^{*} Round2 + \gamma X + + \sum \delta v V + \varepsilon ivt$$

Where Yivt is the outcome for adolescent i in group v at time t

Round 2 is a time dummy/ follow-up survey

SF is a school feeding/ treatment indicator

SF*Round 2 is school feeding*time interaction

β3 is DiD estimate

X represents sociodemographic characteristics

V stands for the set of dummy variables for both groups.

εivt is the error term.

TABLE 2 Differences in differences between baseline and end-line measurements of anthropometric indices among school feeding and non-school feeding groups of adolescents in Addis Ababa and Adama, Central Ethiopia, 2020/2021.

	School feeding program			Non-school feeding program			DID (SFP—Non-SFP) Mean (SE)	*P*
	Baseline Mean (SD)	End-line Mean (SD)	Difference (EL-BL)1 Mean (SD)	Baseline Mean (SD)	End-line Mean (SD)	Difference (EL-BL)1 Mean (SD)		
Height	146.5 (7.61)	148.7 (7.62)	2.13 (1.72)	145.9 (8.14)	146.7 (8.18)	0.81 (6.18)	1.31 (0.31)	<0.001
Weight	39.35 (6.04)	43.57 (7.03)	4.22 (6.72)	39.70 (6.62)	41.17 (7.01)	1.46 (2.60)	2.75 (0.40)	<0.001
BAZ	−0.62 (1.32)	−0.01 (1.10)	0.60 (1.33)	−0.88 (1.39)	−0.62 (1.44)	0.24 (1.09)	0.36 (0.09)	<0.001

EL, End-line mean; BL, Baseline mean; DID, Difference in difference (mean difference of SFP—mean difference of Non-SFP); SD, Standard deviation; SE, Standard error.

TABLE 3 Multivariable linear regression models predicting mean baseline to end line differences of the differences in BAZ score among school feeding and non-school feeding groups of adolescents in Addis Ababa and Adama, Central Ethiopia, 2020/2021.

Model	β (95% CI) in Z score	Covariates
Model 1	0.36 (0.17, 0.55)***	Unadjusted
Model 2	0.35 (0.16, 0.54)***	Model 1 adjusted Sex, age
Model 3	0.35 (0.16, 0.54)***	Sex, age, family size, wealth index, household head, paternal work, maternal work, paternal education, maternal education
Model 4 (fully adjusted model)	0.40 (0.18, 0.62)***	Sex, age, family size, wealth index, household head, paternal work, maternal work, paternal education, maternal education, dietary diversity, work other than being a student at least for 1 h, physical inactivity, time spend on television, computer, and social media and mental health

*Significant at $P < 0.05$, **Significant at $P < 0.01$, ***Significant at $P < 0.001$, all β-coefficients (95% CI), were from multiple linear regression analysis, and related to the non-exposed groups.
Model 1, Unadjusted; Model 2, biological factors; Model 3, Biological & sociodemographic factors; Model 4, Biological & sociodemographic factors, health and lifestyle factors (fully adjusted).

Analysis

The data were doubly entered into Epi-Data version 3.1 and checked using a side-by-side comparison to check clerical errors. Then the data were exported to SPSS for windows version 24 to check for missing values and outliers, and for further analysis. Principal Component Analysis was performed to generate a household wealth index—a composite index of living standards based on multiple variables including materials used for house building, access to a drinking water source and sanitation facilities, ownership of livestock, house, and agricultural land. A varimax rotation was applied and the Kaiser–Meyer–Olkin measure of sampling adequacy was acceptable (0·64), and Bartlett's test of sphericity was significant. The variables that had communality scores >50% were retained in the analysis. The factor with the highest eigenvalue was taken and then divided into three equal tertiles: poor, middle, and rich. Descriptive analyses were carried out to generate means and proportions and compared them by BAZ score using Chi-square tests.

The Z score values for height-for-age, weight-for-age, and BMI-for-age were calculated using the WHO Anthroplus 2007 reference. As there were baseline differences in some variables between exposed and unexposed groups, the difference in differences was employed in all analyses for comparison of the exposed and unexposed to determine the effectiveness of the school feeding program on BMI Z-score changes. The Difference in Difference (DID) linear regression was performed to assess the effect of the SFP on BMI for age z-score, and the assumptions of the model (normality and homoscedasticity of error terms and linearity of relationship) were assessed using partial plots and found to be satisfied. In all multivariable models, the absence of multi-collinearity was evaluated using the variance inflation factor and found to be within the acceptable range (variance inflation factor < 10).

Result

Out of the 676 study participants, 663 adolescents completed the questionnaires at baseline and additional 19 students were not included due to dropping out at the end line. We excluded a total of 32 adolescents (An equal number from both exposed and unexposed at random) who were not found in the school. A total of 644 adolescents aged 10–19 years old were enrolled in 78 selected primary schools. Of these, 322 were from the SFP beneficiary group whereas 322 were from the non-SFP beneficiary group and the response rate was 95%. Nearly, 50% of the respondents in non-school feeding and 48% in the school feeding adolescents were female. The mean (SD) age of school feeding and non-school-feeding adolescents were 14.9 (1.86)

and 15.04 (1.67) respectively. Similarly, the mean (SD) family size of respondents for school feeding was 5.47 (1.57) and for non-school feeding, adolescents were 5.59(1.77) (Table 1).

The coefficient on the BAZ score is positive and statistically significant. These results indicate that there is a relationship between school feeding program participation and adolescent BAZ-score based on observable and time-invariant characteristics. In Table 2, a comparison of anthropometric indices based on exposure status at baseline and end-line was made and the differences in the differences between the baseline and end-line values were compared. The results showed that there was a significant difference in differences in anthropometric indices. The school feeding program had a high difference of differences in height, weight, and BAZ. The mean difference of differences was higher in the school feeding group by 1.31 cm ($p < 0.001$) for height, 2.75 kg ($p < 0.001$) for weight, and 0.36 Z-score ($p < 0.001$) for BAZ (Table 2).

In linear regression, unadjusted model (Model 1), compared with the non-school-fed adolescents, the mean difference in difference of BAZ-score of school-fed adolescent was higher by 0.36 (β 0.36, 95% CI 0.17, 0.55). The beta coefficient remained positive after adjusted for age and sex (Model 2: β 0.35, 95% CI 0.16, 0.54) and sociodemographic variable (Model 3: β 0.35, 95% CI 0.16, 0.54). In the final model, adjusted for model four, lifestyle and health status there was a significant difference in favor of school-fed adolescents on BAZ-score indices (Model 4: β 0.4, 95% CI 0.18–0.62) (Table 3).

On the contrary, for a unit increase in family size the BAZ score will decrease by 0.06 (β 0.06, 95% CI −0.12–−0.01). Similarly, adolescents with a middle tertile wealth index were decrease BAZ score by 0.30 (β 0.30, 95% CI −0.55–−0.05) as compared to the higher tertile wealth index.

Discussion

In this study, the nutritional impact of school feeding was examined by measuring the difference in difference (DID) of the BAZ score of adolescents. In crude comparisons, the findings of the study indicated that the intervention group has a significantly positive impact on the nutritional status of school adolescents. Furthermore, adjusted for all possible covariates, the SF program was found to have a statistically significant positive effect on adolescents' BAZ scores with a coefficient of 0.40. Our finding is in line with a systematic review of randomized controlled trials (RCTs) done in low and middle-income countries that showed a small but significant effect of school meals on weight gain among adolescents (44). Furthermore, a study done in Bangladesh reported that the average BMI of SFP participating students is 0.62 points higher than the average BMI of enrolled children in the control area (45). Cole also suggested the positive impact of the school feeding program on BAZ scores in Lao People's Democratic Republic (46). Similarly, earlier observational studies conducted in Ethiopia (47, 48) in Addis Ababa and Sidamo, reported improvement in BAZ scores following the school feeding program.

On the contrary, there existed other studies which reported the null effect of school feeding programs on Nutritional benefits in Africa (49, 50). One of the key elements which could have a substantial influence on the effectiveness of the SF program was the delivery modality of the SF program. For example, a study from Burkina Faso reported no effect of school meal programs carried out in the form of take-home ration (THR) rather than in school feeding (49). It is plausible to attribute the failure of the THR program to food sharing among household members, compromising its impact on BAZ of school-aged children. In the study conducted in Uganda, the nutritional status did not differ significantly between children who take porridge at mid-morning break and those who do not (50). This study may indicate simple calorie supplements may not be good enough in realizing anthropometric changes. Additionally, the parents of school-fed adolescents reduce the food portion size at home in the sense that they fed at school. Similarly, it may be due to the high level of poverty in the community selected to take SFP. Moreover, the report by the Ghana school feeding program indicated that the SFP faces challenges like the inconsistent release of funds which makes feeding irregular, and loss of meeting the RDA for macro-nutrient (51, 52).

In the midst of these contrasting observations, the available evidence supports the use of school environment can be used to improve the dietary habits of children. For example, the report of systematic review and meta-analyses of RCTs reported that primary school nutrition interventions implemented in Asia are effective in decreasing BMI and BAZ among school-aged children (53). A healthy school food environment has the potential to play an important role in controlling a BMI since it could influence students' diet (54, 55) and diet is a key factor in determining and reducing overweight and obesity (56). These observations can justify the use of school in obesity prevention programs.

On the contrary, for a unit increase in family size the BAZ score will decrease by 0.06 (β 0.06, 95% CI −0.12–−0.01). Similarly, adolescents with a middle tertile wealth index were decrease BAZ score by 0.30 (β 0.30, 95% CI −0.55–−0.05) as compared to the higher tertile wealth index.

Strength and limitation

The strength of this study was applying a 6-month prospective cohort study to show the cause and the effect relation of school feeding programs on BAZ score. Even though we have tried to control for potential confounders in our study there may be residual confounders from unmeasured

variables. Furthermore, small sample size could be considered as a limitation.

Conclusions

School feeding was positively associated with a change in BAZ score whereas family size and middle tertile wealth index were negatively associated. This implies that school feeding can serve as an optimal strategy for addressing the nutrition needs of adolescents.

Recommendation

As human capital development of children is vital for a country in many ways, investing in it has proven to help children achieve their best as well as create productivity, stability, and improve resilience in communities. The Government of Ethiopia devotes significant funding to sustain the program.

These program require multisector involvement, strong institutional resource management, capacity building, and linkages with non-governmental fund-raising organizations (World Bank, WFP, FAO).

Finally, it is important to point out the need for a further RCT study which addresses the sustainability and potential long-term impacts of the program for a better policy implication.

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 ethical approval and clearance were obtained from the Jimma University, Institute of Health, Institutional Review Board with a reference number of IRB/261/2020. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

BM, KA, TB, and SK designed and supervised the study and ensured quality of the data and made a substantial contribution to the local implementation of the study and assisted in the analysis and interpretation of the data. BM did the analysis and drafted the manuscript and had the responsibility to submit the manuscript for publication. All authors critically reviewed 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.

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Factors influencing dietary patterns among the youth from higher educational institutions in India

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Purpose: To determine the factors influencing the dietary habits of the varied groups among adults in India.

Design/approach: Data on food habits such as choice of diet, preference toward meat, spicy food, sugar/calorie etc., were collected from the participants (from several higher education institutions) of different training programmes and events organised at ICAR-NAARM, Hyderabad and its students of Post Graduate Diploma in Agribusiness Management.

Findings: Results of the study indicated that the food choice of the respondents is highly influenced by their region, age and gender. Most of the respondents preferred vegetarian food with increasing age. We also noticed that as age of the respondents increased, their preference toward simple & plain food (with less oil/spice) also increased. From the present investigation, it is recommended that the customized food menu should be prepared in every food serving institution based on the region, age and gender of the consumer.

Novelty: Analysis of dietary patterns can be helpful for doctors, dieticians, food policy-making, restaurateurs, youth hostels, food organisations, mega kitchens etc. that would also contribute to responsible food consumption.

KEYWORDS

dietary behavior, customised meal, responsible food consumption, multivariate logistic regression, educational institutes, SDGs

1. Introduction

Over the past few decades, people's food preferences and dietary habits have shifted dramatically. People decide what to eat based on various criteria, scientifically defined as a "Diet." The Analysis of dietary habits gives a more comprehensive impression of the food consumption habits within a population (1). Dietary pattern analysis, which summarises the entire diet, the foods, food categories, and nutrients contained, their combination and diversity, and the frequency and amount with which they are routinely ingested, has therefore been the focus of modern nutritional epidemiology investigations (2). For many individuals, the standard description of a food's "taste" includes the chemical senses of style and olfaction (capacity of smelling) on which a person or group lives (3).

It is well known that people from different part of the country have different tastes for food. One of the explanations for various food preferences is that we have different experiences with food as we get older. Except for the formerly mentioned natural factors, most of our food preferences are learned through gests, and there are numerous ways of learning regarding food (4). It has been shown that with at first unlikeable food, intermittent exposure to new foods may increase feeling for that individual food (5). It is also systematically examined how different sugar statement forms influenced people's perceptions of food categories (i.e., yoghurts, ice creams, cookies, and breakfast cereals) (6).

There is a growing interest in the analysis of dietary patterns of people for sustainable environmental development as the food habits of any individual is intrinsically connected to the human-food-environment chain. Good dietary habits may lead to a healthier life and longevity. Otherwise, it leads to unnecessary fat accumulation and severe health issues that negatively impact human health. A study on consent feeding revealed that people with high body fat percentages are highly vulnerable to impulsive dietary choices when compared with people with low body fat percentage people. This also increases the risk of obesity over time (7). Therefore, interventions in food taste regulations could help alter peoples' evaluating of their food preferences, ultimately reducing the consumption of unhealthy foods (8). Nevertheless, following or adopting plant-based food with minimum consumption of meat products would also help contribute to environmental security through climate mitigation. Minimizing meat consumption and increasing healthy foods like vegetables and seafood helps reduce the Greenhouse Gases (GHGs) emission from the food production process besides meeting people's health needs (9). The present work realises its significance because Indian food processing industries account for 32% of the country's food market (10). Contrary to this belief, we must realise that 71% of the total Indian population self-identifies as non-vegetarian, though 39% eat non-veg occasionally, and 26% eat at least once a week (11). The United Nations Environment Programme (UNEP) (12) report brings out some fantastic facts: (i) The end consumer share of food waste share is about 61%, (ii) about 8–10% of GHGs emissions are associated with food that is not consumed.

Higher education institutions and academies conduct various learning programs and trainings for which participants from different parts of the country are being invited. During the program, different types of food is being served to the participants based on the availability of ingredients in local market. Most of the times, many participants may not like food which is served during their stay at program venues. As a result, there will be huge wastage of food due to the dietary pattern of the participants as their region, age, gender etc. are highly influences the food consumption patterns. Day by day, food wastage reduction is becoming serious challenge for the administrators of the higher educational institutions. Changes in the food consumption pattern and planning the food menu based on the people's preferences would significantly help in minimizing the food wastage. Nevertheless, food wastage is becoming a serious issue in the world. About 1.3 billion tonnes of food waste is produced yearly, approximately 1/3rd of global food production (13). As per the data of FAOSTAT, there is about 20.7% per capita food loss (**Figure 1**) in Central and South Asia. Therefore, United Nations' sustainable development goal (SDG) 12.3 has set a target to halve the per capita global food waste and reduce food losses by 2030 (14). India is also holding many mega kitchens (Ex: Dharmasthala in Karnataka; Shirdi in Maharashtra; Golden Temple in Amritsar; Jagannath Temple in Puri; Kalinga Institute Kitchen Bhubaneswar) which serves the food for large number of people daily and also generates food wastage in large amount. Thus, it is the need of the hour to take appropriate actions toward reducing food wastage. Hence, changing our mindset on food preferences and reducing food waste plays a vital role in food sustainability.

We hypothesized that knowing the preference concerning age, gender, and regional diversity will help develop the most accepted food recipes, reduce food wastage, and improve the nutritional regime. Therefore, the present investigation aimed to determine the factors that impact the dietary habits of the varied groups among the Indian population.

2. Materials and methods

2.1. Dietary habits in India, vis-à-vis average around the world

There are some similarities and variations between the diets of Indians when compared with that of the world (**Figure 2**). One standout observation is that about a quarter of the Indian and world diet comprises animal produce. Similarly, almost 40% of the diets of the Indians and also the world altogether met from processed foods. Indians eat almost thrice (11%) of nuts and seeds, and the world population's diet solely contains a stripped-down four-dimensional of nuts and seeds. Moreover, 23% of a typical Indian diet comprises vegetables and fruits, 6% less than the average global diet. Based on this assumption, we have conceptualized a framework of customized food planning (**Figure 3**) for responsible food consumption by analyzing the food preferences and dietary patterns.

2.2. Preparation of questionnaire and data collection

The data used in this study was collected through a structured questionnaire (**Figure 4**) from the Post Graduate Diploma in Agri Business Management (PGD-ABM) students and participants of different training programmes and events during 2018–2020 organised at ICAR-National Academy of Agricultural Research Management (NAARM), Hyderabad, India, which is an organisation under the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture & Farmers Welfare, Govt. of India. The information related to the participants'/respondents' food habits, such as their choice of diet, choice of meat, likeness toward spices, choice of beverages, garlic & ginger, sugar etc., was collected. In addition, respondents' personal information, such as age, gender and their residing region, was also collected. All the variables under the study are categorical except age. The data was collected from 500 participants. The customised meals were served to the participants after administering the questionnaire and analysing the collected data. The food planning chart based on the food choice is depicted in **Figure 5**.

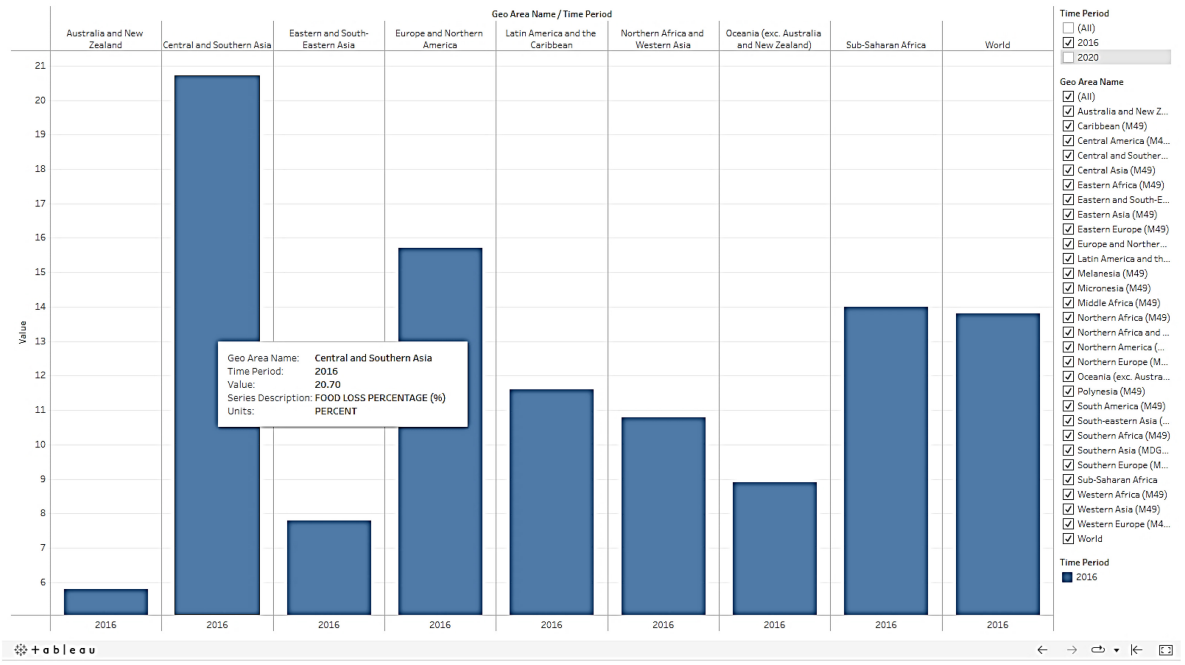

FIGURE 1
Food loss percentage in Central and South Asia (https://www.fao.org/sustainable-development-goals/indicators/1231/en/).

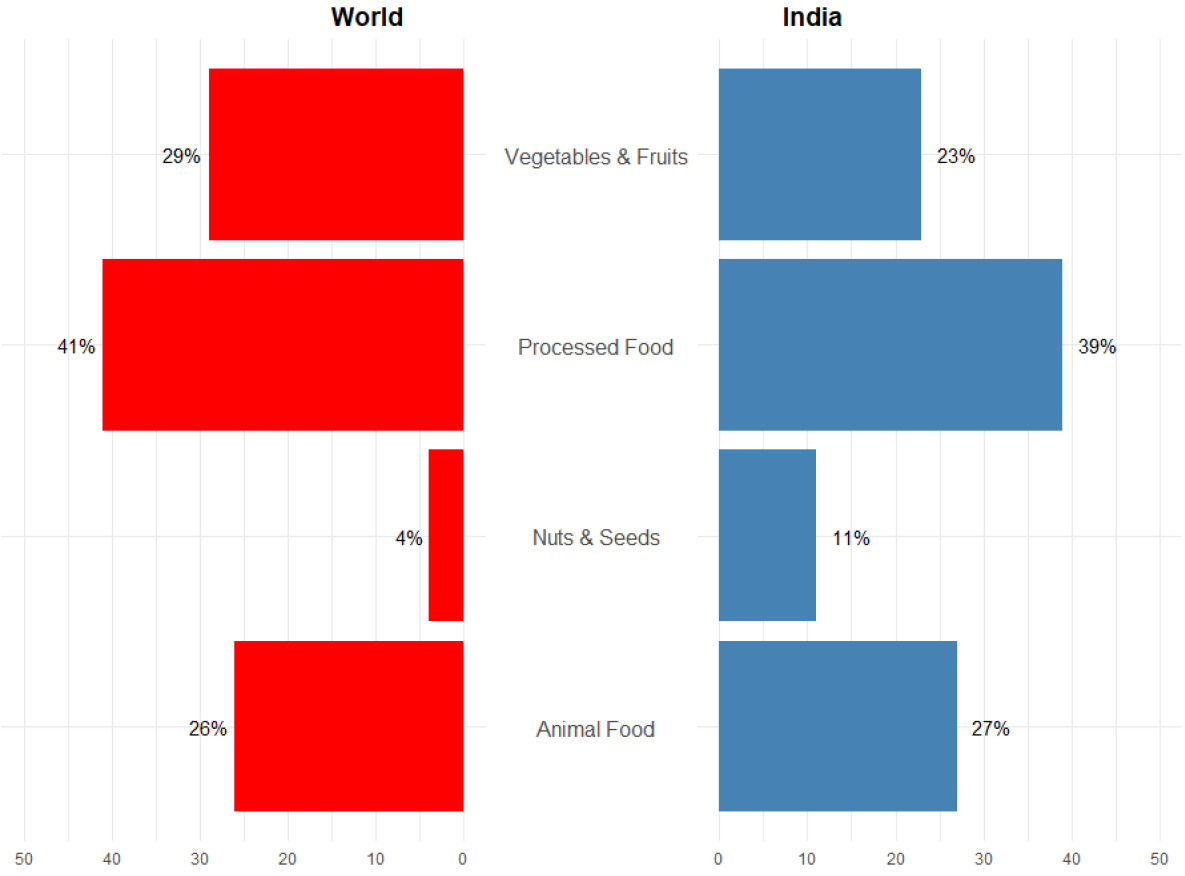

FIGURE 2
Components of food consumed by Indians and the world population (https://www.fao.org/3/ca9692en/online/ca9692en.html).

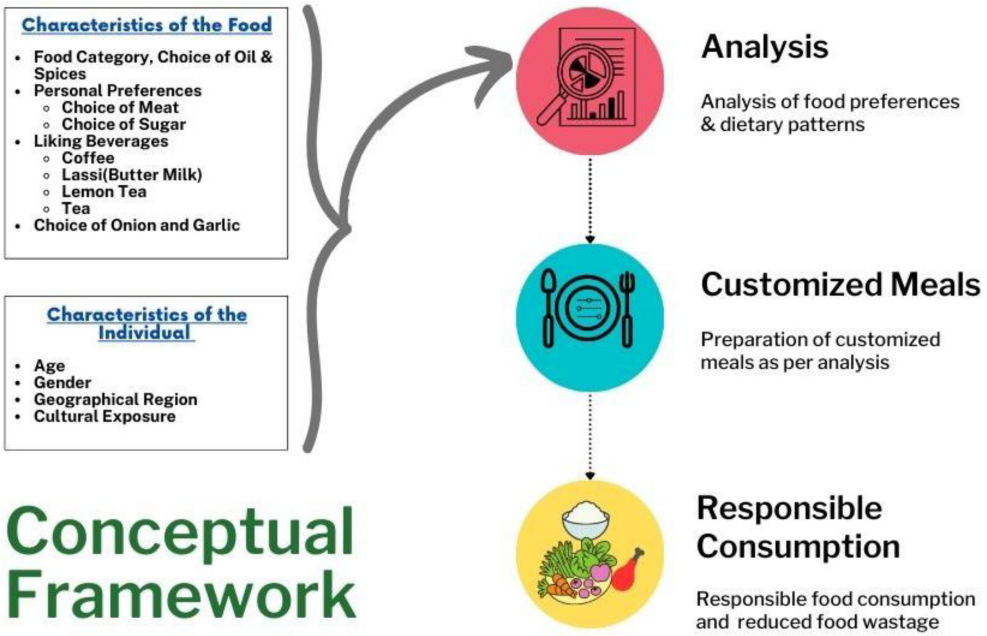

FIGURE 3
Conceptual framework of customised food planning.

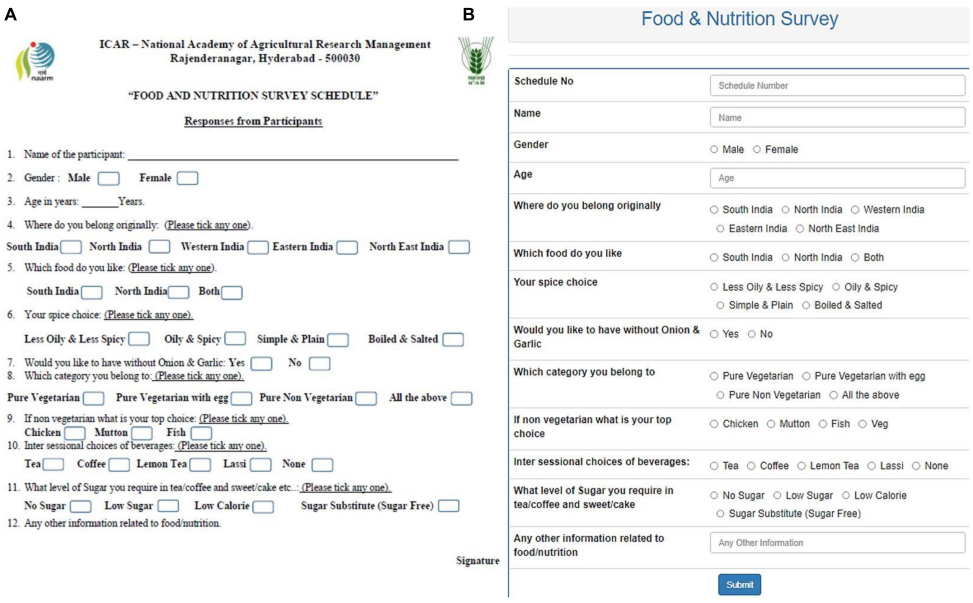

FIGURE 4
(A) Questionnaire on Food and Nutrition Survey Schedule. **(B)** Questionnaire portal.

2.3. Statistical analysis

The influence of factors like age, gender and region of residence on food habits was studied using different appropriate statistical techniques. Since the variables are categorical, multinomial logistic regression was used to see the effect of these personal factors on dietary habits. Multinomial logistic regression is an extension of binary logistic regression, which helps predict when the dependent variable has three or more categories. The independent variables may be continuous or dichotomous (i.e., binary). Like binary logistic regression, multinomial logistic regression assesses the likelihood of categorical membership using maximum likelihood estimation (15). Out of 500 observations, 70% of the data was used for model building, and the remaining 30% was used for validating the developed model. Since there were seven predictor variables, each with k different number of classes, multinomial logistic regression equations were developed for each variable and k-1 class. The personal variables such as gender, age and region

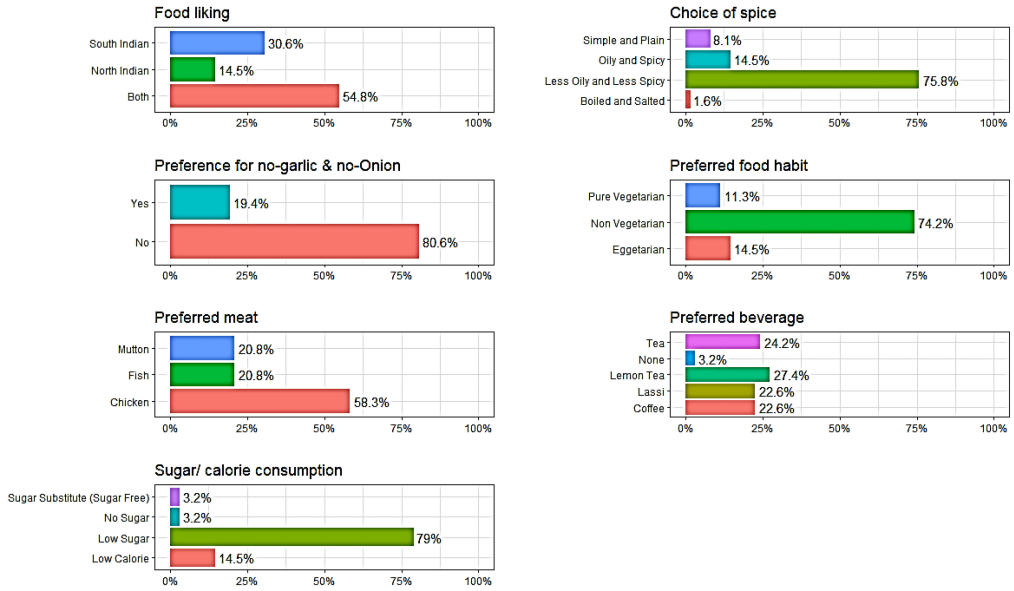

FIGURE 5
A food planning chart for the various programmes at ICAR-NAARM.

of residence were considered predictor/independent variables, and the variables representing the dietary habits were considered response/dependent variables. The log odds values obtained from the multinomial logistic regression are presented in Table 2. A log odd values greater than zero indicates a positive association between the predictor variable and the outcome category, while a log odd less than zero indicates a negative association. The significance of the predictor variables is established by checking whether the log odds' confidence interval includes zero. The accuracy percentage of the different multinomial logistic regression models built for training and validating data is presented in Table 3. The normalised chi-square test for association using Monte Carlo simulation of p-values was used to check for any association between response variables.

3. Results and discussion

3.1. Basic information about participants

Five hundred participants who responded to this study include students of Post Graduate Diploma in Agribusiness Management (PGD-ABM) of NAARM, probationary scientists and faculty from various higher education institutes in India. The respondents were aged between 19 and 59 years, with an average age of 30. About 60% of the respondents were males. The respondents from north India constituted the highest (about 57%).

3.2. Dietary behaviour and personal factors

Though the data was collected from 500 respondents, subjects with missing elements were ignored to avoid the problems of missing values. Accordingly, 14 records were expelled from the data, and the remaining 486 records were used for further statistical analysis. The different variables related to dietary behaviour and personal factors considered in the study are given in Table 1. The distribution of subjects based on the study variables is also given, along with whether they are used as a predictor or response variables in the multivariate logistic regression analysis. Regarding food likeliness, respondents liked both south and north Indian dishes. Most of the respondents preferred "less oily and less spicy" food, whereas the majority preferred dishes that included garlic and onion. Fifty per cent of the respondents identified themselves as preferring both vegetarian and non-vegetarian food. Among non-vegetarians, chicken was preferred by more respondents, followed by fish and mutton. Among the beverages, tea was preferred by most respondents, followed by lemon tea, coffee and lassi. Most respondents (66%) preferred low sugar in their food. The respondents in this study are well educated and have a good knowledge of food and nutrition that influence the dietary habit of an individual. Indeed, the level of education can influence food consumption patterns during adulthood (16).

3.3. Food likeness

The multinomial logistic regression results presented in Table 2 show that the food likeness is influenced by age and the region of residence. As the age increases, it is observed that the preference changes from their regional dishes toward both. In fact, from an early age itself, taste and familiarity influence food preference. However, the preferences for tasty foods develop through experiences and are highly influenced by an individual's attitude, beliefs and expectations (17). Regionality is also found to have a significant influence on food likeness. Log odds of likeness toward north Indian food (with reference class "both") decreases by

TABLE 1 Study variables and distribution of subjects.

Variables	Classes	Frequency	Percentage	Variable type
Gender	Female	192	39.51	Predictor
	Male	294	60.49	
Age	Continuous variable	–	–	Predictor
Region	North India	276	56.79	Predictor
	South India	210	43.21	
Food liking	Both	282	58.02	Response
	North India	102	20.99	
	South India	102	20.99	
Choice of spice	Boiled and salted	13	2.67	Response
	Less oily & less spicy	317	65.23	
	Oily and spicy	64	13.17	
	Simple and plain	92	18.93	
Exclude onion and garlic.	No	407	83.74	Response
	Yes	79	16.26	
Food category	Non-vegetarian	102	20.99	Response
	Pure vegetarian	85	17.49	
	Eggetarian	54	11.11	
	All the above	245	50.41	
Choice of meat	Chicken	171	48.72	Response
	Fish	101	28.77	
	Mutton	79	22.51	
Choice of beverages	Coffee	96	19.75	Response
	Lassi	70	14.40	
	Lemon tea	134	27.57	
	None	15	3.09	
	Tea	171	35.19	
Sugar preference	Low calorie	108	22.22	Response
	Low sugar	320	65.84	
	No sugar	23	4.73	
	Sugar substitute (sugar-free)	35	7.20	

2.54 if the respondent belongs to the southern region. Food intake habits and diet patterns will be significantly influenced by one's culture and lifestyle (18, 19). One's culture can strongly influence their dietary habit because of the peculiarity of different cultures' food and cuisine (20). However, likeness toward south Indian food (with reference class "both") increases by 3.13 log odds when the respondents belong to the southern region. This indicated that food choice is highly influenced by regionality. Gender was found not to influence food likeness. However, one of the studies conducted by Soam (21) on the organoleptic study of Hyderabadi Haleem (a type of food that made by cooking meat, wheat, barley or lentil in liquid for a long time) revealed that gender, regional and product familiarity influenced the acceptability of Haleem.

3.4. Choice of spice

The choice of spice in food was found to be influenced by regionality. For example, if the respondents belonged to south India, the preference toward "simple & plain" food or "less oily and spicy" food (with reference class "oily & spicy") increased by 2.21 and 1.62 log odds, respectively. Also, as the age of the respondents increased, their preference toward simple & plain food (with reference class "oily & spicy") significantly increased by 0.06 log odds. In one of the studies, it is observed that youngsters are more likely to eat spicy food (22).

3.5. Level of sugar

The level of sugar was found to be influenced by the age of the respondents. As the age increased by one year, log odds of the preference toward no sugar (with reference class low calorie) increased by 0.12. Similar findings were reported by many other authors (23–25) and stated that high intake of free sugar is associated with poor diet, obesity and risk of non-communicable diseases such as diabetes and heart disease. Hence, it is advised that free sugar consumption should be reduced. Furthermore, people tend to avoid high-calorie foods which are high in sugar and salt as they age. For instance, one study showed that the elderly tend to restrict fast and nutrient-dense foods and adopt high-fibre and nutritious foods like fruits, vegetables and grains (26). Regionality was found to have no significant influence on the level of sugar.

TABLE 2 Log odds values from the multinomial logistic regression.

Dependent variable	Reference class	Dependent class	Log odds (95% CI)			
			Intercept	Gender (male)	Age	Region (South India)
Food likeness	Both	North Indian	0.24 (−0.71, 1.19)	0.17 (−0.35, 0.68)	−0.03 (−0.06, −0.01)#	−2.54 (−3.48, −1.61)#
		South Indian	−1.61 (−2.94, −0.28)	−0.09 (−0.63, 0.45)	−0.06 (−0.09, −0.02)#	3.13 (2.27, 4)#
Choice of spice	Oily and spicy	Boiled & salted	0.32 (−3.97, 4.61)	0.08 (−1.5, 1.65)	−0.05 (−0.2, 0.1)	−0.8 (−2.31, 0.71)
		Less oily & Less spicy	1.15 (−0.53, 2.84)	−0.34 (−1.1, 0.42)	0.05 (−0.01, 0.1)	1.62 (1.07, 2.17)#
		Simple and plain	−0.87 (−2.71, 0.96)	−0.61 (−1.51, 0.28)	0.06 (0.02, 0.1)#	2.21 (−2.04, 2.38)#
Level of sugar	Low calorie	Low sugar	0.92 (−0.17, 2)	−0.23 (−0.79, 0.32)	0.01 (−0.02, 0.05)	−0.4 (−0.93, 0.12)
		No sugar	−5 (−7.07, −2.92)	−0.25 (−1.58, 1.09)	0.12 (0.06, 0.17)#	−0.85 (−2.1, 0.39)
		Sugar substitute (sugar-free)	−2.2 (−4.04, −0.37)	0.2 (−0.83, 1.23)	0.03 (−0.03, 0.08)	0.2 (−0.72, 1.13)
With or without onion/garlic	Yes	No	−2.29 (−3.36, −1.21)	−0.13 (−0.75, 0.49)	0.02 (−0.01, 0.05)	0.18 (−0.41, 0.77)
Category	All	Non-vegetarian	0.06 (−1.15, 1.28)	0.13 (−0.49, 0.75)	−0.03 (−0.07, 0.01)	−0.39 (−0.97, 0.19)
		Pure vegetarian	−0.95 (−2.02, 0.12)	−0.59 (−1.23, 0.04)	0.03 (−0.01, 0.06)	−1.16 (−1.82, −0.49)#
		Eggetarian	−1.7 (−3.11, −0.3)	−1.02 (−1.83, −0.2)#	0.03 (−0.01, 0.07)	−0.65 (−1.46, 0.15)
Choice of meat	Chicken	Fish	−1.27 (−2.43, −0.12)	−0.3 (−0.95, 0.34)	0.04 (0.01, 0.08)#	−0.45 (−1.05, 0.16)
		Mutton	−0.67 (−2.14, 0.8)	0.84 (0.05, 1.62)#	−0.02 (−0.07, 0.03)	−0.23 (−0.9, 0.44)
		Veg	−0.62 (−1.71, 0.47)	−0.63 (−1.24, −0.03)#	0.04 (0.01, 0.08)#	−1.16 (−1.76, −0.55)#
Choice of beverage	Coffee	Lassi	1.7 (−0.05, 3.46)	0.22 (−0.61, 1.05)	−0.06 (−0.12, 0)	−1.44 (−2.31, −0.57)#
		Lemon tea	0.39 (−0.83, 1.61)	0 (−0.67, 0.68)	0 (−0.03, 0.04)	−0.51 (−1.15, 0.13)
		None	−0.73 (−3.49, 2.03)	−0.32 (−1.6, 0.96)	−0.03 (−0.12, 0.06)	0.1 (−1.17, 1.36)
		Tea	0.9 (−0.26, 2.05)	0.15 (−0.49, 0.79)	0 (−0.04, 0.03)	−0.72 (−1.32, −0.11)#

#Indicates the significance of the log odds value since the confidence intervals do not contain zero.

3.6. With or without onion/garlic

Any of the determinant variables did not influence preference toward food with or without onion/garlic. This could be because many Indian traditions and Ayurveda suggest avoiding garlic and ginger as age increases. This is because it is believed that food, including garlic, meat, liquor and spices, brings out human behaviour's lowest, crass qualities. In Indian culture, these items are considered Tamasika foods (27). However, recent research has demonstrated the benefits of garlic/onion and its extracts in various applications. This research suggested that the medicinal benefits of garlic and onions for several disorders may be returning. Garlic and onions include a variety of chemicals that are believed to lower the risk of cardiovascular disease, have anti-tumour and anti-microbial properties, and have benefits for high blood sugar levels (28). Therefore, eating garlic and onions should not be avoided.

3.7. Food category

Preference toward vegetarianism or non-vegetarianism was influenced by gender and regionality. If the respondent is male, the eggetarian decreased by 1.02 log odds (with reference class "all"). On the other hand, if the respondent belongs to the south Indian region, log the odds of preference toward pure vegetarian by 1.16 (with reference class "all"). The study conducted by Green et al. (29) showed that the intake of numerous food groups varied between studies in various parts of India. Dietary patterns from the east and south were also more likely to be characterised by meat or fish-eating than those from the north and west. They added that vegetarian diets are still typical in India and are associated with lower blood pressure. On the other hand, fruit, dairy products, and snacks were associated in a way that was favourably correlated with hypertension.

3.8. Choice of meat

The choice of meat was influenced by gender, age and regionality. For male respondents, log odds of the preference for mutton increased by 0.84, whereas the preference for vegetarian

TABLE 3 Accuracy percentage for different multivariate logistic models.

Model for	Training data	Validation data
Food likeness	57.35	63.70
Choice of spice	64.12	66.44
Level of sugar	65.00	66.44
With or without garlic	82.94	85.62
Food category	50.88	46.58
Choice of meat	41.17	34.25
Choice of beverage	35.29	37.67

TABLE 4 Results of the normalised chi-square test for association.

	Choice of spice	With or without onion/garlic	Category (Veg/Non-veg/Veg + Egg/All)	Choice of meat	Choice of beverage	Level of sugar
Food likeness	29.009**	1.077	23.708**	34.818**	12.722	4.111
Choice of spice		8.676*	7.122	27.765**	22.211*	10.641
With or without onion/garlic			14.371**	9.307*	2.614	3.977
Category				NA	9.037	15.404
Choice of meat					22.811*	20.263*
Choice of beverage						22.908*

NA, not applicable.
*Significant at 5% level.
**Significant at 1% level.

food decreased by 0.63 (with reference class "chicken"). As the age increased by one year, log odds of the preference toward fish and vegetarian food increased by 0.04 (with reference class "chicken"). This may be because as age increases, the efficiency of Gastro Intestinal System reduces to digest complex food like meat (30). Thus, aged respondents preferred vegetarian food and fish. Usually, red meat is rich in protein and filled with dense nutrients, and the gastrointestinal system plays a crucial role in digesting the same. Many studies reported that risk factors for chronic disease have shown that vegetarians have lower serum cholesterol concentrations, lower body mass indices, lower incidence of diabetes and possibly lower blood pressure than comparable non-vegetarians (31). Region-wise, log odds of the preference toward vegetarian food decreased by 1.16 if the respondent belonged to the South Indian region (with reference class "chicken"). Similar results were obtained by Green et al. (29), who, in their study, separated the models by region, year, age and sex in order to determine whether they showed a relationship with the specific food groups found in Indian dietary patterns. The consumption of many food groups varied across the studies from different regions. Sweets and snacks were more likely to characterise diets in the East and South, whereas fruit, vegetables, rice and pulses were more likely to characterise diets in the north and west. Dietary patterns from the East and South were also more likely to be defined by meat or fish consumption than those from the north and west.

3.9. Choice of beverages

The choice of beverages was found to be influenced by regionality. For respondents belonging to South India, coffee was most preferred. The log odds of preference toward Lassi and Tea decreased by 1.44 and 0.72 log odds (with reference to class "coffee") for the respondents from south India. However, the model seems insufficient, indicating the influence of other factors not captured in the model (Table 3).

3.10. Association between response variables

The chi-square test was performed to check the association between different predictor variables in the study. The test's null hypothesis is that there is no association between the two variables under consideration. The results of the chi-square test are given in Table 4. The results show a significant association at 1% level of confidence was found between food likeness and choice of spice; food likeness and category; food likeness and choice of beverage; choice of spice and choice of meat; and onion/garlic with category. At a 5% level of confidence, a significant association was observed between the choice of spice and onion/garlic; choice of spice and choice of beverages; onion/garlic and choice of meat; choice of meat and choice of beverage; choice of meat and level of sugar; and choice of beverage and level of sugar. All other variable combinations showed no significant association at 1 and 5% significance levels.

3.11. Contribution to the reduction of greenhouse gas emissions and sustainable development goal

In this study, it is evident that as age increases, the consumption of meat-based foods decreases, and the preference toward vegetarian food has increased. Additionally, the respondents of higher education institutes were greatly concerned about healthy diets as their age increased. These kinds of healthy diet patterns among people significantly reduce food wastage and contribute to reducing greenhouse gas (GHGs) emissions. Therefore, food planning can be done considering the factors influencing food intake, which can help reduce food wastage. Reducing food wastage would directly reduce excess food production (that consumes more energy and releases more GHG to atmosphere), which minimises GHG emissions. In addition, minimizing meat consumption, adjusting the diet structure, and increasing the low carbon healthy foods like vegetables and seafood helps reducing the GHGs emission from the food production process besides meeting people's health needs (9). They also revealed in their study that a plant-based diet could significantly reduce total GHG emissions by 41%. Usually, the meat production process releases large amounts of GHGs into the atmosphere. When the demand for meat production increases, the production process will gradually increase that results in emitting enormous concentrations of GHGs. A study conducted by Clune et al. (32) revealed that the production of beef per kilogram emits approximately 28.73 kg of carbon dioxide equivalent (CO_2-eq), which is ten times more than that of rice production. This indicates that meat production releases more GHGs than that of plant production. Therefore, promoting low-carbon life by changing one's diet structure would possibly

reduce the GHG emissions that contribute to "SDG-13: *Climate Action*". About 8–10% of GHGs are associated with food not being consumed, while target 12.3 of the Sustainable Development Goal (SDG) aims to reduce food wastage.

The EAT-LANCET commission paper published by Willett et al. (33) on healthy diets from sustainable food systems suggested the universally appropriate healthy diet, i.e., inclusion of legumes, nuts, unsaturated oils, whole grains, and fruits in the daily diet. Regarding non-vegetarian preferences, low to moderate seafood and poultry consumption was suggested. The study also addressed strictly lowering the consumption of red meat, processed meat and added sugar. Adopting this dietary plan in the individual's lifestyle would help feed the global population of about 10 billion people a healthy diet within food production boundaries by 2050, besides achieving the SDG and Paris agreement.

3.12. Strengths and weakness of the study

The present study on the analysis of dietary trends is a novel approach to contribute immensely toward food menu planning in higher educational institutions. Indeed, the outcomes from the present investigation would be helpful for doctors, dieticians, food policy-makers, restaurateurs, mega kitchens, youth hostels, food organisations etc. For instance, the Kalinga Institute of Industrial Technology of Bhubaneshwar, the world's largest tribal school, provides food to 25,000 students daily. It holds a mega kitchen, serves over 50,000 meals daily, and contributes to SDG #3 & #2 besides mitigating Global Hunger Index (GHI) through food planning. Thus, the present conceptualisation will help mega kitchens achieve the SDGs and GHI through proper food planning considering dietary preferences based on regionality, age and other choices.

However, to further improve the evaluation pattern of dietary-related studies, considering food wastage estimation, large-scale planning and analysis, increased sample size and inclusion of samples from multiple regions are crucial. In the present research, scientific food wastage estimations were not carried out because the customised meals were served after administering the questionnaire and analysing the collected data. As a result, there was no wastage observed.

4. Conclusion

In summary, our investigation revealed that the respondents of higher education institutes had a higher preference for a healthy diet with increasing age. Their preference for different food items was influenced by their regional differences, age, gender and other choices. We noticed that respondents from the south India region preferred simple and healthy food, while the north Indian respondents preferred both the south and north Indian dishes. The present study also reported that most respondents preferred vegetarian food with increasing age. In addition, most respondents preferred low-sugar food, indicating that knowledge of food and nutrition influence the dietary habit of an individual. The study also suggested proper food planning is required for higher educational institutions and mega kitchens where participants and stakeholders are from multiple regions. The present research findings can be helpful for menu planners at different institutes and programmes, including doctors, dieticians and researchers.

Conclusively, our research demonstrated that the food menu should be prepared based on the region, age, and gender of the consumer in any food-serving institution. So that zero-food wastage can be achieved through customised meal serving. In addition, appropriate food planning and management in higher educational institutions would immensely contribute to SDG and GHI, which helps reduce food wastage in India.

Data availability statement

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

Author contributions

SS performed the conceptualization, methodology, and supervision. SR and RB performed data collection. BY, RB, and RS performed the data curation. BY and RB performed software validation and formal analysis. SR, RB, SS, and BY performed writing—original draft. BY, RB, SR, TD, and BM carried out the literature survey and materials collection. SS, BY, TD, BM, SR, and RB carried out the review and editing. All authors read and approved the final manuscript and contributed to the study's conception and design.

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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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Student conceptions of the production of cow's milk—An exploratory interview study with 6th- and 10th-grade students

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The production of food and the associated livestock farming contribute significantly to climate change and the global loss of biodiversity, hindering the achievement of the United Nations Sustainable Development Goals (SDGs). To promote responsible consumption and production of food (SDG 12), ensuring that students understand the production of our food, the associated livestock farming, and the interrelatedness of production and consumption is essential. Thus, Education for Sustainable Development (ESD) is an important tool for achieving the SDGs. To develop effective teaching and learning strategies to educate students about the production of food from livestock, it is important to identify students' existing conceptions of this topic. Thus, this study examined sixth-grade ($n = 4$; $M_{Age} = 12$ years; $SD_{Age} = 0.7$ years; 50% female) and tenth-grade students' ($n = 4$; $M_{Age} = 16$ years; $SD_{Age} = 0$ years; 50% female) conceptions of milk production, focusing on dairy farming, the milking process and techniques, and the production of cow's milk. Semi-structured interviews were conducted with students from Osnabrück (Lower Saxony) to elicit student conceptions. The evaluation of the students' conceptions was carried out using qualitative content analysis. The results largely indicated that both sixth and tenth graders had realistic conceptions of dairy farming and the milking process and techniques. However, some students also expressed romanticized conceptions of pasture grazing and calf rearing. In addition, unrealistic statements regarding the formation of milk were identified. The conceptions of the sixth and tenth graders were compared, and with a few exceptions, no significant differences were found between the two cohorts. However, the tenth graders tended to have more differentiated conceptions about milk production than the sixth graders. In conducting the analysis, it became clear that students' conceptions of the production of milk are influenced by individual primary experiences with dairy farms. Finally, based on these results, educational recommendations for the school teaching framework in the context of ESD and implications for further research are presented.

KEYWORDS

agriculture, dairy cow, milk, student conceptions, education for sustainable development (ESD), Germany

1. Introduction

Climate change and loss of biodiversity are caused to a considerable extent by the production of our food as well as our eating habits (1–5). Husbandry of farm animals, such as cattle for meat and milk production, is a main factor responsible for the current global environmental issues (2, 4). Approximately one-fifth of global anthropogenic greenhouse gases come from the agricultural sector (5). Around 80% of this is due to livestock farming, which accounts for 9% of global CO_2 emissions and 40% of global methane emissions (4).

Germany is the largest cow's milk producer in the European Union, with approximately four million dairy cows and 33.1 million tons of cow's milk produced in 2019 (6, 7). Globally, Germany ranks third in imports and exports of agricultural goods (8). In 2019, approximately 16.7 million hectares of arable land were cultivated (9). Ninety percent of the farms in Germany specialized in one branch of agricultural production, such as arable farming or pig fattening. Approximately 69,000 farms were dairy farms (6, 10). In 2019, 45.5 billion euros were generated in Germany with agricultural products. Milk comprised 24% of the total product sales, with 11.1 billion euros in sales (11).

To keep up with this, farms in Germany have undergone a fundamental structural change in recent decades that is often referred to as "agricultural structural change" (6). Farms with livestock were particularly affected. As a result of increasing mechanization and specialization of farms focusing on certain products, livestock, and feed, the number of farms decreased steadily from 1.15 million in 1970 to 262,780 in 2020 (6, 12). In parallel, the number of people employed in the agricultural sector also decreased from 24.6% (1950) to 1.3% (2019) (13). In contrast, milk yield per cow increased from 2,480 kg (1950) to 8,457 kg (2020) per year (6, 12).

Due to these developments, there is an urgent need for action concerning various environmental burdens and the consequences of livestock farming. Agriculture—and with it, the agricultural and food system—needs restructuring with the goal of sustainable nutrition. This mainly affects dairy farming, one of the largest branches of agriculture (6). To bring about changes promoting sustainable nutrition, society's attitudes toward milk and dairy products need to be educated. It is essential to focus mainly on children and adolescents because eating behavior already manifests itself at these stages of life and is difficult to influence in adulthood (14, 15). Therefore, a central role in promoting sustainable nutrition is played by Education for Sustainable Development (ESD), which aims to bring about sustainable changes in dietary habits (16). ESD aims to develop sustainability competence, enabling learners to think and act sustainably. The goal is to make students aware that their actions impact the world and, accordingly, teach them to make responsible choices (17). As part of the 2030 Agenda for Sustainable Development, the United Nations drafted 17 Sustainable Development Goals (SDGs) in 2015. SDGs encompass areas in which sustainable development should be strengthened, such as sustainable food production and consumption (SDG 12). Understanding the production and consumption of livestock products, such as meat or milk, is an important part of sustainability competence that learners should develop through ESD. Therefore, teaching the topic "Sustainable Nutrition" within ESD offers a great potential for achieving the SDGs (17).

To develop educational implications for teaching specific topics of sustainable development within ESD, an exploration of student conceptions is necessary. There is only a small amount of research on students' conceptions of the production of livestock products, including conceptions of the production of cow's milk. Therefore, this research examines sixth- and tenth-grade students' conceptions of milk production, focusing on students' conceptions of dairy farming, the milking process, milking techniques, and milk production.

1.1. Student conceptions, moderate constructivism, and conceptual change

In this study, the basis for studying student conceptions is the theory of moderate constructivism (18, 19). According to this theory, knowledge acquisition is actively constructed by the learner and is based on their pre-existing conceptions (18–20). Students already have simple conceptions about most subjects. These conceptions can be deeply embedded and affect the learning process in class. Therefore, students' conceptions are highly relevant for the didactic and methodological preparation of lessons in science education (19). On the one hand, students' conceptions can be obstacles to learning if they do not correspond to the scientific conceptions. On the other hand, they can form the basis of the learning process and thus promote understanding (18).

Changes in student conceptions can be explained using the conceptual change theory, which is concerned with the conditions under which simple conceptions can change into scientifically justified conceptions (21–24). However, since student conceptions are not simply replaced by scientific conceptions, as "change" implies, Krüger (23) uses the term conceptual reconstruction, which clarifies that conceptions can only be reconstructed, not replaced. According to Posner et al. (24), four conditions must be met for reconstruction of pre-instructional conceptions: (1) the student must be dissatisfied with their existing performance; the new conception must be (2) logical, understandable, and (3) plausible; and (4) the new concept should be fruitful (i.e., applicable to other areas) (19, 23).

For the development of school lessons that build on existing student conceptions, the Model of Educational Reconstruction (MER) is of great use. This model is based on, among other things, the theory of moderate constructivism and the theory of conceptual change (25, 26). The MER is used to design and evaluate an effective learning environment in the classroom by mutually relating existing student conceptions and scientifically justified conceptions. The model is thus composed of three mutually influencing components: (1) the technical clarification of the specific science content, (2) the elicitation of student conceptions regarding the specific science content, and (3) the design and evaluation of learning environments. Under the MER, a balance is struck between knowledge transfer and pedagogical aspects. This enables students to develop appropriate conceptions within the

classroom setting (25–27). In this study, we focused on the second emphasis of the MER.

After a brief technical clarification of the topics of dairy farming, the milking process, milking techniques, and lactation, we present the collected student conceptions about milk production and discuss them to formulate practical educational implications. To optimize ESD with the goal of acquiring relevant knowledge, skills, and competencies to achieve the SDGs, the aims of our study are to investigate students' conceptions about the production of an agricultural product (cow's milk) and to compare the conceptions of students of different grade levels/ages as an indicator of their learning gains (SDG 4) (16).

1.2. Clarification of science content—Dairy farming in Germany

The stock size of most dairy farms in Germany is between 20 and 49 animals, while the second most common stock size is 100 or more animals (12). An average of 70 cows are kept on a German dairy farm, with the number of dairy cows per farm ranging from 10 to 1,000 (7, 12). Forty percent of dairy cows in Germany have regular pasturing. However, there are regional differences: In eastern Germany and Bavaria, less than 20% of cows have pasturing, while in Lower Saxony, North Rhine-Westphalia, and Schleswig-Holstein, most cows are kept on pasture in the summer (6, 10, 12, 28). The number of dairy farms varies significantly by state. Almost 50% of all German dairy cows are kept in Lower Saxony and Bavaria, with Bavaria having the highest number of dairy farms in Germany (7, 29). A large proportion of milk is produced at sites with a high proportion of grassland, as the grass serves as a feed base for the dairy cows. In terms of volume, the states with the most milk production are Lower Saxony, North Rhine-Westphalia, Schleswig-Holstein, and Bavaria (7, 12).

Regarding the husbandry practices of dairy cows, 83% of dairy cows in Germany are kept in cubicle housings (30). In a cubicle housing system, the cows move freely in the herd and go independently to the milking parlor, the feeding and watering place, and their lying area *via* walking areas. The design of the lying sites must allow for any lying shape of the cow and the animals must be able to stand up and lie down without hindrance. In cubicle housings, slatted floors with rubber mats are usually installed to ensure dryness and sure-footedness for the animals. There is a distinction between cubicle housings with a free lying area and box cubicle housings, in which the individual lying areas are separated with partitions. In dairy farming, cubicle housing has proven its worth, as it requires little bedding, the animals have a protected place to lie down, and the farmer's working time requirement is low (31).

Another husbandry practice is tethered housing, in which the animals are kept exclusively in a confined area where all animal-related activities such as milking, feeding, and manure removal are carried out. In this case, the animals are secured by the neck with a tether. However, the tether must not interfere with the cows' standing up, lying down, or eating. Manure removal is carried out using either the flow manure method, in which the lying surface passes into a grating through which the manure can fall directly into a drifting manure channel and, from there, is directed into a storage container, or solid manure preparation, in which the lying area ends at the manure ditch, into which the manure falls. The manure pit must be regularly mucked out, which can be done by a machine. Due to the animals' lack of freedom of movement, species-appropriate husbandry is only possible to a limited extent in tethered housing (31). In 2020, only 10% of the enclosures for dairy cows in Germany were still in tethered housing. Since tethered housing is no longer being built, it can be assumed that the number of enclosures in tethered housings has decreased further in the course of agricultural structural change (28, 30, 31).

Two other relevant housing types are the calving pen and the calf pen. To ensure hygiene and freedom of movement during birth, a calf should be born in a calving pen. It also serves to build a mother–child relationship. The calf should be transferred to a separate calf pen 24 h after birth (31). The individual housing is justified by a lower risk of infection to the calves. It also allows intensive monitoring of health and feed intake (31, 32).

The formation of milk (lactation) is the most characteristic feature of mammals. The center of lactation is the udder, which consists of four teats; the milk-forming glandular body; a cavity system of teat ducts; milk cisterns; and blood, nerve, and lymphatic systems. With sexual maturity, various hormones cause the development of glandular tissue in the udder. After the first fertilization, pregnancy leads to an increased hormone concentration, which results in the development of milk-forming secretory vesicles (alveoli). Shortly before calving, a change in hormone levels causes the onset of lactation. Capillary forces hold most of the milk in the alveoli and milk ducts, with only a tenth flowing into the cisterns (31).

Cow's milk consists mainly of water, proteins, fats, and carbohydrates in the form of milk sugar (lactose). Nutrients ingested in food are filtered from the blood by the alveoli. The amino acids filtered from the blood are ultimately used to form the milk proteins. The synthesis of milk fat also takes place in the alveoli. To produce 1 liter of milk, 400 to 600 liters of blood must pass through the udder (31).

A dairy cow becomes pregnant for the first time at approximately 18 months of age. Fertilization occurs *via* artificial insemination in 90% of dairy cows in Europe. On German organic farms, 80–90% of dairy cows are artificially inseminated. Natural sprouting is mainly used by extensively managed farms or organic farms, or in the case of fertility problems (33, 34). A dairy cow is pregnant for approximately 9 months and is milked for about 10 months after birth. The cow is inseminated again shortly after birth to avoid long dry stall periods. The milk yield of a cow depends on her age, since the milk-forming cells (alveoli) multiply with each pregnancy (31, 35). Furthermore, milk yield depends on the dairy breed (36). For example, the dairy breed Holstein (*Bos taurus taurus)* has a higher milk yield (9,224 kg milk/year) than the dairy breed Jersey (6,428 kg milk/year) (36). Physical conditions like pain, metabolic diseases, stress, separation of mother and young animal, or inflammation can have a negative effect on milk yield (31). Today, a dairy cow in Germany has an average of two to three calves and is ultimately slaughtered after about 4.5 years (10, 28).

To prepare for milking, the teats are actively stimulated by pre-milking them. This eventually causes the milk to shoot from the alveoli into the teats. The greater the time interval between milking, the greater the pressure in the udder, which can inhibit milk production. Thus, milk yield can be increased through more frequent milking (31). Dairy cows are milked 2 to 3 times a day, depending on milk yield (28). The milking process takes between 5 and 8 min. In addition to machine milking, a few farms still milk by hand. However, this is usually limited to pre-milking or performed the udder needs to be completely emptied in cases of udder disease (31).

Semi-automated milking plants or automatic milking systems (AMS) are used for milking. If the milker is relieved of individual work steps by technical systems, a milking plant is considered to be partially automated. Milking plants are considered AMS or milking robots if all steps of the milking process occur without a milker's intervention. AMS do not require fixed milking times, as the cows visit the milking plant independently. The animals are lured in with feed to maintain regular and timely milking. AMSs can accommodate from 20 to 48 animals. They clean themselves automatically between milkings and are ready for use 24 h a day, allowing for more than two milkings per day (31).

1.3. Current state of research—Student conceptions of "milk production"

As part of her dissertation, Hamann (37) investigated fourth graders' conceptions of agriculture in the context of ESD. In the study by Hamann (37), the cow was the most familiar of all farm animals. Almost all children knew that a cow provides milk. Furthermore, the elementary school students were able to describe in detail the housing of pigs, chickens, and cows. The idea that cows are largely kept on pasture and can switch between barn and pasture prevailed. The students linked this conception to the wellbeing of the animals. Most students assumed that the animals would be kept indoors only at night, during bad weather, or in case of illness. Overall, correlations were found between the students' primary and secondary experiences with farms and their conceptions. It also became apparent that real-life encounters with agriculture shaped the children's conceptions more than any other influencing factors (37).

In an interview study, Folsche and Fiebelkorn (38) investigated the conceptions of six elementary school students regarding the keeping of fattening pigs and dairy cows. Three of the students grew up on a conventional fattening pig farm (farm students). The survey revealed different conceptions of farms, from romanticized to elaborated. Students who did not grow up on a farm (urban students) associated keeping fattening pigs and dairy cows with small stock sizes and access to an outdoor run. In contrast, the farm students had realistic conceptions about stock sizes, barns with slatted floors, and technical equipment (e.g., automatic feeding). Primary experiences were shown to have a significant influence on the students' conceptions (38).

The research accompanying the Youth Report Nature 2010 by Brämer (39) provides an overview of the state of research on children's conceptions about agriculture. In a ranking scale of farm animals, the cow was the most frequently mentioned. Likewise, milking and the product associated with it (milk) were mentioned particularly often in relation to farm animal handling. It was found that children have romanticized conceptions of farms without technical equipment. Furthermore, students' knowledge about livestock farming came mainly from parents and media, while curricular school content had only a small effect on knowledge acquisition (39).

Schütte and Busch (40) investigated the implementation of the topic of agriculture in school lessons at high schools and grammar schools in Lower Saxony. According to this study, approximately 90% of the teachers surveyed stated that agricultural topics are included in the school's internal curriculum, but there were differences in the regularity of the implementation of lesson series with an agricultural focus: Only just under half of teachers taught agricultural topics on a regular basis. This topic was taught most frequently in grades five and six, followed by grades nine and ten. Sixty percent of the teachers surveyed went on a field trip with their classes, with farms being the most frequent destination (40).

1.4. Aims of the study

As indicated by the current state of research, studies on elementary school students' conceptions of agriculture (37) and the keeping of fattening pigs and dairy cows have already been published (38). However, to our knowledge, no study has yet examined students' conceptions of milk production. Thus, the following research questions were formulated:

- Research Question 1: What conceptions do students have of keeping dairy cows?
- Research Question 2: What conceptions do students have of the milking process and the technology used?
- Research Question 3: What conceptions do students have of milk production in dairy cows?

The focus of this paper is to compare the conceptions of sixth- and tenth-grade students. This comparison can be used to determine learning gains between sixth and tenth graders.

2. Materials and methods

2.1. Sample

The sample included four students each from the sixth (n = 4; M_{Age} = 12 years; SD_{Age} = 0.7 years; 50% female) and tenth grades (n = 4; M_{Age} = 16 years; SD_{Age} = 0 years; 50% female) from one grammar school in the city of Osnabrück (Lower Saxony, Northwest Germany). To ensure the anonymity of the students, a pseudonymization was performed. None of the students lived on a farm at the time of the interviews. A more detailed description of the sample and their primary and secondary experiences with dairy cow farms can be found in Tables 1, 2.

The sample is a convenience sample whose size was determined by the availability of the schools in the city of Osnabrück (41). For recruitment, a general call for participation in the study was

TABLE 1 Overview of sixth-grade students.

Name, age, gender	Primary experiences	Secondary experiences[1]
Anna, 13 years, female	Relatives' small farm in their home country	High school: Cow stomachs
Johannes, 11 years, male	Class trip to farm in elementary school	High school: Ruminants (one lesson)
Mark, 12 years, male	Regular vacation on Austrian alpine pasture, can milk cows and make dairy products there yourself	High school: Ruminant stomachs, cloven-hoofed animals, farm, sustainability; watches knowledge shows at home
Marie, 12 years, female	Grandmother's dairy farm in her home country; field trip to dairy farm in elementary school: tour of the milking equipment and independent milking	Elementary school: Stomachs of the cow (uncertain)

[1]Self-reported secondary experiences. Some students had limited recollection of secondary experiences with (dairy cow) farms, so these statements were marked with "uncertain".

TABLE 2 Overview of tenth-grade students.

Name, age, gender	Primary experiences	Secondary experiences[1]
Eva, 16 years, female	Father grew up on a farm with few cows; vacationed on a farm with cows in South Tyrol and was allowed to milk cows there	Elementary school (uncertain)
Kristina, 16 years, female	Farm vacation as a child	Elementary school (uncertain)
Michael, 16 years, male	Was sometimes in a farm shop/farm restaurant, farm kept fattening bulls	Biology class (uncertain)
Jürgen, 16 years, male	Was allowed to try a lot while working with dairy cows, pigs, and chickens on vacation	Elementary school (uncertain)

[1]Self-reported secondary experiences. Some students had limited recollection of secondary experiences with (dairy cow) farms, so these statements were marked with "uncertain".

launched at Osnabrück city schools. One school responded to the general call for participation and selected four students each from the sixth and the tenth grades in a self-selection process. All students volunteered for the interview and were selected by a teacher using a lottery. The students were not known to the interviewers before the start of the study. Written consent was obtained from both the school administration and the participants' legal guardians before the study was conducted. The students gave verbal consent for the interviews in advance.

2.2. Data collection

Data collection took place in June 2018. The interviews with the sixth graders were conducted by the fourth author, while the interviews with the tenth graders were conducted by the third author. Interviews were recorded with two digital recording devices (Olympus LS-P1). To optimize the interview questions and the interview procedure, two interviews were held in advance with a 12-year-old sixth grader and a 15-year-old tenth grader in May 2018. To elicit student conceptions of milk production, students completed a schematic of a cow and an udder during the interview (see Section 3.3.2., Figure 9). In addition, after the interview recording, a brief questionnaire was conducted with each student to ask about sociodemographic information, primary and secondary experiences with dairy farms, and dairy product consumption. The duration of the interviews ranged from 15 to 25 min ($M_{Duration}$ = 18.4 min; $SD_{Duration}$ = 3.1 min) for sixth graders and from 29 to 48 min ($M_{Duration}$ = 38 min; $SD_{Duration}$ = 8.5 min) for tenth graders. Interviews were conducted in German and translated into English for the purposes of this study. The study was conducted in accordance with national and institutional guidelines, the Declaration of Helsinki, and guidelines from the German Research Foundation and the American Psychological Association. Participants' anonymity was assured, and participation was voluntary (42, 43). All participants had the opportunity to decline to participate in the study at any time and without any consequences. All materials used to conduct the interviews were provided to the students' guardians prior to conducting the interviews, and all questions were clarified during the interview. The content of the interview guide was not shared with the students. Our research will not affect the rights and welfare of our participants, and no sensitive personal information was assessed. Thus, an ethics approval was not required by institutional and national guidelines (42).

2.3. Interview procedure and study design

To collect the students' conceptions, an interview study was conducted. A semi-structured interview guide was used to ensure comparability of data, and a multi-method interview approach combining drawing and verbal questioning was used (37, 38, 44). In general, the interviews were divided into three parts: (1) an introduction to the study, (2) the main part in which questions about students' conceptions of milk production were asked, and (3) a closing, which included a short questionnaire. The main part of the interview consisted of three phases relevant to the three research questions: (1) student conceptions about dairy farming, (2) student conceptions about the daily routine of a farmer on a typical dairy farm, and (3) student conceptions about milk production in a dairy cow. In the first phase, the students' conceptions of dairy farming were surveyed. For this purpose, the students were asked about their conceptions of dairy farms in Germany, the structure of a typical dairy farm, and the keeping of dairy cows. The focus was on the localization of

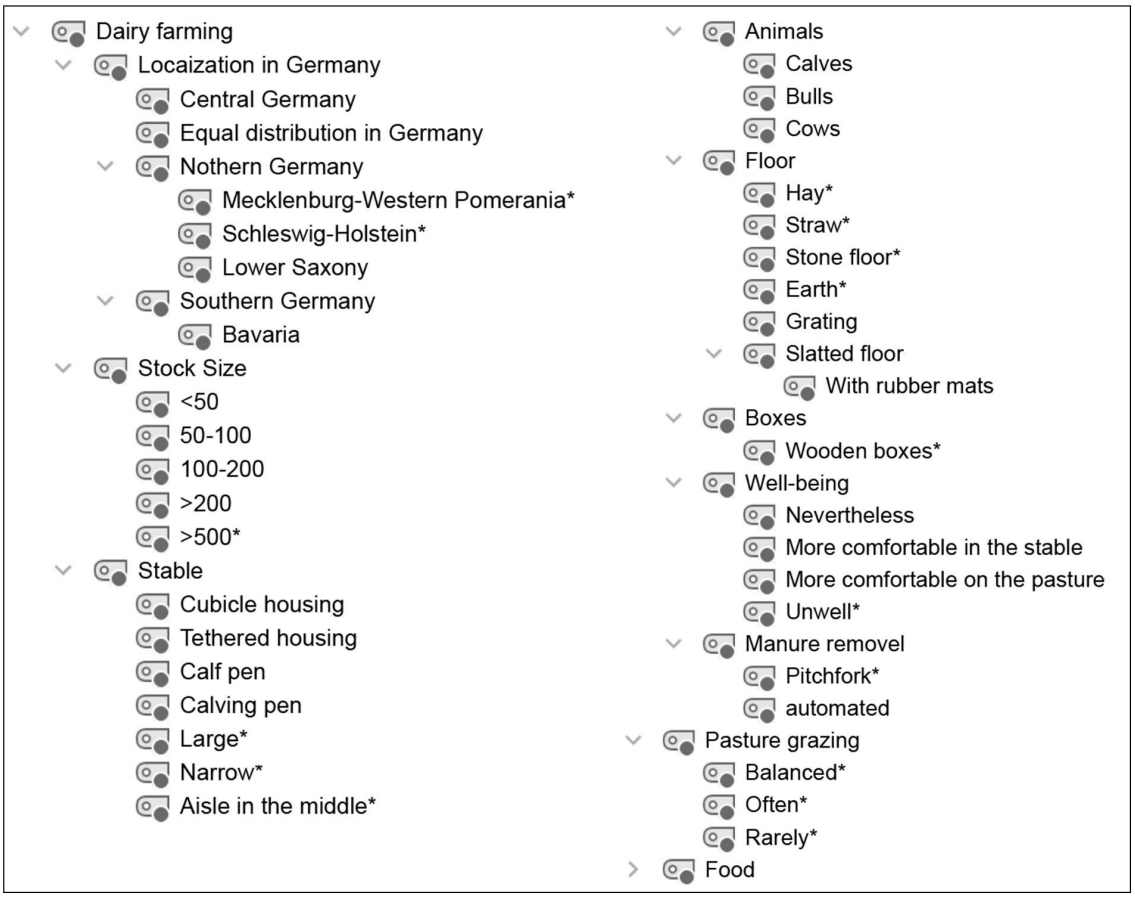

FIGURE 1
Category system for analyzing student conceptions of dairy farming. *Inductively coded categories.

dairy farms in Germany, stock sizes, the design of cow housing, and pasture grazing (Figure 1). In the second phase, students' conceptions of the daily routine of a farmer on a typical dairy farm were surveyed. The focus here was on asking the students about the milking process and milking techniques (Figure 2). In the third phase, the students' conceptions about the milk production of a dairy cow were surveyed. This involved first ascertaining the students' conceptions of why a cow produces milk and then asking how milk is produced in the cow (Figure 3). The latter was to be depicted by the students in drawings during the interview. For this purpose, students completed a schematic of a cow and an udder in which they could draw their conceptions about milk formation (see Section 3.3.2., Figure 9). This was followed by a review and discussion of the drawing. The statements of the students were further deepened with the help of a questionnaire covering different topics in dairy farming, milking, and milk formation.

2.4. Data processing and analysis

Audio recordings of the interviews were transcribed using the transcription program f4transcript according to the guidelines of Dresing and Pehl (45). The transcripts were analyzed in MAXQDA (46) using qualitative content analysis according to Kuckartz (47). Based on the research questions and three phases of the interview, a deductive category system was created according to the clarification of the technical concepts with the superordinate categories of (1) dairy farming (Figure 1), (2) milking process/techniques (Figure 2), and (3) lactation (Figure 3). In addition, inductive categories were added to the deductively created category system of technical conceptions during the analysis process.

For research economy, coding of all statements by a second person and using intercoder agreement as a consistency check were not performed. However, it can be assumed that coding by a second person would reveal only minor differences, since the deductive codes of the coding family tree correspond to a large extent to the questions on the interview guide and the questionnaire.

3. Results

Student conceptions were sorted and summarized based on the research questions and using the category systems (Figures 4–8). Students' statements were assigned to the corresponding categories, with an indication of their grade level after the pseudonym in round brackets in the category system.

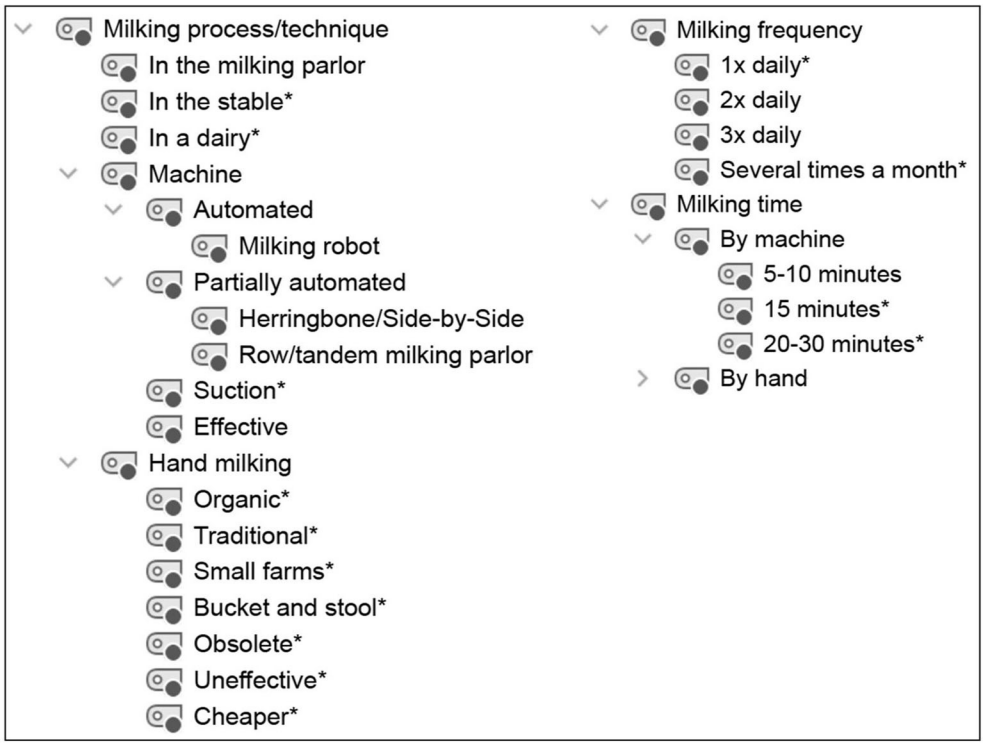

FIGURE 2
Category system for analyzing student conceptions of the milking process/technique. *Inductively coded categories.

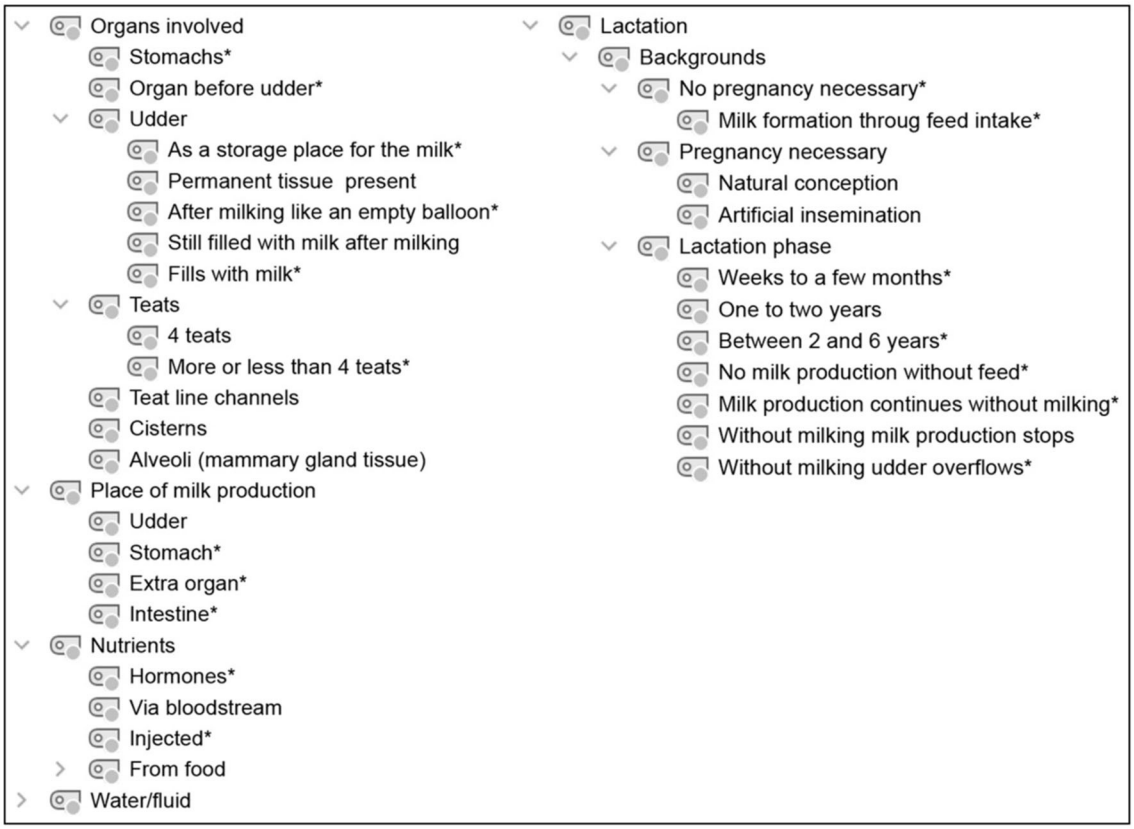

FIGURE 3
Category system for analyzing student conceptions of lactation. *Inductively coded categories.

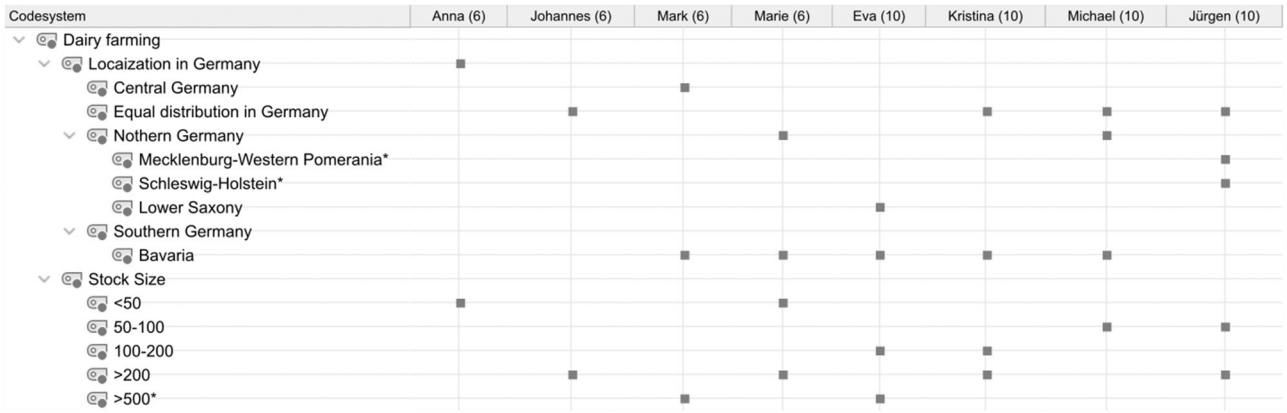

FIGURE 4
Overview of the students' statements on the localization of dairy farms in Germany and their stock sizes. *Inductively coded categories. The marks by the categories indicate that they were named by the student.

3.1. Students' conceptions of keeping dairy cows

3.1.1. Localization and stock size of dairy farms in Germany

The statements of all students on the localization of dairy farms in Germany as well as their typical stock size are shown in Figure 4.

Half of the students assumed an equal distribution of dairy farms across Germany. Some of them elaborated on their statements regarding the localization of dairy farms in Germany. Most of the students assumed a relatively high localization of dairy farms in the federal state of Bavaria. Marie (6) and Michael (10) also indicated that dairy farms are localized in northern Germany, while Mark (6) also mentioned central Germany and Jürgen (10) added Schleswig-Holstein and Mecklenburg-Western Pomerania. Mark (6) justified his conception with the fact that dairy farms are located near many meadows and that "better grass" grows on mountains. Eva (10) was the only student who explicitly stated that many dairy farms are located in Lower Saxony.

The students estimated that stock sizes on a typical dairy farm ranged from 20 to 30 animals on small farms to over 500 animals on large farms. Mark's (6) statement is particularly striking, as he assumed stock sizes of 1,000 to 1,200 animals.

3.1.2. Design of the cowsheds and pasture grazing

The statements of all students concerning stalls and pasture grazing of dairy cows are shown in Figure 5.

Except for Kristina (10), all students mentioned characteristics of cubicle housing. Johannes (6) and Anna (6) described that the cows can move freely in the stable. Anna (6) also emphasized that the cows have a lot of space to get to the pasture through a passageway. In Marie's (6) conception, the cows have the opportunity to walk to the feeding area. Anna (6) and Johannes (6), as well as Kristina (10), Michael (10), and Jürgen (10), described the animals being kept in boxes. Eva (10) and Kristina (10) mentioned characteristics of tethered housing. For example, Eva (10) described that "exactly one cow fits between two partitions," while Kristina (10) assumed that the animals cannot turn around or lie down in the barn. In their statements, both emphasized that the cows in the barn are kept in a very confined space.

A common conception of all students was a separate barn for pregnant cows to which they are brought shortly before birth at the latest and where the calves are born. Anna (6), Marie (6), Mark (6), Johannes (6), and Michael (10) also assumed that the cow and her calf would stay together in this separate barn for a certain time after birth. Eva (10), Kristina (10), and Jürgen (10), on the other hand, described that the cow and calf are separated shortly after birth and that the calves are subsequently kept in a calf pen. All students except Anna (6) assumed that at least one bull is kept on a dairy farm in addition to cows.

Regarding conceptions of the barn's layout, few differences were evident between the sixth and tenth graders, with most students describing cubicle housing. Similarly, all students imagined a calving pen. However, differences can be observed with regard to the cohabitation of cow and calf after birth: All sixth graders, as well as Michael (10), assumed that the cow and the calf would stay together. In contrast, Eva (10), Kristina (10), and Jürgen (10) assumed that they would be separated soon after birth.

The individual student conceptions of the stable floor varied. Anna (6) and Johannes (6) described a floor made of soil, while Kristina (10) and Jürgen (10) imagined a stone floor. For Michael (10), the floor is covered with straw, whereas Eva (10) assumed that the floor would have a grid for the drainage of feces and urine. Marie (6) and Mark (6) imagined a slatted floor. Mark (6) also described rubber mats in the stall areas.

Most of the students thought that cows feel more comfortable in the pasture than in the barn. However, Mark (6), Marie (6), and Eva (10) also believed that cows can also feel comfortable in the barn. For Kristina (10), pasture grazing is rarely if ever an option, so she believes that the animals feel uncomfortable overall, but "put up with being kept indoors." With the exception of Kristina's (10) conceptions, no tremendous year-specific differences could be found concerning conceptions of animal welfare.

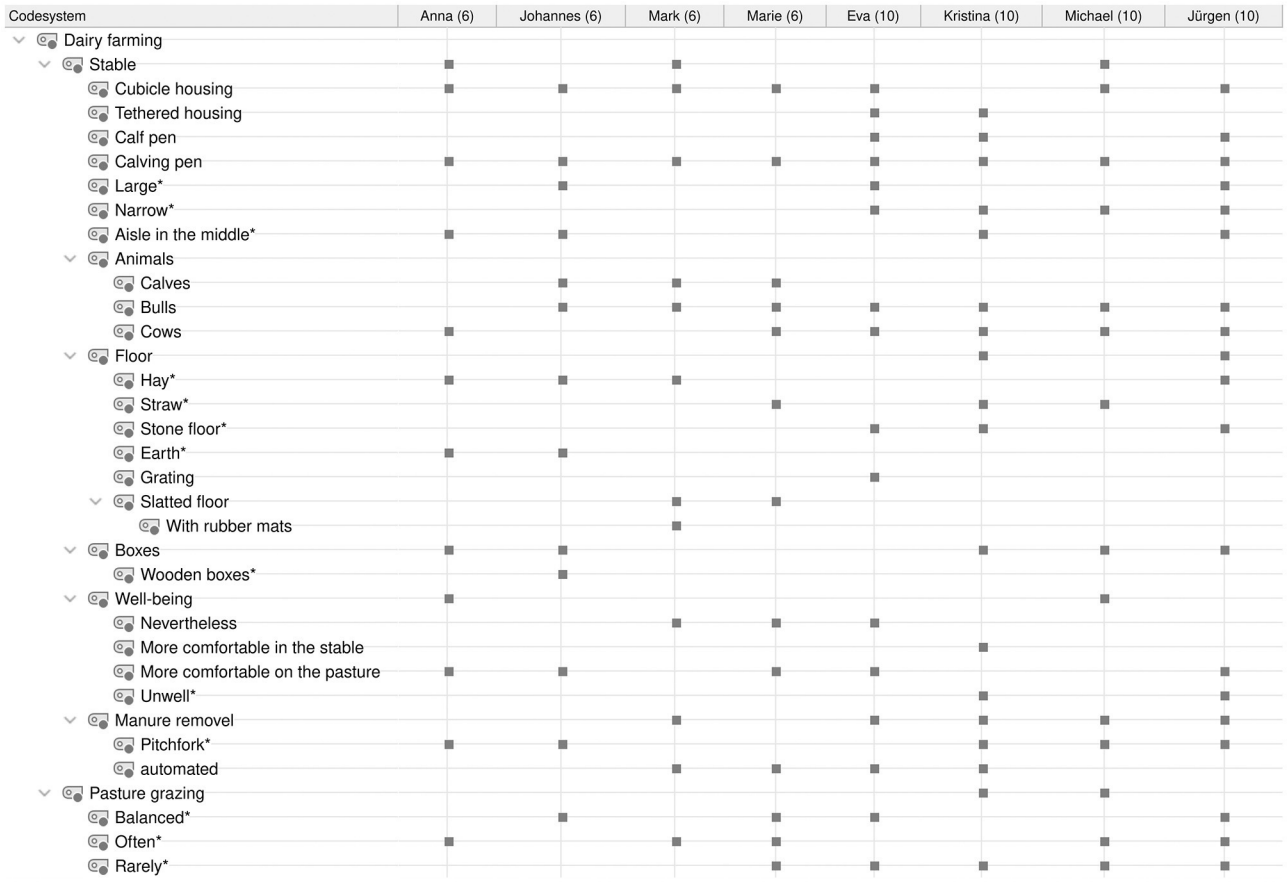

FIGURE 5
Overview of the students' statements on stable and pasture husbandry. *Inductively coded categories. The marks by the categories indicate that they were named by the student.

The students assumed that dairy farming takes place predominantly on pasture. With the exception of Kristina (10), all students imagined a passage from the barn to the pasture. For Jürgen (10), pasture grazing is limited to organic farming. Accordingly, he had more differentiated conceptions than the sixth graders. In contrast, Kristina (10) and Eva (10) believed that the cows rarely if ever graze outside. Their conceptions thus differ significantly from those of the rest of the participants.

3.2. Students' conceptions of the milking process and milking technique

The statements of all students regarding the milking process and milking techniques are shown in Figure 6.

All students imagined a mechanical milking process utilizing partially automated milking plants. Eva (10) was the only student who additionally assumed that a fully automatic milking robot takes over the work of the dairy farmer. In this context, five students associated the verb "suck" with the mechanical milking process. Moreover, the students stated that the mechanical milking process is more effective than milking by hand. Hand milking was considered somewhat outdated or traditional by the students. According to Anna (6), Mark (6), Marie (6), Kristina (10), and Jürgen (10), hand milking is used only by small farms with a few cows. Johannes (6), Mark (6), and Marie (6) suspected that farms practice milking by hand for cost-related reasons, as it seemed to be cheaper than buying a milking machine. In the conceptions of Anna (6) and Marie (6), milking by hand is classically practiced with a bucket and stool.

Regarding milking frequency, most of the students imagined that a cow is milked one to three times a day. What stands out is the statement by Michael (10), who assumed that a cow without a calf is milked once a month and a pregnant cow or one that has already calved is milked three to four times a month.

Regarding the duration of milking with a milking machine, the students estimated that it generally takes 5 to 10 min per cow. However, Kristina (10) and Eva (10) assumed a milking time of 15 to 30 min. Apart from Michael's (10) conceptions of milking frequency, no significant year-specific differences could be found regarding overall conceptions about the milking process and milking technique.

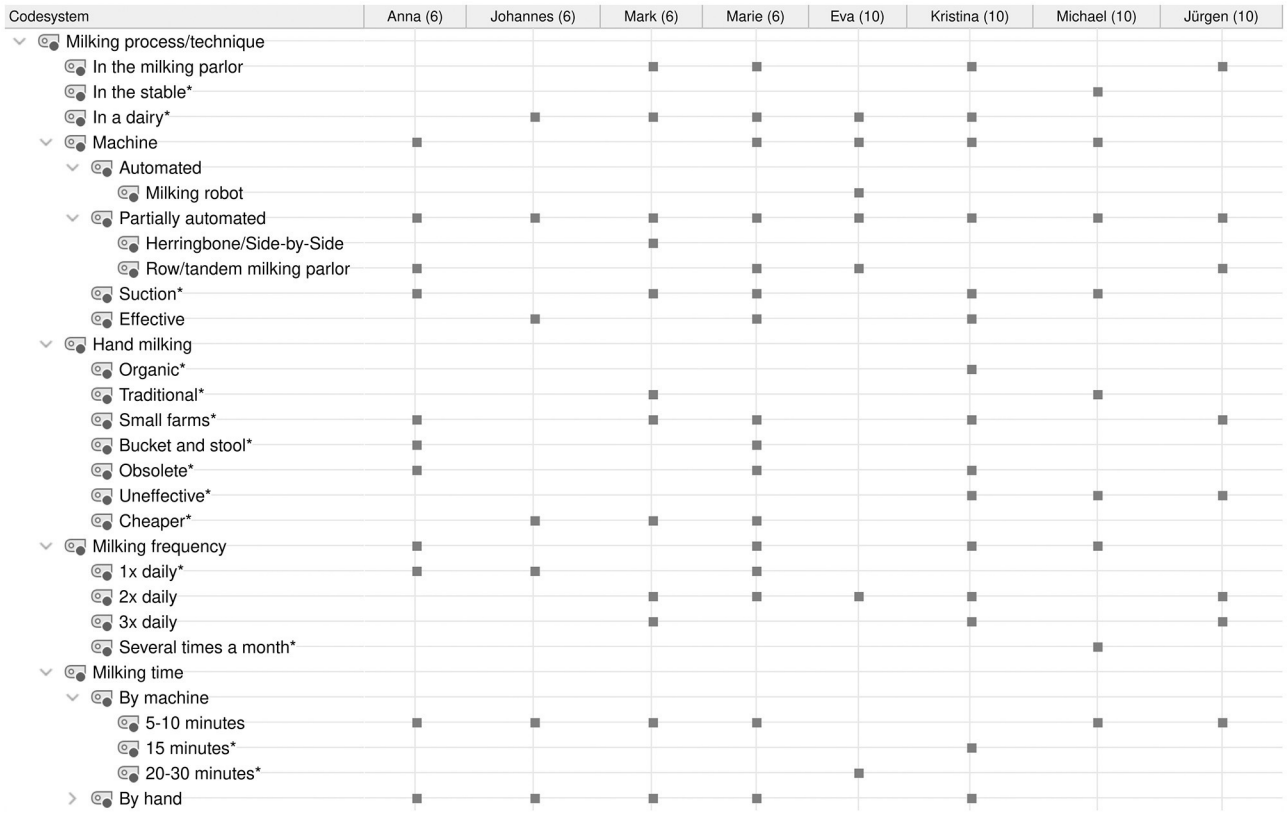

FIGURE 6
Overview of the students' statements on the milking process and milking techniques. *Inductively coded categories. The marks by the categories indicate that they were named by the student.

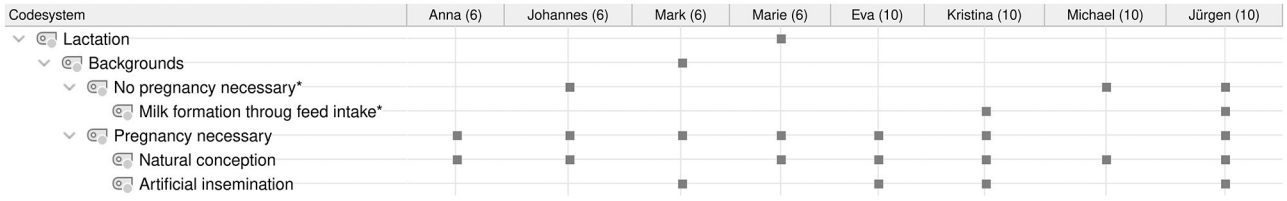

FIGURE 7
Overview of the students' statements on the reasons for milk production. *Inductively coded categories. The marks by the categories indicate that they were named by the student.

3.3. Students' conceptions of milk production in dairy cows

3.3.1. Reasons for milk production

The statements of all students on the reasons for milk production are shown in Figure 7.

Regarding the reasons for milk production, Anna (6), Mark (6), Marie (6), and Eva (10) stated that a cow typically produces milk for her calf and therefore has to calve once. Johannes (6), Kristina (10), and Jürgen (10) were not aware of this at first. After a hint from the interviewer, however, they also independently concluded that a cow must have once been pregnant to produce milk. Michael (10), on the other hand, believed that cows already produce milk "passively" before the first calving and that production is enhanced by a pregnancy and a calving. This is what Michael (10) called a "passive side effect of being a cow mother." He added that the milk is drunk by the calf and that milk is "taken away" from it by milking.

All students except Mark (6) basically imagined natural insemination by a bull. Eva (10), Kristina (10), and Jürgen (10) also considered artificial insemination, which Eva (10) associated with large farms, in particular. Jürgen (10) understood artificial insemination to mean that "genetic materials" are inserted into the cow or that they are ingested through the feed.

Overall, the tenth graders had more differentiated conceptions about why a cow produces milk. They could imagine artificial insemination in addition to natural insemination, while the sixth

graders anticipated only natural conception. Mark (6) was the only respondent to rule out natural insemination. He had precise conceptions about the process of artificial insemination, explicitly naming a technician for artificial insemination methods.

3.3.2. Process of milk production

The lactation process was described and outlined very differently by different students. The expressions of all students on the process of milk formation are shown in Figure 8. Figure 9 shows two exemplary drawings of students' conceptions of milk production in a cow's udder by Mark (6) and Michael (10).

All students except Anna (6) named the cow's stomachs, which are responsible for nutrient utilization, and the udder as organs involved in milk production. Marie (6) and Jürgen (10) imagined that milk production itself occurs in a separate organ in front of the udder, while Johannes (6) and Kristina (10) stated that milk production occurs in one of the stomachs. For Anna (6), milk production takes place in the intestine. Mark (6) was the only student to describe the mammary gland tissue and the cisterns in the udder. He described that the udder is mainly responsible for milk production. Johannes (6), Marie (6), Kristina (10), and Jürgen (10) imagined that the udder is like an empty balloon after milking. Only Mark (6) believed that the udder is permanently made of tissue and that some milk remains in it even after milking.

All students except Anna (6) described an udder with four teats. Anna (6) described an udder with six or seven teats. Kristina (10) also considered an udder with more than four teats, although she described it as unusual.

There was a predominant consensus that the nutrients in milk are absorbed from food. Anna (6), Johannes (6), Marie (6), Kristina (10), and Michael (10) were also convinced that a cow must ingest food as a prerequisite for milk production. Furthermore, Mark (6), Eva (10), and Jürgen (10) stated that milk yield can be increased by special feed. According to Kristina (10) and Michael (10), the feed significantly affects milk quality.

Overall, it is clear that the students' conceptions of the lactation process vary widely.

4. Discussion

4.1. What conceptions do students have of keeping dairy cows?

4.1.1. Localization and stock size of dairy farms in Germany

The results reveal different students' conceptions regarding the localization of dairy farms in Germany. Most of the students imagined that dairy farms are predominantly in Bavaria. In

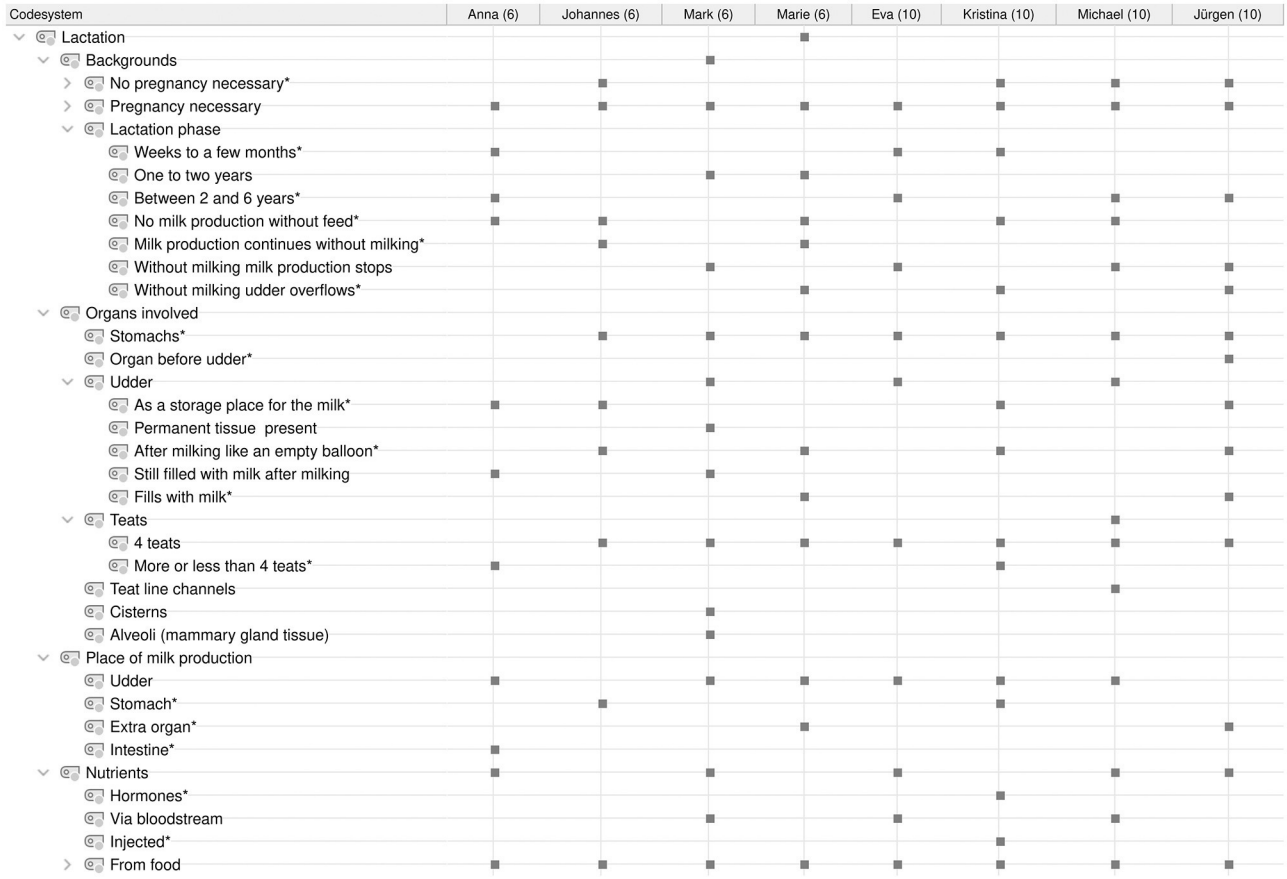

FIGURE 8
Overview of the students' statements on the process of milk formation in a cow. *Inductively coded categories. The marks by the categories indicate that they were named by the student.

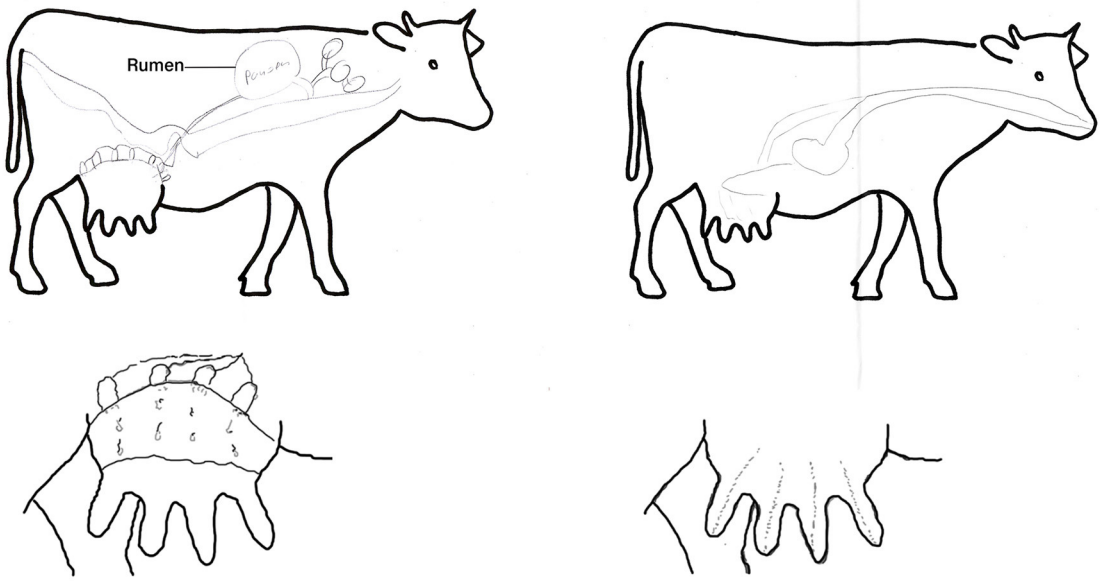

FIGURE 9
Drawings by Mark [6th grade, 12 years; **(left)**] and Michael [10th grade, 16 years; **(right)**] of milk production in the body and udder of a cow.

addition, Marie (6) and Michael (10) named northern Germany, while Mark (6) also mentioned central Germany and Jürgen (10) localized dairy farms in Schleswig-Holstein and Mecklenburg-Western Pomerania. This roughly corresponds to the actual distribution of dairy farms in Germany, as the most significant milk production occurs in Bavaria, Lower Saxony, North Rhine-Westphalia, and Schleswig-Holstein (7, 12). Although about half of all German dairy cows are kept in Bavaria and Lower Saxony (7, 12), Lower Saxony was only associated with increased dairy farm establishment by Eva (10). Thus, Bavaria was the federal state primarily associated with dairy farming by the students in this study, even though dairy cows in Lower Saxony graze more frequently in percentage terms than those in Bavaria (7, 12). Moreover, given that the students lived in Lower Saxony, it would be expected that dairy farming in Lower Saxony would be more present in students' conceptions. Thus, the regional correlation between students' hometowns in Lower Saxony and the high density of dairy cattle in northwestern Germany turned out to be weaker than expected. This might be due to the influence of the marketing of cow's milk, which tends to convey an idyllic image of grazing cows on an alpine pasture rather than cows in the plains. The students' conceptions of stock size (from 20 to over 200 animals depending on farm size) are quite close to actual stock sizes; most dairy farms in Germany keep between 20 and 49 animals or over 100 animals (12). These realistic conceptions are consistent with the results of a study on conceptions of stock sizes size of fattening pigs, dairy cows, and laying hens by Folsche and Fiebelkorn (38). On the other hand, Mark (6) expressed the conception of intensive livestock farming, as he could only imagine dairy farms with a stock size of 1,000 to 1,200 animals. These results are in contrast with the findings of Hamann (37), who could not identify any conceptions of industrial farming with stock sizes of several thousand animals among the students surveyed.

4.1.2. Design of the cowsheds and pasture grazing

Regarding housing, almost all students described dairy cattle being kept in cubicle housing, where the animals can move freely. This is in line with common husbandry practice in Germany, as 83% of dairy cows are kept in cubicle housing (12). In the context of cubicle housing, most of the students imagined that the animals can choose between the stall and pasture utilizing a passageway. This is in line with the results reported by Hamann (37) and Folsche and Fiebelkorn (38). The students indicated that the cows can choose between being outdoors and staying indoors at will. This is matched by the students' conceptions of dairy farming as a combination of confinement and pasture grazing. Thus, their conceptions reflect the typical landscape of Northwest Germany of dairy cows on pastures (12, 37, 38). However, since the students hardly associated Lower Saxony or Northwest Germany with dairy farms, this idea can be described as "idyllic."

Kristina (10) and Eva (10) showed that the keeping of dairy cows can also be associated with less species-appropriate factory farming. In their conceptions, tethering dominates. Notably, however, the number of cows kept in tethered housing has decreased by 62% since 2010 (30). Their negative conceptions could have been influenced by primary experiences with dairy farms, as the quality of (dairy) farm visits influences conceptions of agriculture (37, 48, 49).

All students expressed the realistic view that pregnant dairy cows are kept in a calving pen shortly before calving and give birth to the calf there. In more differentiated responses, Eva (10), Kristina (10), and Jürgen (10) described that the cow and calf are separated promptly after birth and the calves are subsequently kept in a calf pen. These conceptions are in line with real-life practices on dairy farms after calving (31). In contrast, Anna (6), Marie (6), Mark (6), Johannes (6), and Michael (10) had romanticized conceptions

about practices on dairy farms after calving, as they imagined that the cow and calf stay together for a longer period after birth.

The students' descriptions of the stable floor varied widely. Marie (6) and Mark (6) imagined a slatted base, which in Mark's (6) description is additionally covered with rubber mats. This image is very realistic, as it corresponds to the typical floor of cubicle housing (31). Also realistic is Eva's conception of a floor with grating to drain feces and urine. This description corresponds to the ground in tethered housing when manure is removed using the flow manure method (31). Notably, Folsche and Fiebelkorn (38) found realistic conceptions of a barn floor only among children who grew up on farms. Accordingly, their results are not in line with the realistic conceptions of Marie (6), Mark (6), and Eva (10), who only gained primary experiences on farms during vacations or when visiting relatives. In interviews with the other students, a floor consisting of earth, a stone floor, and a floor exclusively covered with straw were described. These conceptions are less realistic and can be compared to the research findings of Hamann (37), who described that children anticipated a floor covered with hay or straw.

Regarding animal welfare, Kristina (10) stated that grazing was rarely (if ever) an option, as this might explain why she stated that animals feel unwell overall. This conception can be explained by the findings of Folsche and Fiebelkorn (38). In their study, students stated that domestic animals kept only indoors have less space and are not well due to limited movement. In the current study, the remaining students' conception was that the wellbeing of the animals is higher in the pasture than in the barn. This reflects the view of the majority of the students in this study that dairy farming is predominantly pasture-based. Mark's (6) and Marie's (6) conception of the animals' feeling equally comfortable indoors can be justified by the fact that in their conceptions, the animals are kept in cubicle housing in which the animals do not suffer from lack of space and movement restrictions.

4.2. What conceptions do students have of the milking process and the technology used?

All students' conceptions about milking systems corresponded to the methods used in Germany for milking: partially automated milking systems or AMS (31). They described a milking process carried out mechanically and employing partially automated milking plants. Eva (10) was the only student who could also imagine a milking robot. The machine milking process was considered by the students to be more effective than traditional milking by hand. These results contrast with the findings of Brämer (39), who identified a romanticized conception of farms without technical aids in the majority of students surveyed. Therefore, most students have increasingly realistic ideas of industrialized agriculture with automated milking equipment.

Students' conceptions of the duration of machine milking are predominantly consistent with milking durations in partially automated milking systems (31). In addition, most of the students also had realistic conceptions about milking frequency, as dairy cows are milked two to three times per day (28). In contrast, Michael (10) believed that a cow that has never calved is milked once a month, while a pregnant cow or one that has already calved is milked three to four times a month. Michael's example shows a romanticized idea of livestock farming with a small stock size on dairy farms and a very low milking frequency.

4.3. What conceptions do students have of milk production in dairy cows?

4.3.1. Reasons for milk production

Anna (6), Mark (6), Marie (6), and Eva (10) immediately associated the reason for a cow's milk production with the fact that a cow typically produces milk for her calf and consequently has to calve at least once. Accordingly, the four students had realistic conceptions about the reasons for lactation (31).

Johannes (6), Kristina (10), and Jürgen (10) could only explain the reason for cow's lactation after a hint from the interviewer. One reason for this could be that the students were aware of the connection between pregnancy and the production of milk as food for the newborn in humans, but this knowledge was not yet transferred to the context of the cow.

Michael (10), on the other hand, believed that dairy cows produce milk before the first calving and that milk production is enhanced by a pregnancy and calving. At the same time, he emphasized that milk is produced for the calf and that the calf is deprived of milk when its mother is milked. This suggests that Michael (10) could not identify any interdependence between pregnancy/calving and milk production. Thus, the awareness that a cow produces milk for her calf is not alone sufficient to trigger a cognitive conflict regarding milk production prior to first calving (50).

All students except Mark (6) imagined that a cow on a dairy farm is naturally inseminated. Students' conception of natural insemination on dairy farms explains why almost all of the students imagined at least one bull on a dairy farm in addition to dairy cows. This romanticized conception does not correspond to the reality on dairy farms, as the majority of conventional dairy farms and even 80–90% of organic dairy farms in Germany use artificial insemination (33, 34). Eva (10) and Jürgen (10) showed more elaborated conceptions of insemination on dairy farms. For example, Jürgen (10) described artificial insemination on dairy farms as a process in which genetic materials are inserted into the cow. However, he assumed that the genetic materials for insemination could also be ingested through feed. He might have derived this unrealistic conception from his knowledge about special feed for increasing milk yield.

Mark (6) was the only student who excluded natural insemination on dairy farms. He even named an insemination technician in the context of insemination on dairy farms, which is consistent with the real-life approach (31, 33).

4.3.2. Process of milk production

The students predominantly described the stomach (for nutrient utilization) and the udder as organs involved in lactation.

This conception can be classified as realistic, as is the conception that the nutrients in milk are absorbed through food (31).

In contrast, the conceptions about the anatomical location of milk production were largely unrealistic. Anna (6) stated that milk production occurs in the intestines, while Johannes (6) and Kristina (10) assumed that it occurs in one of the cow's stomachs. Marie (6) and Jürgen (10) believed that milk production occurred in an unspecified separate organ in front of the udder. Accordingly, for a large proportion of the students, the udder functioned only as a "storage location" for the milk, not as a "production location." In this context, Johannes (6), Marie (6), Kristina (10), and Jürgen (10) also imagined the udder as an empty container after milking. However, since milk formation takes place exclusively in the udder, which consists of mammary gland tissue and complex blood, nervous, and lymphatic systems, among other things (31), it is clear that the majority of the students do not have a basic understanding of the production of milk. Along these lines, only six of the eight students described an udder consisting of four teats. The students' conceptions about the structure of an udder are fundamentally in line with the results from the study by Brämer (39), according to which only 64% of the students knew that a cow's udder has four teats.

Mark (6) was the only student who showed elaborate conceptions of milk formation, describing the udder as the place where milk is produced and, in this context, naming the mammary gland tissue as well as the cisterns. According to Mark's (6) statement, the mammary gland tissue is permanently present in the udder and some milk remains in the udder even after milking. It is likely that Mark's (6) conceptions about the milk formation process are based on his primary experiences on a dairy farm (milking and making dairy products; Table 1).

4.4. Comparison of the conceptions of the sixth- and tenth-grade students

When analyzing the students' conceptions of keeping dairy cows, no significant differences could be discerned between the sixth- and tenth-grade students (RQ1, Section 3.1.). Regarding the stock size and the localization of dairy farms in Germany, both the sixth and tenth graders had realistic conceptions (see Section 3.1.1.). The only conspicuous feature was the differentiation of the statements by the tenth graders. Tenth graders overwhelmingly indicated multiple locations where dairy farms are localized. Moreover, they anticipated several stock sizes, while the sixth graders mostly gave only one answer. Regarding pasture grazing, the conceptions of both the sixth and tenth graders were idyllic and romanticized. It can be inferred that for the students, the conception of cows grazing in a pasture was sufficient to explain the production of milk and that neither sixth- nor tenth-grade students had ever needed to construct a new conception of pasture grazing (23, 24).

The conceptions regarding the design of the cowsheds were very detailed and mostly realistic for both the sixth and tenth graders (see Section 3.1.2.). However, negative and partly outdated conceptions about the keeping of dairy cows could be identified in the case of two tenth graders. These results are in line with those of the study by Folsche and Fiebelkorn (38), in which elementary school students realistically described common husbandry practices in dairy farming, although romanticized as well as decidedly negative conceptions could be identified (38). For the two tenth graders, negative and partly outdated conceptions about the design of cowsheds may have been shaped by primary and secondary experiences with dairy farms.

In contrast, the sixth and tenth graders differed in their conceptions of calf husbandry. While the sixth graders had romanticized conceptions of the cohabitation of mother cow and calf after birth, the tenth graders had mainly realistic ideas (see Section 3.1.2.). The romanticized conception that the dairy cow and her calf stay together for a long time after birth may be due to the fact that the sixth graders do not yet associate the birth of a calf with industrialized agriculture and mass production. In this regard, an individualization and personification of the dairy cow and her calf could contribute to this romanticized conception (51).

The conceptions of the sixth and tenth graders about the milking process and milking techniques can also be classified as mostly realistic (RQ2, Section 3.2.). All students were aware that nowadays, the milking process is carried out by machines to increase its effectiveness. In this context, the students had realistic conceptions about milking frequencies and duration. Sixth and tenth graders' conceptions of the milking process and milking technology did not differ significantly. It is clear that the sixth and tenth graders had a basic understanding of industrial agriculture with regard to the technical aspects of the milking process (6).

Sixth and tenth graders' conceptions of the reasons for and process of milk production differed from scientific concepts (RQ3, Section 3.3.). Comparing the stated reasons for milk production among all students, more sixth than tenth graders linked milk production to calving (Section 3.3.1.). The tenth graders were only able to imagine that a cow must have been pregnant at one time to produce milk after a hint from the interviewer. One reason for this could be that in the Lower Saxony curriculum for science education, the topic of livestock farming is only covered until the sixth grade (52). This is also reflected in the secondary experiences of the tenth graders with the topic of dairy farming, as all the students were unsure when they had learned about dairy farming in school and what content was covered (Table 2).

Regarding reproduction on dairy farms, the tenth graders showed more differentiated conceptions than the sixth graders. However, only the sixth grader Mark had realistic and elaborated conceptions about artificial insemination on dairy farms (see Section 3.3.1.). Therefore, it could be assumed that the students do not have a basic knowledge of the quantities of milk produced for consumption in Germany, which results in the need for artificial insemination. In addition, the students may not be aware of the limitations of relying on natural insemination, as this may also be a factor in their unrealistic conceptions of insemination on dairy farms. Awareness of the increased efficiency in milk production with using automated milking systems is apparently not sufficient to trigger a cognitive conflict related to natural insemination on dairy farms (50).

In a more specific consideration of milk production in a cow's body, neither sixth nor tenth graders envisioned the udder as the location of milk production (see Section 3.3.2.). Accordingly, the udder functions only as a "storage place" for them. Where and how

milk production takes place was described realistically and in detail only by the sixth grader Mark.

In summary, it can be stated that both the sixth and tenth graders have realistic conceptions regarding dairy farming, the milking process, and milking techniques. By comparing the conceptions of the sixth and tenth graders, it became apparent that the conceptions of the tenth graders were more differentiated and elaborate. For example, the tenth graders gave several possibilities for stock size (see Section 3.1.1.). The more differentiated conceptions of the tenth graders could be due to developmental psychological factors. Adolescents' factual knowledge increases significantly as part of the intelligence domains in the context of cognitive development. In addition, working memory, which is responsible for reasoning, among other things, also makes substantial developmental progress between the ages of five and twenty (53).

The conceptions of the sixth-grader Mark and the tenth-grader Michael are particularly striking: Mark had a particularly well-founded expertise on certain topics for his age, while Michael sometimes had particularly unrealistic conceptions, despite being one of the older students. Their conceptions may be due to the influence of their primary experiences with dairy farms.

4.5. Influence of primary and secondary experiences on students' conceptions

The results show that students' primary experiences can significantly influence their conceptions about the production of cow's milk.

With the exception of Michael (10), all students had already been on a farm as part of a class trip or during vacation. Mark (6), Marie (6), Eva (10), and Jürgen (10) had already visited milking plants, and some were even allowed to milk cows themselves. These students had realistic conceptions about the keeping of dairy cows as well as the milking process and the technology used (see Sections 3.1. and 3.2.).

Michael (10) was the only student who had only minor primary experience with farms—he had only had contact with a farm with fattening bulls. The lack of intensity and quality of experiences with dairy farming could be a reason for Michael's unrealistic conceptions about, for example, milk production (48, 49).

The particularly elaborate and detailed conceptions of Mark (6) can be explained by his regular primary experiences on an alpine pasture, where he was allowed to milk cows and make dairy products himself. In addition, he expressed that in his free time he watches knowledge programs on agriculture topics. Thus, active primary experiences with dairy farms can contribute to improved conceptions about dairy farming (48, 49).

The studies by Hamann (37) and Folsche and Fiebelkorn (38) also demonstrated that students' primary experiences can have a major impact on their conceptions of agriculture.

In contrast, it can be assumed that students' secondary experiences play a rather minor role in their mental constructs. Agricultural topics, such as livestock farming, are covered in science lessons in Lower Saxony once in elementary school and once at the beginning of high school (52, 54). The tenth graders had only vague recollections of the treatment of agricultural topics in science classes (Table 2). In comparison, the sixth graders could remember their secondary experiences more concretely (Table 1). Therefore, it can be hypothesized that secondary experiences with dairy farms have an impact on students' conceptions only shortly after the experience.

5. Implications for education and research

The results of this study show that, depending on their age and experience with dairy farms, students' conceptions can vary significantly from idyllic, romanticized conceptions to detailed and elaborated conceptions of dairy farming and milk production. Moreover, even if students grow up in a region with intensive dairy cow husbandry, primary and secondary school teachers should not assume that students have realistic conceptions of dairy farming and milk production. To promote students' understanding of the production and consumption of animal products like milk, an important component of promoting responsible consumption and production of food (SDG 12), the stock size and husbandry of dairy cows as well as the process of milk production can be crucial information to include in lesson design (17, 38). For example, the relationships between the amount of milk produced on a dairy farm in Germany, the development of herd size, dairy cow husbandry, and the process of milk production could be addressed in class. This is also a suitable context in which to highlight the social (SDG 1, 3), ecological (SDG 6), and economic aspects of livestock production that affect the sustainable production of our food in the context of ESD (SDG 12) (17, 55).

Here, we present an example of how to use student conceptions of dairy farming and milk production to structure teaching lessons to stimulate the reconstruction of students' conceptions. Notably, Posner et al. (24) listed dissatisfaction with the existing conception and logic, plausibility, and fruitfulness of the new conception as conditions for changing pre-instructional conceptions. Michael's (10) conceptions of the milking process, milking frequency, and milk production provide a good starting point for reconstruction. For example, his conceptions of the milking process and milking frequency could be contrasted with the amount of milk produced annually in Germany. Michael could first explain why he believes that a cow is milked in the stall and only several times a month. Based on this conception, students could be asked to assess whether an annual production volume of 33 million tons of cow's milk is feasible under these circumstances (6). For this purpose, the students could be given the number of dairy cows in Germany and the amount of milk that a cow produces per day as further information. Subsequently, the teacher could lead a discussion on how a cow produces 25 liters of milk per day. This would also make the connection between food production and consumption patterns in terms of ESD (17). To show the interdisciplinarity of the topic, the global demand for milk in view of the growing world population, factory farming and the impact on the environment could be discussed in the context of SDG 2, 6, and 12.

As demonstrated in previous studies, primary experiences with dairy farming and dairy cattle can influence students' conceptions

(37, 38, 48, 49). To counteract the romanticized conceptions—which exist among both sixth and tenth graders—field trips should be designed to provide direct experiences with dairy farms. To ensure that field trips do not present a limited picture of agriculture, the teacher should provide appropriate preparation and follow-up. Previous studies have demonstrated that real-life encounters with farms have a positive effect on interest in agricultural topics and promote realistic conceptions of farm animal husbandry (48, 49).

In this study, it was found that secondary experiences tended to play a minor role in students' conceptions. In this context, the study by Schütte and Busch (41) demonstrated that only half of primary and secondary teachers in Germany teach agricultural topics on a regular basis. In addition to differences in the regularity of teaching series related to agriculture, the way agricultural topics are taught in the classroom may vary (40). Therefore, it is not possible to derive a generalized statement about the influence of secondary experiences with dairy farms on students' conceptions. However, regularly conducting farm-related lesson series can be promoted among teachers by, for example, developing a lesson series on ESD that promotes students' expertise in farm animal husbandry and sustainability and addresses the social, environmental, and economic aspects of farm animal husbandry for sustainable production of our food.

Due to the small sample size and the qualitative research design, the results of this study are not representative of sixth- and tenth-grade students in Germany. Therefore, to generate valid statements regarding student conceptions of milk production with a focus on dairy farming, milking, and milk formation, one could increase the sample size. If the sample is enlarged, an expansion of the ages/school classes should be considered to obtain representative results on student conceptions of milk production in Germany and the differences across ages/school classes. As a further option, the students' conceptions of milk production could be investigated in a quantitative follow-up survey.

Furthermore, it should be noted that the students' conceptions were evaluated with an interpretative methodology. Therefore, misinterpretations of the students' statements cannot be excluded (25–27). Moreover, this study did not distinguish between the conceptions of students who grew up in the city and those who grew up in the countryside. For a differentiated consideration of the influence of primary experiences, one could take this parameter into account when designing the sample in another study.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

LS: formal analysis, writing—original draft, and writing—review and editing. FF: conceptualization, writing—review and editing, project administration, resources, and supervision. GO: investigation, data curation, formal analysis, and writing—original draft preparation. LA: investigation, data curation, and writing—original draft preparation. EF: 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.

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Knowledge, attitudes, and practices of registered dietitians and nutritionists regarding enteral and parenteral nutrition support in Ghana: a needs assessment study

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Background: There is a paucity of data on enteral and parenteral (EN and PN) nutrition support (NS) provided by nutrition and dietetic practitioners in adult acute care settings in Ghana. Furthermore, gray literature suggests that Ghanaian clinical nutrition professionals (CNPs) are seldom involved in advanced nutrition care teams.

Objectives: To assess the knowledge, attitudes, and practices of Ghanaian CNPs regarding EN and PN.

Methods: An online cross-sectional survey was administered to Ghanaian CNPs ahead of a professional development workshop on EN and PN Support. Participants were asked questions about initiation and timing of NS, and knowledge on availability of commercial formula. A 5-point Likert scale was used to assess self-efficacy in using EN and PN. To assess practical knowledge on EN and PN, participants were asked to identify whether EN or PN was indicated for seven short case scenarios. Open-ended questions were used to assess reasons for participant self-ratings.

Results: A total of 76 dietitians, nutritionists, students, and interns completed the survey. For EN, self-efficacy scores were lowest for the calculation of enteral goal rate, and goal volume (mean 3.20±1.27), and writing of EN prescriptions (mean 3.07±1.29). Self-efficacy scores for the formulation of alternative formulas in lieu of commercial formula were the highest (3.63±1.36). For PN, self-efficacy scores for all domains were lower than 3, with the lowest scores observed for writing PN prescriptions (2.19±1.14) and determining micronutrient additives (2.12±1.04). We identified limited training and lack of practical exposure to NS, limited ability to effectively monitor tube feeds, and prohibitive cost and limited availability of EN and PN formula among the barriers impacting self-efficacy scores.

Conclusion: Given the vital role that CNPs play in the delivery of EN and PN, it is important to develop professional training programs especially focused on PN to bridge knowledge and practice gaps.

KEYWORDS

enteral nutrition, parenteral nutrition, nutrition support, dietitian, nutrition professionals, Ghana

1. Background

Both enteral and parenteral nutrition support have been used to deliver nutrients to patients in acute care settings to reduce the risk of malnutrition, improve disease prognosis, and reduce hospital length of stay (LOS), among other outcomes (1, 2). Given the highly specialized nature of enteral and parenteral nutrition support (sometimes referred to by the authors as advanced nutrition support), associations like the American Society for Parenteral and Enteral Nutrition (ASPEN) and the European Society for Clinical Nutrition and Metabolism (ESPEN) provide resources to nutrition professionals who are interested in pursuing careers in nutrition support. These include professional development products like webinars and podcasts, and resources and links to accredited professional certifications in nutrition support (3, 4). While their certifications are internationally recognized and available to dietitians outside of the US and Europe, the costs might be prohibitive to some nutrition professionals working in sub-Saharan Africa.

ASPEN and ESPEN periodically provide up-to-date guidelines on nutrition support which are useful references that provide tools for the safe initiation and use of enteral and parenteral nutrition (1, 5, 6). In Ghana and the West African region at large, there are no known societies or organizations focused on advanced nutrition support (7). Additionally, knowledge, attitudes, and practices of nutrition professionals regarding enteral and parenteral nutrition support has not been extensively studied.

Ghanaian clinical nutrition professionals (CNPs) have continued to rely on locally available solutions to mitigate the risk of malnutrition, especially in the pediatric population. With the help of governmental and non-governmental agencies, they have delivered several oral nutritional supplementation programs, including the community-based management of acute malnutrition (CMAM) program (8) to help mitigate malnutrition both at the clinical and community levels. These have helped improve maternal and child nutritional status throughout the country (9, 10). In severely malnourished hospitalized children for example, the CMAM protocol recommends use of the therapeutic milk-based formula F-75 as the initial line of therapy to stabilize patients while they receive treatment for any identified medical complications (usually 2–7 days). Provision of F-100 after the stabilization phase is then made to help the children with their catch-up growth (11). Due to cost and limited availability of these commercial formulas, they are usually prepared in-house by nutrition professionals from reconstituted milk powder, vegetable oil, and sugar with addition of a vitamin and mineral mix. Another product that is integral to the CMAM program is Ready-to-use Therapeutic Food (RUTF), which is an energy and nutrient dense peanut-based supplement provided to children who have malnutrition and are 6 months and older. This is also used among vulnerable adults with severe malnutrition including pregnant and lactating women, people with HIV and/or tuberculosis, and geriatric populations (12).

Although there are extensive guidelines for the treatment of acute severe malnutrition in children and some adults through the CMAM program (9), there is limited information on nutrition support, specifically enteral and parenteral nutrition support, in critically ill adult patients. For adult patients in critical condition and unable to eat by mouth, it is unclear from the literature if Ghanaian nutrition professionals are directly involved in the provision of tube feeding recommendations and how much expertise they have, to make such recommendations. The limited research studies available on nutrition support in Ghana also suggest that there are limited to no guidelines used within health care facilities to provide nutrition support to critically ill patients, so that individual practitioners mainly adopt published ASPEN/ESPEN guidelines to make their own personal protocols (13, 14). Additionally, it appears that nutrition professionals are not always part of advanced nutrition care teams. This has the potential to impact their knowledge base on nutrition support from limited exposure.

Based on the current scope of practice around the world, dietitians are an integral part of the nutrition support team and are the health care professionals required to make prescriptions and provide tube feeding recommendations for patients in need of nutrition support. Given the socio-economic disadvantage of some patients in Ghana and the limited resources available for medical nutrition therapy, it is possible that dietitians currently equipped with the skills to deliver these services may face challenges, including access to commercial formulas, in providing advanced nutrition support. Unfortunately, the enteral and parenteral nutrition experiences and knowledge base of practicing CNPs in Ghana is poorly understood. Research is therefore needed to identify existing knowledge gaps among nutrition professionals so that appropriate programming and training can be developed to help bridge these gaps as well as to develop standard guidelines for the provision of advanced nutrition support in the Ghanaian context. Therefore, this study aimed to assess the knowledge gaps and barriers to providing advanced nutrition support to patients in clinical care settings in Ghana.

Abbreviations: ASPEN, American Society for Parenteral and Enteral Nutrition; CMAM, Community-based Management of Acute Malnutrition; CNPs, clinical nutrition practitioners; CPD, continuous professional development; EN, enteral nutrition; ESPEN, European Society for Clinical Nutrition and Metabolism; GAND, Ghana Academy of Nutrition and Dietetics; GV, Goal volume; GR, Goal rate; ICU, Intensive care unit; KAP, Knowledge, attitudes, practices; LOS, Length of stay; NS, Nutrition support; PN, Parenteral nutrition; PO, per OS (by mouth); Post-op, Post-operation; RUTF, Ready-to-use therapeutic food.

2. Methods

2.1. Study design and participants

A cross-sectional needs assessment survey was administered to Ghanaian dietitians, nutritionists, nutrition and dietetic students, and dietetic interns. Dietitians and Nutritionists are considered two separate designations in Ghana, with separate requirements for credentialling. While dietitians usually work in the clinical setting,

nutritionists tend to work in the public health/community setting. Nevertheless, there are some overlaps in the roles that they play. For instance, some nutritionists who work with the CMAM program receive in-service training/specialization to enable them to provide tube feedings. To that end, it was important to include nutritionists in our assessments. Two weeks ahead of a planned remote professional development workshop on Advanced Nutrition Support, participants were invited to complete an online survey to identify their knowledge, attitudes, and practices (KAPs) regarding enteral and parenteral nutrition support. This also served as a pre-test for the planned workshops. We opted for an online survey because the advent of the COVID-19 pandemic made online meetings popular and feasible among nutrition and dietetic professionals in Ghana.

No sample size estimates were calculated for this project. According to the leadership of the Ghana Academy of Nutrition and Dietetics (GAND), the total number of dietitians and nutritionists registered with the Academy is about 400. Approximately twice this number (800) are students/interns (undergraduates and graduate students at various stages of their training), yet less than a quarter of these students were registered with GAND at the time of the study (personal communication with Mr. Agordoh, Vice President of GAND). Of the total number of registered members, the number who usually participate in continuous professional development (CPD) workshops is 100 to 150. Given the fact that there are so few practicing CNPs in Ghana, we aimed to reach all nutrition professionals who historically worked with the Academy through its continuing professional development workshops. Therefore, being a currently active dietitian, nutritionist, nutrition/dietetics student, or dietetic intern, and willingness to complete the survey were the only criteria for participation. The study was reviewed and deemed exempt by the institutional review board at the University of Massachusetts Amherst, and all participants signed an informed consent form online before completing the survey. Links to the online survey were shared using the official WhatsApp page of the Ghana Academy of Nutrition and Dietetics, with a script describing details of the study. Once participants completed the consent forms, they were directed to the main survey. Daily reminders were posted on the WhatsApp page, and participants who had incomplete surveys received daily reminders via emails sent through REDCap.

2.2. Research instruments

The online surveys were self-administered using REDCap (see Supplemental data). Of note, this needs assessment was part of a broader project, and participants completed 2 surveys, one prior to a planned workshop and the other after the workshop. The needs assessment survey comprised a total of 31 questions: 6 related to nutrition support practices and types of formula used in participants' facilities; 12 related enteral nutrition (EN) knowledge and EN self-efficacy; and 13 related to parenteral nutrition (PN) knowledge and PN self-efficacy. Participants were asked questions about their knowledge regarding indications for enteral and parenteral nutrition, timing of nutrition support, and commercial supplements available on the Ghanaian market.

To reduce participant burden, simplify IRB application for exempt review, and ensure utmost privacy and confidentiality of participants, demographic information was not collected from participants. Email addresses and hospital affiliation were the only identifiable information collected (some hospitals may have only one or two dietitians, making hospital affiliation identifiable information). Participants were asked to indicate whether they were a dietitian, nutritionist, or student/intern, as well as provide their number of years of work practice where applicable. The data was de-identified during the analysis phase of the project.

2.3. Evaluation of enteral and parenteral nutrition support practices in the clinical nutrition setting

All participants were asked to indicate the name of the hospital or facility in Ghana where they worked in an open-ended question. They were also asked using a binary "yes," "no" question if their facilities provided clinical nutrition support services to inpatients. To evaluate current enteral and parenteral nutrition support practices in facilities that offered nutrition support, respondents were asked to answer questions regarding the proportion of patients who received nutritional support based on ASPEN/ESPEN guidelines, types of malnutrition screening tools typically used to assess patients, types of professionals who usually performed the screening, and types of enteral and parenteral nutrition formula typically used in their facility, if any.

2.4. Assessment of self-efficacy in using enteral and parenteral nutrition

A 5-point Likert scale was used to assess participants' self-efficacy using enteral and parenteral nutrition support. We were interested in 5 domains of self-efficacy for each aspect of nutrition support. Domains for EN were (1) indications for EN, (2) selection of EN Formula, (3) calculation of goal volume (GV) and goal rate (GR) of EN; (4) writing of EN prescriptions and (5) preparation of alternative enteral formula in lieu of commercial formula. Domains for PN were (1) indications for TPN; (2) calculation of macronutrient provision of PN; (3) calculation of GV and GR of TPN infusion; (4) writing TPN prescriptions; (5) determining TPN micronutrient additives. Enteral and parenteral nutrition had 5 questions each, and each question was scored 1 through 5 (1 = lowest, 5 = highest). Therefore, the highest possible score after summing all 5 questions was 25 for enteral and 25 for parenteral nutrition.

To assess overall confidence in prescribing enteral and parenteral nutrition, participants were asked to rate themselves on a scale of 1 to10 (1 = least confident, 10 = most confident) in terms of their general comfort level using enteral and parenteral nutrition support. To assess factors related to self-efficacy scores, we included 2 open-ended questions, a single question repeated for enteral nutrition and the other for parenteral nutrition, asking participants to explain the reasons for allocating their scores.

2.5. Assessment of practical knowledge on the indications for enteral and parenteral nutrition

To assess practical knowledge about enteral and parenteral nutrition support, participants were asked to identify whether enteral or parenteral nutrition support was indicated for seven short case scenarios. The case scenarios were: (1) paralytic gastric ileus, (2) poor PO intake in hemodialysis patient, (3) poor PO intake in patient with pancreatic

cancer, (4) small bowel obstruction (5) partial small bowel obstruction with gastrostomy-jejunostomy tube with venting gastrostomy port, (6) malnourished patient with BMI of 13 kg/m^2, intubated, unable to obtain access for feeds, (7) patient with gastroparesis with residuals consistently 450–600 ml. One point was assigned for each correct answer, and no point for an incorrect answer (1, 0 respectively) making a total of seven possible points for the practical knowledge aspect of the survey. The case scenarios were based on study questions provided to Yale-New Haven Hospital dietetic interns during their medical ICU rotations (Please see questionnaire from Supplemental data).

2.6. Assessment of student and intern exposure to enteral and parenteral nutrition support

Participants who identified themselves as students or dietetic interns were asked to answer 8 student-specific questions related to level and field of study, and prior exposure to enteral and parenteral nutrition in class or on rotation. An open-ended question was used to collect responses on what their idea of enteral and parenteral nutrition support entailed either from class, personal studies, or rotations.

Students were asked to complete the practical knowledge sections of the survey but were not required to complete the self-efficacy portions of the questionnaires.

2.7. Statistical analyses

Statistical analyses were conducted using IBM SPSS Stats Version 28.0 for Windows (IBM Corporation). Chi-square analyses were conducted for qualitative variables to test for associations between professional background and years of experience, and knowledge of enteral and parenteral formula available on the Ghanaian market. A p value ≤ 0.05 was considered statistically significant. Open ended questions were analyzed qualitatively, by first manually coding the data and then thematizing responses to identify emergent themes.

3. Results and discussion

A total of 76 dietitians, nutritionists, students, and interns completed the needs assessment survey (Table 1). The number of initial survey responses to the consent forms was 111. Out of these, there were 100 completed consent forms and 11 incomplete consent forms (forms that were not included if they had not been signed by participants). By the closing time of the pre-workshop surveys, there were a total of 77 completed pre-workshop surveys (out of the 100 completed consent forms). Out of these, 7 were duplicates (cross-referenced with participant email addresses). These were excluded, leaving the total number of completed surveys at 70. Upon further quality control checks, 6 surveys were identified as surveys that could count as competed surveys—likely were not read into the system as complete due to glitches. These were manually coded as complete and included to the 70 completed surveys, bringing the total number of completed pre-test surveys to 76. Please see Supplemental data (Supplementary Figure 1) for participant flowsheet.

TABLE 1 Occupational characteristics of participants.

	N (%)
Professional background (all participants)	
Nutritionist	12 (16)
Registered dietitian	47 (62)
Student/intern	17 (22)
Total	76 (100%)
Years of experience for nutrition professionals	
Years	*N* (%)
3 or less	20 (34)
4 or more	39 (66)
Total	59 (100)

TABLE 2 Classification of hospitals where respondents work.

Classification	Number of Hospitals	Regions where Hospitals are located
Teaching Hospitals	6	Greater Accra, Ashanti, Central, Volta, Northern
District/Mission Hospitals	10	Greater Accra, Ashanti, Central, Eastern, Western, Bono, Ahafo, Northern, North-Eastern
Regional/Military/ Police Hospitals	8	Greater Accra, Northern, Bono
Private Hospitals	7	Greater Accra, Northern, Ashanti
Quaternary Hospital	1	Greater Accra
Total	32 hospitals	10 regions total*

*Participant hospitals were located in 10 out of 16 regions in Ghana, representing 63% of the regions.

Most participants self-identified as registered dietitians (62%), followed by Nutritionists (16%), and students or interns (22%). Among dietitians and Nutritionists, two thirds (66%) reported 4 or more years of work experience (Table 1). The clinical settings in which the dietitians and nutritionists worked (32 hospitals) included teaching hospitals, district and mission hospitals, regional/military/police hospitals, private hospitals, and a quaternary hospital. These hospitals together were situated in 10 out of the 16 regions of the country (Table 2).

3.1. Nutrition screening practices for acutely ill patients

Most participants ($n = 62$, 82%) indicated that their facility provided clinical nutrition services to inpatients. Of the participants who reported providing clinical nutrition services to hospitalized patients 65% ($n = 40$), indicated that nutrition screening was routinely practiced, while 35% reported either no routine screening or did not know. According to ASPEN guidelines, nutrition risk screening is recommended for all hospitalized patients in the ICU to identify those who might benefit the most from enteral nutrition (15). Providing standard guidelines for the

Ghanaian context could help increase the number of facilities that perform routine nutrition screening as part of patient care.

Based on the responses provided by the 40 participants who selected "yes" for nutrition screening, dietitians were ranked first by most of the participants (45%) as the main professionals performing nutrition screening in their facility, followed by Nutritionists, who were ranked second by 33% of participants (Figure 1). In a UK-based study assessing nutrition support attitudes and knowledge among health care providers, there was strong agreement that dietitians were responsible for decisions regarding nutrition support, although in their study there was also strong agreement that anesthetist/intensivists and medical and surgical teams were responsible for decision making, demonstrating that it was unclear to participants who was responsible for nutrition support decision-making (16). None of the respondents in our study ranked nurses first. Indeed, the same number of participants ($N=9$, 23%) ranked medical doctors and nutritionists as the main professionals who conducted nutritional screening of patients. While this was unexpected given the central role that nurses play in patient care in Ghana and deviates from the UK study where nurses were considered integral to nutrition support decision making (16), this finding is consistent with results from a Europe-wide survey that showed minimal involvement of nurses in performing nutritional assessments in ICU settings (17). In developing nutrition support teams, it would be useful for dietitians, nutritionists, and nurses to work together to provide screening protocols for critically ill patients.

3.2. Nutrition screening tools

Most participants (90%) indicated that BMI or body weight assessments (including one response for Bioelectric impedance analysis) were the main screening methods used in their facilities. While BMI is a convenient, easy-to measure screening tool, it may not be reflective of nutritional status when used on its own. It is the current position of the [American] Academy of Nutrition and Dietetics that the Malnutrition Screening Tool (MST) be used to screen adults for malnutrition regardless of their age, medical history, or setting (18). However, only 33% of participants who performed screening in their facilities indicated that the MST was used. Given that the MST is also an easy to administer tool and asks questions about weight loss (and degree of weight loss), and appetite or food intake, considering it in protocols for Ghanaian dietitians might be useful.

3.3. Initiation of nutrition support

Less than half of participants who provided inpatient clinical services ($n=24$, 39%) indicated that patients were usually kept for <48 h prior to initiation of nutrition support. However, 21% reported that they did not know or were not sure. This elucidates the challenge identified from literature that CNPs are not always part of nutrition support teams in Ghana. Additionally, combined, the number of participants indicating that patients are not screened within 48 h was 40%. This percentage suggests the need for providing protocols for nutrition screening upon admission to the ICU to promote early initiation of nutrition support.

For patients with indications for enteral nutrition, 28% of respondents indicated that <10% of them did receive enteral nutrition within 48 h. Again, many of the participants (25%) did not know or were not sure, which is expected given our results regarding initiation of nutrition support.

3.4. Types of EN and PN formula used in facilities

Majority of participants (63%) indicated that kitchen-prepared blenderized tube feeds (BTF) were the main formula used for enteral nutrition in their facilities, followed by commercial ready-to-use

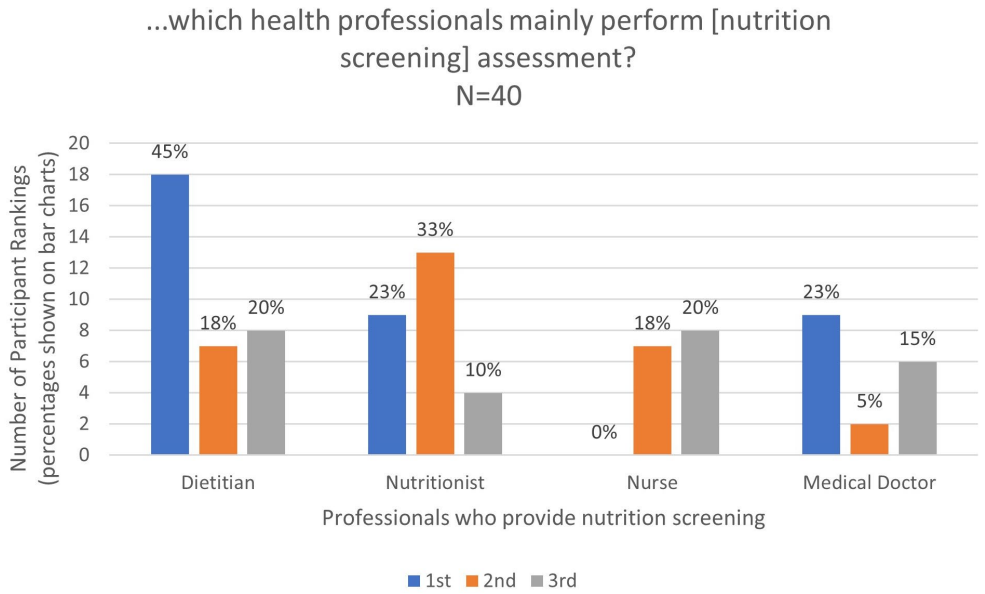

FIGURE 1
Ranking of professionals who perform nutrition screening.

formula (50%). Future protocols for enteral nutrition in Ghana must take this into consideration and possibly provide guidance for the use of BTF.

When asked to list the types of formula used for tube feeds, the majority of the participants who listed commercial formula listed oral nutrition supplements rather than enteral formula (brand names withheld). While the oral nutrition supplements that were mentioned were most comparable to 1.0 and 1.5 kcaL/ml polymeric formula from the same company and could be used in the short term for tube feeds, it is not ideal for use as sole source nutrition for a prolonged period. This is because it is more likely to exceed micronutrient RDAs while using it to meet daily Caloric goals. For instance, based on the nutritional information provided on its label, a single cartoon of the 1.5 kcaL/ml oral nutrition supplement mentioned by participants is designed to meet 25–50% of the RDAs for most micronutrients. Most oral nutrition supplements also have a higher amount of sugar, making them hypertonic, compared to enteral formula. This might enhance tube feed blockage and degradation if used for a prolonged period (19). There is limited literature about what the typical ICU LOS is in Ghana. In a study published among burns patients in the Komfo Anokye teaching hospital, the mean LOS for each year, over a 4-year analysis, ranged between 6 and 9 days (20). Among patients with surgical site infections in the Korle Bu teaching hospital, post-op hospitalization ranged between a day for limb amputations to 16 days for rectal surgeries (21). Among COVID patients, ICU stays ranged up to 7 days (22), and based on field observations, ICU stays could generally range between 10 and 21 days (personal communication with Mr. Agordoh, Vice President of GAND). For short-term use, the benefits of oral nutrition supplement as tube feeds might outweigh the risk of overnutrition. However, unless otherwise contraindicated, polymeric isotonic enteral formula are recommended as the gold standard for enteral nutrition for patients in the ICU (15). We recommend that future studies assess ICU LOS and other clinical outcomes of patients on different types of oral and enteral nutrition formula in Ghana.

About a third of participants in our study (37.1%) indicated that no PN formula was used in their facilities, while some of the participants did not know which PN formulas were used in their facilities (30.6%). Two-in-one and three-in-one solutions were indicated by 10 and 9% of participants, respectively, suggesting the limited access to PN formula in Ghana. Two participants (3.2%) who selected the "other" option on the survey mentioned that they used single nutrient solutions including dextrose, amino acid, and fat emulsions (brand names withheld). Given the limited knowledge of facility-specific PN formula among many respondents, it is important that health facilities provide in-service training on formulary as part of dietitian orientation so that they are aware of formulas available in their institutions.

3.5. Knowledge of enteral and parenteral nutrition formula on the Ghanaian market

About half (51%) of the participants reported that they had no knowledge of the enteral or parenteral nutrition formulas available on the Ghanaian market. Chi-square analyses showed no statistical differences in knowledge of available enteral and parenteral nutrition supplements/formulas based on profession (dietitian vs. nutritionist). There were also no statistical differences in knowledge of the available enteral formula based on number of years of practice (Table 3). Similarly, there were no differences in knowledge of parenteral nutrition formula by profession or number of years of practice (Table 3). Given the relatively fewer number of nutritionists who participated in the study, it is likely that there was not enough statistical power to detect true difference between the two groups.

3.6. Nutrition professionals' self efficacy and practical knowledge in prescribing and using enteral and parenteral nutrition

Table 4 shows the mean scores for self-efficacy of nutrition professionals regarding the use of enteral and parenteral nutrition support. Scores for each question (maximum score = 5), as well as for the sum of scores for all questions (maximum score = 25) are shown here. Scores for overall confidence level (maximum score = 10) and practical knowledge (maximum score = 7) are also displayed.

For enteral nutrition, self-efficacy scores were lowest in the calculation of enteral goal rate and goal volume (mean 3.20 ± 1.27) and writing enteral nutrition prescriptions (mean 3.07 ± 1.29). Self-efficacy scores were highest for the formulation of alternative enteral formulas in lieu of commercial formula (3.63 ± 1.36).

For parenteral nutrition, self-efficacy scores for all domains were lower than 3, with the lowest scores observed for writing parenteral nutrition prescriptions (2.19 ± 1.14) and determining micronutrient additives (2.12 ± 1.04).

Consistent with the above results, participants rated themselves lower in overall confidence in their ability to prescribe and use parenteral nutrition (2.75 ± 2.56) compared with enteral nutrition (5.27 ± 3.08). Our results show that there are more deficits in knowledge and practice of parenteral nutrition compared to enteral nutrition. Training protocols focused on parenteral nutrition support are warranted, and in-service specialization might be needed to help bridge this knowledge gap.

3.7. Underlying factors related to low self-efficacy

We identified two themes that described underlying factors for low self-efficacy in the use of enteral and parenteral nutrition support among Ghanaian nutrition professionals: limited training and exposure to nutrition support during professional education and practice, and limited knowledge of available formula for administering enteral and parenteral nutrition support. Some participants reported exposure to enteral and/or parenteral nutrition support through online courses, overseas training, and hands on experience in the work setting. However, most reported they had limited training and were rarely exposed to nutrition support in their practice setting. These results are consistent with findings from a similar study performed among health professionals in the UK, who cited lack of knowledge, no clear guidelines, or unclear responsibilities as barriers to delivery of nutrition support (16). In

TABLE 3 Knowledge of available enteral and parenteral nutrition formula according to profession and number of years of practice.

	Professional practice				Number of years of practice*			
	Nutritionists *N*=12	Dietitians *N*=47	Total *N*=59	value of *p* (2-sided)	3 years or less *N*=20	4 years or more *N*=39	Total *N*=59	value of *p* (2-sided)
Do you know of any enteral nutrition (EN) formulas available on the Ghanaian market?								
Yes	4 (33%)	25 (53%)	29 (49.2%)	0.333	7 (35%)	22 (56%)	29 (49.2%)	0.170
Do you know of any parenteral nutrition (PN) formulas available on the Ghanaian market?								
Yes	4 (33%)	17 (36%)	21 (36%)	1.000	5 (25%)	16 (41%)	21 (36%)	0.263

*Years of experience dichotomized due to small sample sizes.

their study, sources of knowledge for dietitians were largely from reading (>50%), followed by additional courses (>40%), and work-based training (30%). Less than 30% of the dietitians in their study cited University training and nutrition teams as sources of knowledge on nutrition support. This shows that even within settings where dietitians are expected to have more experience with nutrition support, continuous professional development post-University training is an integral part of their competency building for nutrition support therapy.

Some participants in our study mentioned that they did not know what types of formula were available on the Ghanaian market. Given the low confidence of many nutrition professionals to administer these important aspects of nutrition care, additional training and specialization could be made available to them to help increase their knowledge regarding delivery of enteral and parenteral nutrition, including exposure to information about types of formula available on the market. More importantly, intensive training to improve skills related to calculation of GV and GR of both EN and PN is required, given that these were the areas where the participants had the lowest self-efficacy. This would make them valuable members of the medical team as they would be able to make recommendations to other health practitioners and patients about both appropriate formula type and tube feed administration.

3.8. Challenges with administering enteral and parenteral nutrition

In addition to the themes that appear to characterize reasons for the perceived low confidence in the use of enteral and parenteral nutrition among this group of participants, some participants identified challenges that directly related to the administration of enteral and parenteral nutrition support. Three themes emerged for this (1) monitoring of patients, (2) cost of commercial formula, and (3) availability of commercial formulas. Some participants reported that even when enteral nutrition was available and used in their practice setting, monitoring of feeds was a challenge. While additional information was not provided by participants, a plausible explanation for this finding could be due to lack of skilled personnel. The only published study on nursing protocols for nasogastric feeding in Ghana suggests that there are limited opportunities for in-service training and insufficient tube feeding protocols available to nurses (14). Limited availability of commercial formula was another recurring theme from the open-ended questions. From the responses, many nutrition professionals who did provide enteral nutrition support usually provided blenderized tube feeds (BTF). Although BTF have several advantages, including promotion of a diverse microbiome, better tolerance to enteral feeds, and potential cost savings, there are some challenges, including concerns with safety and nutritional adequacy (23). Additionally, a recent Master's thesis assessing the nutritional composition of hospital prepared blends (fortified soups), identified that there were no standardized recipes available, and the blends were not nutritionally adequate (24).

Protocols that provide standardized recipes and modular additives to improve macronutrient and micronutrient composition could be warranted given the socioeconomic context of Ghana, where dietitians rely more on BTF than on higher costing commercial

TABLE 4 Self-efficacy, knowledge, and practice of enteral and parenteral nutrition support among ghanaian dietitians and nutritionists.

	Mean score (SD)
Enteral nutrition	
Indications for EN	3.51 (1.24)
Selection of EN formula	3.32 (1.25)
Calculation of GV and GR of EN	3.20 (1.27)
Writing EN prescriptions	3.07 (1.29)
Preparation of an alternative enteral formula in lieu of commercial formula	3.63 (1.36)
EN self-efficacy (total)[1]	16.73 (5.84)
Overall confidence in prescribing and using EN (2)	5.27 (3.08)
Parenteral nutrition	
Indications for TPN	2.75 (1.27)
Calculation of macros	2.57 (1.34)
Calculation of GV and GR of TPN	2.34 (1.20)
Writing TPN prescriptions	2.19 (1.14)
Determining TPN micronutrient additives	2.12 (1.05)
PN self-efficacy (total)[1]	11.92 (5.56)
Overall confidence in prescribing and using PN[2]	2.75 (2.56)
Knowledge and Practice Domain	
Practical Knowledge in EN and PN[3]	3.16 (1.92)

EN, enteral nutrition; GV, goal volume; GR, goal rate; PN, parenteral nutrition; macros, macronutrients; TPN, total parenteral nutrition. $N = 59$.
[1]Total possible score is 25.
[2]Total possible score is 10.
[3]Total possible score is 7.

formulas for the provision of enteral nutrition. Additionally, given food safety concerns with the use of BTF, protocols should also include guidelines for safe handling of ingredients, bolus vs. continuous feeding, appropriate hang time of feeds, and policy regarding source of feeds (e.g., feeds brought from home vs. hospital prepared feeds). Training modules should also educate on the contraindications for the use of BTFs, and appropriate equipment (for example specifications for French size of tubes) among other things.

3.9. Student knowledge of enteral and parenteral nutrition support

Less than 50 % of students in our sample (47%) reported that they had encountered information on nutrition support in their training. Twenty nine percent (29%) of them reported that they had encountered information on parenteral nutrition support in their clinical rotations, whereas 71% of students reported that they encountered information on enteral nutrition support during rotations (Table 5). The sample of students and interns was small ($N = 17$) and is therefore not representative of all dietetic students and interns across the country. However, given the fact that the results demonstrate and mirror the need for training on parenteral nutrition compared to enteral nutrition, advocating for more robust training for students and interns both in the classroom and on clinical rotations is warranted.

TABLE 5 Student and intern exposure to enteral and parenteral nutrition support.

Question	Yes
Have you encountered advanced nutrition support (enteral and parenteral nutrition) in your training yet?	8 (47%)
Have you encountered any enteral nutrition on your rotations?	12 (71%)
Have you encountered any parenteral nutrition on your rotations?	5 (29%)

3.10. Strengths and limitations of study

Our study questionnaire (see Supplemental data) contained extensive questions related to nutrition support practices in the clinical setting in Ghana, including nutrition screening practices in hospitals, accessibility of formula, and knowledgebase of practitioners regarding EN and PN. To keep participant burden as minimal as possible, the practice assessment aspect of the questionnaire was limited to participants correctly identifying the indications for EN and PN from seven short case studies. Admittedly, knowledge of the indications for EN and PN on their own might not necessarily reflect practical knowledge of EN and PN. We however believe that this serves as a good proxy to provide some baseline data on this aspect of EN and PN knowledge to aid with future education.

Additionally, while we made efforts to include all CNPs who historically participated in CPDs, 76 participants completed our needs assessment survey, which limited our statistical power to detect differences in knowledge based on profession and years of practice. That said, it is noteworthy that these professionals were affiliated to 32 hospitals across 10 out of the 16 regions of the country. The 63% representation of the country's regions could be suggestive that the data regarding nutrition support practices might be similar across hospitals. Generalizations of these findings should however be done with caution, and future studies specifically exploring regional differences across all the regions of the country might be beneficial. Regarding the findings for students, generalizability is unknown as we had a very small sample of students.

Finally, our study assessed knowledge, attitudes, and practices of CNPs in Ghana but did not examine clinical outcomes of patients in ICU settings in Ghana. Future studies designed to examine outcomes of patients on nutrition support are needed to complement our findings as efforts continue for identifying areas of improvement for future training.

3.11. Implications for research and practice

Our study aimed to identify gaps in enteral and parenteral nutrition knowledge and practices among Ghanaian dietitians, nutritionists, students, and dietetic interns. We found low self-efficacy scores in performing some aspects of enteral nutrition support and even lower scores for parenteral nutrition support. Participants were least confident in their ability to calculate enteral goal rate, goal volume, and writing prescriptions. On the other hand, respondents were most confident in their ability to "formulate" alternative formulas in the absence of commercial enteral nutrition formula. Additionally, participants had low confidence in all domains of PN measured, with the least confidence in parenteral nutrition prescriptions and

determining micronutrient additives. We identified one master's thesis that assessed nutrition support practices in 17 Ghanaian health facilities (13). This project targeted all health professionals and found among other things that there were limited standards in the delivery of nutrition support in the respondent's facilities (13). While this is grey literature, it provides insights into the paucity of research on the question of nutrition support in Ghana and foregrounds the need for continued research in the area. To our knowledge, our study is the first in Ghana to characterize the extent of the gap and the first to do so exclusively among Ghanaian nutrition professionals.

Given the key role that dietetic and nutrition professionals play in the delivery of EN and PN, it is important to develop professional training programs to bridge gaps in knowledge and practice. Further, based on our results, there is a greater need for parenteral nutrition training compared to enteral nutrition, and this must be considered when formulating training programs. This is useful for programming continuous professional development for currently practicing dietitians and nutritionists, as well as future professionals. Furthermore, given that the student participants reported a lack of exposure to enteral and parenteral nutrition support on their rotations, it is important that specialized rotations in this field are developed and made available to this group of future dietetics professionals who might be interested in pursuing careers in advanced nutrition support. This might require additional training for dietitians already in active practice who may in turn serve as professional mentors and preceptors for students and interns.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics statement

This study involving human participants was reviewed and approved by the Institutional review board at the University of Massachusetts Amherst. All participants provided their written informed consent to participate in this study.

Author contributions

RA and PA: conception and design (80% and 20% respectively) and manuscript drafting. RA, PA, EC, and MA: contribution to acquisition, analysis, or interpretation of data. RA, PA, VS, CW-A, LC, MA, and EC: critical revision. 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.2023.1197610/full#supplementary-material

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Effects of intensive nutrition education and counseling on nutritional status of pregnant women in East Shoa Zone, Ethiopia

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Background: Nutritional status is defined as an individual's health condition as it is influenced by the intake and utilization of nutrients. Maternal malnutrition is widespread throughout the world, with Sub-Saharan Africa and Asia bearing the brunt of the burden. The objective of this study was to evaluate the effect of intensive nutrition education and counseling on nutritional status during pregnancy.

Methods and materials: The study was a one-year, two-arm parallel design cluster randomized controlled trial conducted in the East Shoa zone, Ethiopia, from January 1, 2021, to February 30, 2022. A total of 374 participants were enrolled in the intervention (n = 185) and control (n = 189) groups. End-line data were collected from 163 women, from each group. The intervention package provided three counseling sessions by trained midwives, three-page take-home brochures prepared in local languages, and the delivery of 18 weekly serial short text messages. The women in the control group received routine nutrition education from the health facilities. After adjusting for potential confounders, a linear mixed-effects model was employed to assess the intervention effect.

Results: After the intervention, the mean mid-upper arm circumference in the intervention group increased by 1.8% (23.08 vs. 23.44, $p < 0.01$). Similarly, the proportion of undernutrition in the intervention group was 11% (25 vs. 36%, $p = 0.02$) lower compared to the control arm. At the end of the trial, women in the intervention arm had significantly better nutritional status than women in the control group ($\beta = 0.47$, $p < 0.01$).

Conclusion: The findings showed that intensive nutrition education and counseling using the health belief model was effective in improving nutritional status and reducing undernutrition among pregnant women. As a result, nutrition education and counseling using HBM constructs, as well as regular reminder messages, should be provided to pregnant women as part of the routine antenatal care service.

KEYWORDS

nutrition, pregnancy, MUAC, RCT, Ethiopia

Introduction

Prenatal nutrition is a key component of healthy pregnancy outcomes (1). Improving nutritional status before and during pregnancy can reduce their risk of pregnancy complications such as preeclampsia, gestational diabetes, the risk of birth defects, intrauterine growth restriction, and later chronic disease (2). The prevalence of maternal malnutrition is high in the world, mainly in Sub-Saharan African and Asian countries (3, 4). In Ethiopia, maternal undernutrition is persistently high.

According to the Ethiopian Demographic and Health Survey (EDHS) report, 22% of sexually active women are undernourished (BMI less than 18.5) (5). Inconsistent with this report, studies carried out around the various regions of Ethiopia indicated that the proportion of maternal undernutrition is remarkably high. The prevalence of under nutrition ranged from 21.8 to 43.1% among pregnant women, with rural women having a greater prevalence. These studies were conducted at health institutions and community level (6–9).

Maternal anthropometric measurement and intake of optimum diet are determinants of fetal weight and gestational age at birth. Mid Upper Arm Circumference (MUAC) is the recommended measurement technique for nutritional status, because of its sensitivity in identifying undernutrition and its simplicity. It is also the preferable technique in low-resource settings where women have thin subcutaneous fat, changes in MUAC are more likely to reflect changes in muscle mass (10). Low maternal MUAC has been shown effective in identifying adverse birth outcomes such as preterm birth, intrauterine growth restriction, birth asphyxia, and small for gestational age. Therefore, MUAC measurement is recommended over pre-pregnancy weight to determine the risk of unfavorable pregnancy outcomes (11).

A woman's pregnancy is an experience of life that can influence both her current health and the health of her developing fetus; it can also raise awareness of nutrition issues and change a woman's dietary practices over time (11). Nielsen et al. reviews found that prenatal nutrition education and counseling treatments had a beneficial effect on pregnant adolescents' diet quality and understanding of nutrition (12). Another systematic review of RCTs primarily conducted in high-income nations found that prenatal nutrition counseling decreased excessive gestational weight gain. The interventions included in these trials are; individual dietary consultation, group education, consultation with a dietician, and stepped-care behavioral interventions (13).

Gaetke et al. claim that even a single dietary counseling session with a registered dietician is associated with improved short-term clinical results (14). In the general population, it is suggested that nutrition education is a recommended sustainable and promising strategy to reduce maternal malnutrition (15). However, the studies done in Ethiopia show the routine nutrition education given to pregnant women by the health care system is vague and inconsistent (16). Because of this, child and mother malnutrition has continued to be a serious public health issue in the nation (5).

Compared to the period before preconception, pregnant women are more eager to know what they should eat and what not (17). Therefore, pregnancy is a good time for education. However, the effectiveness of counseling depends on the proper use of theories of behavioral science (18). Validated behavior change theories and models within the field of nutrition, provide systematic explanations for dietary behavior change that are integral to the nutrition care process, outcome evaluation, intervention, and guiding nutrition assessment. Health Belief Model (HBM) is the most widely used framework for health-related studies and has focused on disease prevention and preventive behaviors. HBM includes fundamental ideas that foretell why people take precautions to prevent getting sick. These constructs of HBM are perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy (19). A meta-analysis showed that the health belief model applies to many types of behavior across populations (20).

Although healthcare practitioners perceived nutrition education to be important, because of a barrier like shortage of time, inadequate space, poor counseling skills, and absence of documentation, women are not receiving adequate nutrition education during antenatal care (ANC) follow-up (21, 22). Furthermore, counseling was provided only once to the mothers throughout ANC follow-up, that is at their first visit only (23).

In the study area, there was a dearth of information on the effect of intensive nutrition counseling and education package on the nutritional status of expectant mothers. Therefore, the purpose of this study was to evaluate the effect of intensive nutrition education and counseling on nutritional status during pregnancy which was measured using MUAC. The study's findings might help planners and policymakers at the national and local levels improve nutrition counseling practices.

Materials and methods

Study area

The study was carried out in East Shoa Zone, Oromia region, Ethiopia from January 4, 2021, to February 28, 2022. The total population in the East Shoa zone is 1,567,953 of which 48.3% were female. According to the East Shoa zone report of 2020, the healthcare facilities in the zone are providing antenatal care for more than 54,408 pregnant women per year. The research location and participants are fully discussed elsewhere (24).

Study design and ethics

The study design was a two-arm parallel cluster randomized controlled trial. The Helsinki Declaration's guiding principles and the standards of good clinical practice were followed during the study's execution. The Institutional Review Board of Jimma University gave their approval to the research protocol (IHRPGD/S21/2018). Each study participant signed a written informed consent form, and pregnant women who could not read or write gave their fingerprints before the trial could begin. The study was registered on May 29, 2022, in the Iranian Registry of Clinical Trials (IRCT20220508054783N1). Results were reported by the Consolidated Standards of Reporting Trials (CONSORT) guideline (**Figure 1**) (25).

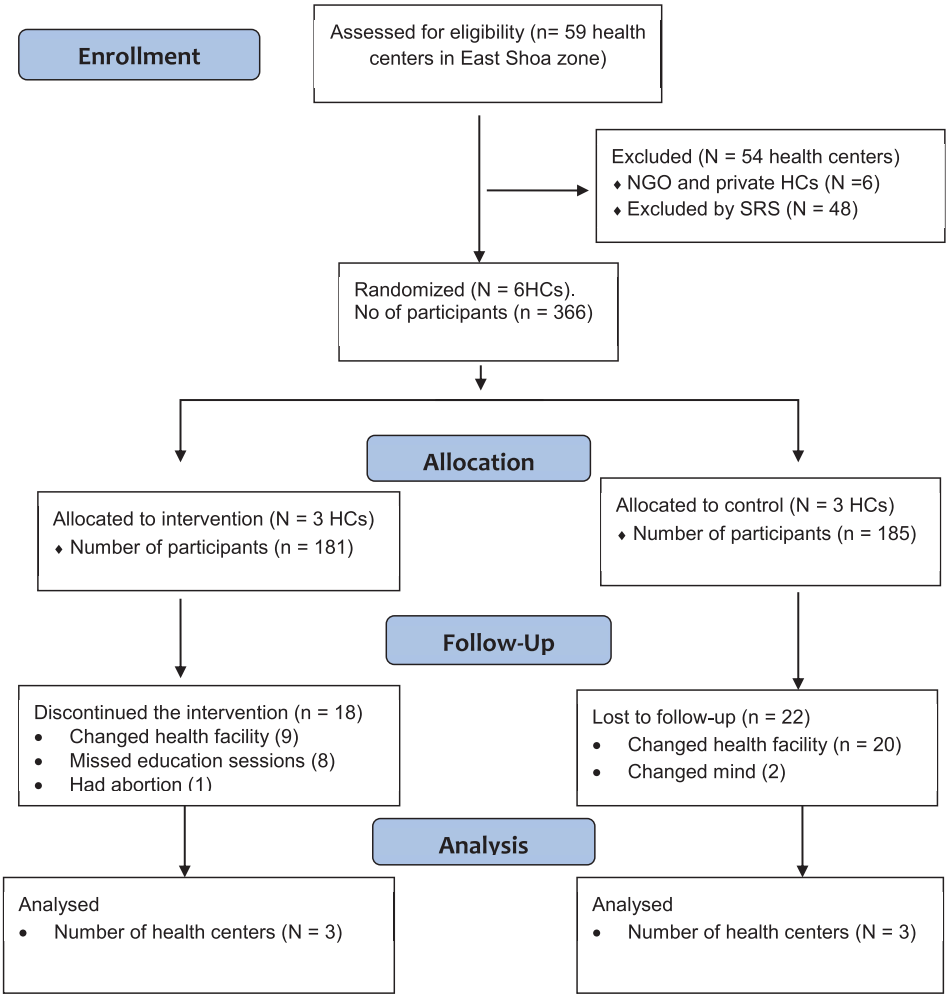

FIGURE 1
The flow of the study participants through the trial according to the criteria recommended in the CONSORT guideline. HCs, health centers; NGO, non-governmental organization; SRS, simple random sampling.

Inclusion and exclusion criteria

Pregnant women were identified using women's self-reports of pregnancy status confirmed by a urine HCG test. The study enrolled pregnant women before 16 weeks of gestational age. Pregnant women who refused to give verbal consent, who intended to leave the research area before delivery, or who had a mental illness or a chronic illness like hypertension or diabetes mellitus were excluded from the study. Those women who had a chronic illness like hypertension or diabetes mellitus were excluded, because these diseases were considered as a factor that can affect the nutritional status of pregnant women and could mask the true effect of nutrition counseling on the nutritional status of pregnant women.

Sample size determination

Using G Power 3.1.9.2 and Fisher's exact test with 80% power and 5% precision, the sample size was calculated. Kedir et al. reported that 24% of expectant mothers (P1) had undernutrition and assuming P1 and P2 have a 17% difference (26, 27).

The calculated sample size was increased by a design effect of two since cluster sampling was employed with a 15% loss to follow-up, the ultimate sample size for both arms was 374 pregnant women. As a result, 189 women in the control group and 185 women in the intervention group were enrolled in the trial, along with all pregnant women who met the inclusion criteria.

Intervention allocation and randomization

From 59 health centers in the East Shoa zone, Non-governmental and private health centers were purposively excluded from the study. Six health centers were selected by simple random sampling (SRS) technique. Health centers with non-adjacent catchment areas were selected from each woreda by SRS (lottery) method. The six selected health centers (Clusters) were randomly allocated to the control and intervention arm by a 1:1 ratio. The cluster size in the control group was 63 study subjects in each

cluster. Whereas, in the intervention arm, 61 participants were allocated to the first cluster and 62 participants were assigned to each second and third cluster.

Study participants were selected using systematic random sampling techniques following the Kth value. By dividing the total number of pregnant women who followed ANC during the study period by the sample size, the Kth value was calculated, and it was found to be five. Pregnant women who arrived first were counted as the first participants, and study participants who came at the fifth interval were also considered until the predetermined sample size was reached.

To minimize message contamination, cluster randomization was used. Pregnant mothers in the same health center were more likely to interact and discuss intervention messages. To prevent this, all pregnant women at one health center were enrolled in the same arm of the study (either in the control or intervention arms). Buffer zones (Non-adjusted catchment area health centers) were left between the control and intervention health centers (clusters) to prevent information contamination.

Intervention

The intervention group received intensive nutrition education and counseling package (INECP) which had 3 components. These include, nutritional counseling was given in three sessions by trained midwives to pregnant women at the intervention arm, three-page brochures to take home in the local languages (Amharic and Afan Oromo) given to pregnant women at the intervention health center, 18 weekly serial short SMS text sent on mobile phone in local language was delivered to pregnant women in the intervention arm. In routine nutritional counseling professionals have been advising pregnant women only to eat one additional meal from available foodstuffs. However, in our study, the intervention given differs from the routine, for it contains intensive nutrition counseling sessions by trained healthcare providers on nutrition during pregnancy and counseling skills, delivery of leaflets containing core messages in local languages, and serial weekly SMS text on mobile phones.

The core nutrition message delivered during the counseling sessions, serial sms text, and delivered leaflet was promoting dietary diversity and additional meals during pregnancy, emphasizing an iron-rich meal, promoting sufficient protein and energy intake, promoting consistent use of the iron-folic acid tablet, use of iodized salt, counseling about healthy eating and reducing heavy workload, preventive deworming after the first trimester, regular antenatal care follow up and bed net use.

The training module was adapted from a blended and integrated nutrition learning module (BINLM). The core message was adapted from the WHO and Ethiopian Ministry of Health national module (27, 28).

The counselors and supervisors received a three-day intensive training that included role-playing using a training manual. As counselors and supervisors of the counseling process, respectively, six BSc midwives and two MSc nutritionists were hired. The training was facilitated by the principal investigator. Invited nutritionists who were certified by training of trainers (TOT) in BINLM supervised the training. The objective of the training was to introduce nutrition during pregnancy by addressing food groups category, expected weight gain, energy requirement, other food ingredients, lifestyle change, food safety issues, common problems during pregnancy, benefits of fulfilling nutrient requirements, and consequences of maternal malnutrition.

Aside from that, susceptibility to and severity of malnutrition in pregnant women and their fetus were included during counseling sessions. In the counseling manual, there was also information on the advantages of eating a sufficient number of diversified meals and the barrier that prevents one from taking a balanced diet.

Additionally, the training aimed to improve important counseling skills, and GALIDRAA steps to counseling (Greet, Ask, Listen, Identify, Discuss, Repeat, Agree, and Appoint) was addressed in depth (29). The health belief model was discussed in detail as a means of delivering nutrition education messages.

Role play, discussion, and power point presentations were used to support the training.

Additional resources, including modules and summary brochures, were also given to the trainees for display in their ANC room. Results of pre-post test questions provided to participants based on the training module were used to evaluate the training. The intervention arm health facilities received one-week follow-up supervision to assist identify and addressing any implementation-related challenges and fill up any training gaps.

Throughout each woman's pregnancy, she went to three counseling sessions. Trained midwives provided individualized dietary counseling. During counseling, counselors employed a client-centered approach to determine the dietary habits and unique nutritional requirements of pregnant women. Counselors took into account the requirements of the women, their household income, and any barriers they found before allowing the women to select advice that was readily available, palatable, and cheap in their area.

A counseling guide containing the main topics was used, and the counseling sessions lasted 30 min over the first three appointments that followed. The initial counseling was provided before 16 weeks of gestation and concentrated on the use of iodized salt, basic nutrition, dietary categories, food selection, preparation, and frequency of meals. The second counseling session included the entirety of the counseling manual and was delivered during the second trimester of pregnancy. In the early third trimester of pregnancy, the last counseling session was provided.

Module, pamphlets, MUAC tape, and revised ANC logbook were provided to health centers in the intervention group. Take-home brochures of Amharic and Afan Oromo were given to study participants in the intervention arm. The pamphlets include clear and easy-to-follow core messages, actionable maternal recommendations in the form of bullet points, and an explanation of the many aspects of pregnancy nutrition.

Messages of the leaflet and serial short SMS text prepared in the local language delivered to the intervention group also incorporated the health belief model as a means of delivering nutrition messages. The health care system routinely provided nutrition education to the women in the control arm. Both the control and intervention arms' pregnant women got access to additional ANC services.

Data collection and measurement

The approaches used to obtain the required data were one-to-one interviewer-administered questionnaires and anthropometric measurements. The questionnaire was developed after a thorough review of the literature on the subject matter. The questionnaires included sociodemographic characteristics of women and their households, food security (30), obstetric history, HBM, MUAC, and nutrition knowledge.

Socio-demographic characteristics and obstetric history information were collected at the baseline. While data on food security, MUAC, and HBM were taken before and after the implementation of the intervention.

Six data collector midwives and 2 supervisors were trained for 3 days using a training guide centered on data collection procedures and tools. Questionnaires were initially written in English and translated to Afan Oromo and Amharic then back-translated to English by an expert fluent in English and the local languages. The tools were pre-tested before using for actual data collection. All data were obtained in the respondents' mother tongue language. The interview takes 40 minutes on average to complete the questions. Data was collected in hard copy. Supervisors and principal investigator daily monitor the accuracy of the data. The privacy of the women was secured during the interview. The data collection procedure was monitored by the principal investigator and supervisors. A daily meeting was conducted by the data gathering and counseling team to go through any problems that came up.

Left mid-upper arm circumference (MUAC) was measured at the anatomic landmark of the midpoint between acromion and olecranon processes of the non-dominant hand by palm facing upward with flexing the women's elbows to 90^0. The measurements were taken twice by using inelastic MUAC tape and reading the measurement to the nearest 0.1 cm. Women with MUAC < 22 cm were considered undernourished, and ≥ 22 cm were considered well-nourished. The primary outcome of the study was the nutritional status of the pregnant women which was determined by measuring MUAC. The household food security status was assessed by using the Food Insecurity Access Scale (HFIAS) measurement tool (30).

The post-intervention data were collected between weeks 36 and 38 of pregnancy. Pregnant women who missed any counseling sessions were deemed to have "did not adhere" to the study's standards, while those who withdrew from it were labeled as "lost to follow up". 27 validated questions were used to measure the food security status (30). A household was classified as food secure, mildly, moderately, or severely food insecure if it possessed less than 2, 2–10, 11–17, and >17 food insecurity indicators, respectively. Those who scored above the mean value for knowledge questions were considered as knowledgeable and those who scored less than the mean value were considered as not knowledgeable. The Likert scale was used to score the perceived susceptibility, severity, benefit, and barriers of women. The responses were re-categorized such that those who answered 'strongly agree' or 'agree' were merged to 'agree' and those who responded 'disagree' or 'strongly disagree' were merged to 'disagree'.

Intervention fidelity

Based on the Health Behavioral Change Consortium recommendations the intervention given was assessed by a fidelity criteria checklist. The checklist includes intervention design assessment, counseling process, training of counselors, recipient of intervention, and implementation of the skills learned from the intervention (31, 32). This checklist was used by the principal investigator and supervisors and the core messages of the intervention were assessed.

The trial used the same number of clusters for both study arms. To prevent information contamination non-adjacent health centers (clusters) were selected. Pretest was done before the initiation of the experiment. A counseling guide and control group was employed in the trial. Every pregnant woman in the intervention arm received an equal number, length of contact, and frequency of the counseling session. For pregnant women who have no mobile phone, their partner or neighbor, or a nearby person's contact number was used.

Counseling skill training was given using a training manual, and it includes a role-play and mock counseling practice. The training session has pre and post-training tests and practical evaluation. Process evaluation of the counseling session was done for randomly selected sessions by the process evaluator. Data collectors, counselors, and participants were all blinded to the study's hypotheses. Until the analysis was finalized the data entry process was blinded by labeling the data with a unique number.

The counseling procedure was overall supervised by the principal investigator and supervisors. Intervention receipt of pregnant women was evaluated by awareness of the women on the core content of the message delivered by intervention through interviews.

Data analysis

The quantitative data were coded and entered into Epidata V.3.1 to minimize design skipping patterns and logical errors. A cleaned copy of all the data was transported from Epidata to SPSS version 26 for cleaning, editing, and data processing.

The baseline socio-demographic characteristics of the women were compiled using descriptive statistics according to group status. To compare the baseline characteristics of the intervention and control groups, a chi-square test was used.

The wealth index was assessed using principal component analysis (PCA) by considering fixed assets such as the source of drinking water, possession of television, radio, mobile phone, availability of a separate kitchen from the living house, household assets, livestock, and agricultural land ownership. These variables were dichotomized and coded '1' for the household possessing the asset and '0' for the rest. Factor scores were produced using variables having a commonality value of greater than 0.5 in PCA. Finally, the factor scores ranked ordered into three relative measures of socioeconomic classes (poor, medium, and rich).

Independent samples and paired sample t-tests, respectively, were used to compare the MUAC between and within the control and intervention groups. In all analyses, a two-sided p-value of < 0.05 was used as a cutoff point to declare statistical significance. Multicollinearity between the independent variables

was assessed by using variance inflation factors (VIF > 10 was considered as the existence of collinearity).

A per-protocol analysis was performed in this trial. The final analysis comprised pregnant women who participated in three counseling sessions and provided end-line information. The effects of the intervention on changes in the nutritional status of pregnant women over time were assessed using a linear mixed-effects model. This model allowed us to account for the correlation of findings, due to the repeated measurements (pre- and post-intervention) and the grouping of individuals within the six randomly selected clusters.

Participants and clusters were analyzed as random effects during model fitting. Additionally, this approach makes it possible to manage the impact of various confounding factors (food security, wealth index, education, family size, and age). The average nutritional status across all clusters varied by 0.004 according to the intercept-only model, which calculates the variance of the cluster-level residual errors as 0.004.

The intra-cluster correlation coefficient was (0.001) which showed that no need to fit a third-level model. The two-level model was therefore fitted to take into consideration time-invariant variables at the individual level.

The difference in difference was used to estimate the effect of intervention by comparing the changes in outcomes over time between the control and intervention groups. The effect of the intervention was assessed by testing the interaction term between time and treatment allocation. The model estimate data on outcomes, treatment allocation, and periods. The coefficient of the interaction term was used as an estimate of the treatment effect. The SPSS software version 26 was used to conduct all statistical analyses.

Results

Response rate and attendance

A total of 366 (89.07%) participants were surveyed at the baseline. All participants in the intervention and control groups attended the first session. 18 (11.0%) from intervention group discontinued the intervention and 22 (13.5%) form control group were lost from the follow up. A total of 326 from both arms were fit for final analyses. The overall follow-up of study participants through the trial was summarized by the CONSORT guideline flow chart (**Figure 1**).

Socio-demographic characteristics

A total of 366 eligible pregnant women were recruited to the study from six health centers. Of these, 326 (Intervention = 163, Control = 163) women who strictly adhered to the protocol were included in the final analysis with an 89.1% retention rate. The mean ± SD age of the participants in the intervention and control groups were 24.78 (± 4.3) and 26.8 (± 4.46), respectively. Most participants in the intervention (87.7%) and control arm (86.5%) were between the 20–24 age groups.

The majority of the study participants in the intervention (60.7%) and control (73.0%) groups were housewives. The socio-demographical characteristics of the participants which are known to affect the nutritional status at baseline had no statically significant difference between the two arms ($P > 0.05$) (**Table 1**).

Health belief model score before and after intervention and their correlation with MUAC

At baseline, there was no significant difference between the HBM constructs score of the intervention and control groups. Perceived susceptibility and perceived benefit were significantly improved among the intervention group. The mean nutrition knowledge score significantly increased from 7.85 to 8.12 ($p < 0.01$) in the intervention group (**Table 2**). Perceived benefit, perceived susceptibility, and nutrition knowledge had a positive significant correlation with MUAC of pregnant women (**Table 3**).

Nutritional status of pregnant women

Before the educational intervention, there was no significant difference in the mean MUAC scores of the women enrolled in the intervention and control groups. (23.08 ± 1.56 Vs 23.26 ± 1.60, $p = 0.07$) (**Table 4**). The intervention and control groups had a comparable proportion of undernutrition at baseline (28 Vs 32%, $p = 0.55$). There was a significant change in both nutritional status and proportion of undernutrition between the intervention and control groups after the intervention. The mean MUAC difference before and after the intervention was 0.36, $p < 0.01$ [23.08 (1.56) Vs 23.44 (1.60)]. The proportion of undernutrition among pregnant women in the intervention group was lower by 11% (25 Vs 36%) as compared to the control group with a p-value $p = 0.023$. The T-test result showed that the intervention improves the mean MUAC by 1.8% (**Table 5**).

Effect of nutrition education on the nutritional status of pregnant women

The variability of average MUAC across individuals was 2.68 and statistically significant ($p < 0.05$). In this study, since the intra-cluster correlation coefficient was 0.02, two-level models were fitted (**Table 6**). After controlling for food security, family size, educational status, women's decision-making, and wealth women in the intervention group showed significantly improved nutrition status at the end of the study trial ($\beta = 0.50$, $p < 0.01$).

The variation of the average nutritional status across all clusters was 0.0035, which was not statistically significant ($p = 0.90$), and the intercept-only model predicts the variance of the cluster-level residual errors as 0.0026. The intra-cluster correlation coefficient was closer to zero (0.001), indicating that no third-level model needed to be fitted.

Discussion

The study assessed the effect of intensive nutrition education and counseling during antenatal care on the nutritional status of

TABLE 1 The baseline characteristics of pregnant women.

Variables	Intervention group (*N* = 163)		Control group (*N* = 163)		
	Frequency	(%)	Frequency	(%)	*P*
Number of clusters	3		3		
Age (years)					
<20	16	9.8	14	8.6	0.23
20–34	143	87.7	141	86.5	
≥35	4	2.5	8	4.9	
Religion					
Orthodox	81	49.7	76	46.6	0.1
Muslim	48	29.4	48	29.4	
Protestant	27	16.6	36	22.1	
Others	7	4.3	3	1.8	
Educational status					
Unable to read and write	32	19.6	33	20.2	0.11
Read and write	36	22.1	26	15.9	
Primary (1–8)	56	34.3	52	31.9	
Secondary (9–12)	26	15.9	33	20.2	
Tertiary (college and above)	13	7.9	19	11.7	
Husband educational status					
Unable to read and write	14	8.8	14	8.6	0.705
Read and write	36	22.5	32	19.8	
Primary (1–8)	39	24.4	45	27.8	
Secondary (9–12)	41	25.6	43	26.5	
Tertiary (college and above)	30	18.7	28	17.3	
Occupation					
Housewife	99	60.7	119	73	0.08
Government employee	17	10.4	12	7.4	
Private employee	32	19.6	16	9.8	
Daily laborer	5	3.1	5	3.1	
Merchant	5	3.1	9	5.5	
Others	5	3.1	2	1.2	
Marital status					
Married	160	98.2	162	99.4	0.42
Others	3	1.8	1	0.6	
Wealth index quartile					
Poorest	19	11.7	16	9.8	0.88
Poor	20	10.4	17	10.4	
Middle	101	52.3	107	65.7	
Richer	23	11.9	23	14.1	

pregnant mothers attending ANC service in selected interventional areas. The primary outcome of this study was nutritional status which was measured by MUAC. The study has compared the effect of the intervention with routine nutrition education given by the existing healthcare system.

In the current study, perceived susceptibility and perceived benefit were significantly improved and were also significantly correlated with the MUAC of pregnant women after the intervention. However, perceived severity and perceived barrier were neither significantly improved nor significantly correlated with MUAC of pregnant women after the intervention. According to the report from northeast Ethiopia, except perceived barrier, all HBM constructs were significantly improved among pregnant women in the intervention group (33). The reason that perceived

TABLE 2 Health belief model construct score before and after intervention among pregnant women in East Shoa zone, central Ethiopia.

HBM constructs	Time	HBM construct scores		*p*-value
		Intervention (*N* = 163)	Control (*N* = 163)	
Perceived susceptibility	Baseline	3.75 (±0.93)	3.62 (±0.88)	0.33
	Endline	4.04 (±0.95)	3.65 (±0.88)	<0.01
	P-value	<0.01	0.79	
Perceived severity	Baseline	3.76 (±1.05)	3.57 (±1.16)	0.12
	Endline	3.85 (±1.06)	3.53 (±1.15)	0.01
	P-value	<0.01	0.25	
Perceived benefit	Baseline	4.09 (±0.91)	3.96 (±1.03)	0.28
	Endline	4.21 (±0.94)	3.97 (±0.97)	0.03
	P-value	<0.01	0.85	
Perceived barrier	Baseline	4.03 (±0.89)	4.11 (±0.93)	0.41
	Endline	4.10 (±0.91)	4.19 (±0.95)	0.40
	P-value	0.43	0.46	
Nutrition knowledge	Baseline	7.85 (±1.31)	7.61 (±1.63)	0.11
	Endline	8.12 (±1.25)	7.69 (±1.64)	<0.01
	P-value	<0.01	0.07	

TABLE 3 Correlation of health belief model constructs with nutrition knowledge and MUAC of pregnant women in East Shoa zone, Central Ethiopia.

Variables	Intervention	Perceived susceptibility	Perceived severity	Perceived benefit	Perceived barrier	Nutritional knowledge	MUAC
Intervention	1						
Perceived susceptibility	0.15 0.05	1					
Perceived severity	0.05 0.39	−0.12 0.32	1				
Perceived benefit	0.14 0.01	0.16 0.00	−0.06 0.31	1			
Perceived barrier	0.14 0.79	0.05 0.41	0.08 0.12	−0.04 0.51	1		
Nutritional knowledge	0.18 0.03	0.29 0.00	0.09 0.08	0.24 0.00	−0.44 0.43	1	
MUAC	0.52 0.00	0.46 0.00	0.15 0.07	0.33 0.00	0.01 0.83	0.33 0.00	1

TABLE 4 Comparisons of mean MUAC scores of pregnant women in the experimental and control groups before and after education intervention in East Shoa zone, central Ethiopia, 2021.

Groups	Baseline[1] MUAC (cm)	End line MUAC (cm)	Difference	*p*-value[2]
Intervention	23.08 (1.56)	23.44 (1.60)	0.36 (1.23)	<0.01
Control	23.26 (1.63)	23.10 (1.67)	−0.15 (1.01)	0.06
p-value[3]	0.07	0.03	<0.01	

[1]Data are mean ± SD.
[2]Paired *t*-test.
[3]Independent *t*-test.

TABLE 5 Differences between baseline and endline measurements of MUAC and difference of the differences between the intervention and control groups, East Shoa zone, Central Ethiopia, 2021.

Variable	MUAC difference in Intervention[1] (cm)	MUAC difference in control (cm)	Difference (cm)	*p*-value
MUAC	0.36 (1.23)	−0.15 (1.01)	0.49 (1.23)	<0.01

[1]Data are mean ± SD, linear logistic regression.

severity was not improved in the current study might be due to poor emphasis given to the adverse effects caused by undernutrition in society. On the other hand, prior studies have shown that perceived severity was less often associated with the desired health behavior whereas, perceived susceptibility and benefit were consistently associated with the desired health behavior (34).

In the present study, nutrition knowledge was significantly improved in the intervention group and also significantly correlated with the MUAC of pregnant women in the intervention group. This finding is in line with the study done in southwest

TABLE 6 Linear mixed effect model predicting the nutritional status of pregnant women in East Shoa zone, Central Ethiopia.

Fixed effect variables	Model 1		Model 2		Model 3	
	Estimate (SE)	95% CI	Estimate (SE)	95% CI	Estimate (SE)	95% CI
Intercepts	**23.40 (0.15)**	23.1–23.7	**23.49 (0.15)**	23.20, 23.79	**23.70 (0.28)**	23.13, 24.27
Intervention effect			**0.46 (0.08)**	0.29, 0.63	**0.47 (0.08)**	0.31, 0.64
Endline control			−0.02 (0.03)	−0.09, 0.48	−0.06 (0.09)	−0.25, 0.12
Baseline intervention			**0.82 (0.03)**	0.76, 0.88	0.9 (0.07)	0.98, 1.01
Food security					0.04 (0.34)	−0.64, 0.73
Educational status					0.38 (0.35)	−0.29, 1.07
Wealth					0.36 (0.50)	−0.62, 1.35
Women decision making power					−0.16 (0.35)	−0.86, 0.53
Family size					0.27 (0.48)	−0.67, 1.22
Random effect						
Variances	3.49 (0.27)		2.92 (1.71)		2.70 (1.6)	
ICC	0.02		0.01		0.03	
AIC	1341.86		645.53		702.87	
Parameters	3		6		14	

ICC, intraclustor correlation coefficient; AIC, Akaike information criteria. The bold values represent the statistical significance at $p \leq 0.05$.

Ethiopia where the mean nutrition knowledge score has significantly increased from 6.9 to 13.4 following nutrition education and counseling intervention (35). One of the key advantages of nutrition education is improving the knowledge of women on optimal diet during pregnancy, thereby positively influencing the attitude and practice towards good nutrition (36–38). Nutrition education and counseling have been shown to have a positive effect on the awareness of expectant mothers about important micronutrient intake and the negative impact of food aversion during pregnancy (39, 40). Integration of nutrition education and counseling supplemented with mobile health during antenatal care should get emphasis to improve the nutritional status of pregnant women and thereby their nutritional status.

In this study, the socio-demographic characteristics of participants in both groups were not statistically different. The nutritional status of pregnant women in control and intervention groups was also similar at the baseline. At the end line, the nutritional status of pregnant women who received at least three counseling sessions and weekly serial SMS mobile phone text significantly increased by 36% after the nutritional education intervention ($P < 0.001$). This finding is in line with the study done in Northwest Ethiopia where guided nutrition counseling given to pregnant women using the health belief model and theory of planned behavior improved the nutritional status during pregnancy ($\beta = 0.615$, $p = < 0.001$) (41).

The prevalence of undernutrition among pregnant women in the control group has risen relative to the baseline, which is consistent with findings from earlier studies in Ethiopia (23.26 vs 23.10) (41). Whereas, the prevalence of under-nutrition in the intervention arm was 11% lower than the control group (25 vs. 36%) with a p-value of 0.023. The finding is consistent with the study done in India that showed positive effects in improving the weight gain and nutritional status of pregnant women after delivering nutrition core messages using individual counseling, weekly home visits, and group meetings (42).

In this study after adjusting for the educational status of pregnant women, food security, women's decision-making power, family size, and wealth, pregnant women in the intervention group showed a significant improvement in nutritional status at the end of the trial. Prior studies have also indicated that nutrition education interventions have improved the nutritional status of pregnant women by improving their dietary practices and improve weight gain during pregnancy (35, 41). The nutrition education intervention can improve the nutritional status by improving the knowledge of women on appropriate diets during pregnancy. The improved knowledge helps them to start good dietary practices and this in turn helps them to have a good nutritional status (43).

Although the study was done in multiple health centers and a well-designed randomized controlled trial, there are still limitations. This study was done among pregnant women who came to the selected health centers and this made the result of this study impossible to generalize for the pregnant women living in the community, who were not attending antenatal care at these health facilities. Furthermore, all of the responses, except the MUAC measurement, were based on the women's self-report, recall, and honesty in responding to the questions.

Conclusion

This study revealed that intensive nutrition education and counseling using the health belief model was effective in improving the nutritional status and minimizing the level of undernutrition among pregnant women. Counseling by using HBM, regular SMS, and leaflets was found to be important in improving the nutritional status of pregnant women in this study area. Therefore, nutrition

education and counseling by using HBM constructs and regular reminder messages have to be provided to pregnant women as part of the regular antenatal care service.

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 the Institutional Review Board of Jimma University (protocol number: IHRPGD/S21/2018), Jimma, Ethiopia. The patients/participants provided their written informed consent to participate in this study.

Author contributions

EW, TB, and TG involved in conceptualization, proposal development, questioner formulation, ethical clearance, registration of clinical trial, supervision in data collection, intervention and follow up, data clearance, data analysis, writing up, and manuscript preparation. All authors contributed to the article and approved the submitted version.

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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Knowledge, attitude, and patient advice on sustainable diets among Spanish health professionals

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Current dietary patterns, especially in high-income countries, are unsustainable. Health professionals, due to their credibility and close contact with the general population, could serve as agents of change for the adoption of sustainable diets. The objective of this study was to assess the knowledge and attitude regarding sustainable diets among the health professionals in Spain. A 24-item online questionnaire was designed for this purpose, and sent to health professionals (i.e., dietitians-nutritionists, nurses, physicians, and pharmacists). From September 2021 to May 2022, 2,545 health professionals answered the survey completely. One-fifth of them had never heard the term "sustainable diet", and most of them recognized having limited knowledge about it. They considered promoting sustainable diets when making dietary recommendations important, and pointed out that they would like to be trained on the topic. Indeed, they reported that all health professionals, independent of their career background, should be educated on sustainable diets. Efforts should be stressed on implementing training courses, at university level but also as continuous post-graduate training, providing health professionals in Spain the necessary knowledge to promote the adoption of sustainable diets among the population.

KEYWORDS

dietary survey, dietary environmental impact, food sustainability, food concerns, dietary counseling, sustainable knowledge, sustainability awareness, health personnel

1. Introduction

The current food system is unsustainable. While millions of people are suffering from nutrition and food insecurity (1), more than one-third of all food is lost or wasted (2); healthy diets are not affordable and accessible to a large proportion of the world's population (3), and unhealthy diets themselves are a leading cause of morbidity and mortality worldwide (4); unfair salaries and working conditions, forced and infant labor

within the food system are constantly reported (5, 6), as long as inequalities between large companies and small producers and farmers persist (7); additionally, the food system is among the main drivers of environmental pollution, natural resources usage, and biodiversity loss (8). Altogether, changing the current food system toward a fair and sustainable one, that provides healthy diets for all within planetary boundaries, is timely. This transformation requires the engagement of all stakeholders, from producers to consumers (9, 10).

The Nutrition sciences need to move beyond the biological dimension, to also address ethical concerns that include social and ecological factors, that, in the end, also affect human health (11, 12). According to the FAO definition, "Sustainable diets" are those diets that are nutritionally balanced, safe and healthy, and that contribute to nutrition and food security, as well as a healthy life for present and future generations. With that aim, sustainable diets have low environmental impact and are respectful of ecosystems and biodiversity, are economically fair, affordable, accessible, and culturally acceptable (13). To encourage the adoption of sustainable diets among the population, a multilevel action approach is necessary, in which nudges and policies are combined with initiatives explicitly tailored to educate and motivate individuals toward the adoption of such diets (14). Indeed, the latest could be a short-term strategy to promote such an urgent dietary behavior change while structural changes and policies are being implemented.

Spain, like other high-income countries, has experienced a dietary transition in recent years. The traditional Spanish diet, rich in whole plant-based foods, has evolved into a diet high in animal-sourced and convenience foods, making the current diet an unhealthy pattern with high environmental impact. It has been estimated that, compared to the current average Spanish diet, the general adoption of healthy plant-based diets could prevent more than 80,000 deaths per year while reducing greenhouse gas emissions by at least 70%, and the use of natural resources such as water, soil, nitrates, and phosphates by 25–55% (15). Reducing food waste is another pending task for the Spanish population, who each Spaniard wastes 77 kg of food yearly (2). Additionally, at the socio-economic level, it has become clear that part of the food consumed in the country does not come from fair sources (6). All the above highlights that Spanish society also needs to change its eating behaviors toward a sustainable diet. The Spanish population seems to be willing to follow a sustainable diet, but they acknowledged not knowing how to follow such a diet (16).

Health professionals that provide dietary counseling, because of their credibility, close contact with the general population, and influence on their dietary choices, have been pointed to as key partners for the promotion of sustainable diets (17). Recent studies suggest, however, that health professionals are not literate on sustainable diets, and that their promotion from healthcare centers lies with their individual knowledge and beliefs (17). So far, those studies have mainly focused on professionals from US and Canada, and to a lesser extent on Europeans. No study has targeted health professionals from Spain. Thus, the main objective of this study was to evaluate the knowledge and attitude, and also the practice of recommending sustainable diets, among health professionals in Spain.

2. Materials and methods

An online *de novo* questionnaire was designed by experts on nutrition, communication, and sociology to conduct this study. The survey consisted of 24 multiple-choice questions and collected information on sociodemographic characteristics (sex, age), professional background (profession, years of professional experience, highest academic degree attained, frequency of taking continuous training courses, and reading of nutrition-related scientific papers), knowledge and awareness about food sustainability, and also the practice of providing dietary recommendations considering food sustainability (Supplementary Table 1, Spanish and English versions). The survey did not contain any items to capture sensitive data, nor data that could identify the participants. Thus, the study is exempt from requiring the approval of any Ethics Committee. The estimated time required to answer the survey was around 15–20 min.

Between September and December 2021, different Spanish Councils of health professional Colleges were contacted. Online meetings were organized with representatives of each of them individually, explaining the purpose of the study, and requesting their collaboration. The option of refining the questionnaire was also offered. Four of them (i.e., Consejo General de Colegios Oficiales de Médicos, Consejo General de Enfermería, and Consejo General de Colegios Farmacéuticos y Academia Española de Dietistas-Nutricionistas de España) agreed to collaborate. They sent an email to all their affiliated professionals explaining the purposes of the study, asking for participation, and providing the link to the survey. The survey, based on a computer-assisted web interview, remained open between September 2021 and May 2022.

Out of the 652,600 invited professionals (i.e., 310,000 nurses, 260,000 physicians, 76,900 pharmacists, and 5,700 nutritionists.), 4,567 of them started the questionnaire. Two thousand and twenty-two respondents were excluded for not completing the entire questionnaire. The final study population analyzed included 2,545 participants, 1,139 being nurses, 427 physicians, 346 pharmacists, 550 nutritionists-dietitians, and 83 who did not report their profession.

Descriptive statistics (percentages) were used to assess the results. The participation rate among the different groups of health professionals was not equal. As the objective of this study was not to compare different groups of health professionals but to assess the knowledge and attitude of health professionals as a whole, the results were weighted considering these differences to make the results equally representative of the different health professions. The distribution of the sample universe and number of answered questionnaires by type of health professional, as well the weight applied for the answers of each type of professional can be found in Supplementary Table 2.

3. Results

3.1. Study population

Most of the sample were women (76%) between 35 and 64 years old (78.7%). The highest level of education achieved by almost half of the sample (49.1%) was a bachelor's degree, while 39%

also had a Master's degree and/or a doctorate. Roughly three out of four of the respondents (72.6%) had professional experience of more than 15 years, and only 7.7% had <5 years. Most of them (80.6%) stated they participate annually in continuing post-graduate training sessions or attend scientific conferences, although 71.1% recognized reading less than two scientific papers related to nutrition and dietetics per month (Table 1).

3.2. Knowledge and attitude about sustainable diets

One-fifth (21.5%) of the health professionals had not previously heard about "sustainable diets". Of those who had done, 44.0% had heard about it through channels unrelated to the healthcare profession, such as the press, social media, or informal conversations. Professional channels, such as dietary guidelines, scientific conferences, scientific papers, continuous education courses, or during their training as a health professional were reported by <20% of the sample (Table 2). However, it is worth highlighting that 62.9% of those younger than 25 years of age acknowledged having known about sustainable diets during their professional training (data non-shown).

After presenting to the participants the definition of "sustainable diet" provided by the FAO in 2010 (13), most of them considered important (32.3%), or very important (60.6%) that the population take into account all dimensions of sustainable diets (i.e., human health, environment, and socio-economical dimensions) when making food choices, although they considered human health dimension more relevant than the other two (Table 2). The consumption of foods high in sugars, highly processed, and containing heavy metals were the most concerning diet-related health effects for health professionals. To a lesser extent, they also considered of concern the consumption of foods high in fat, the presence of organic pollutants, pathogens, antibiotics, pesticides, additives, and allergens, or the consumption of transgenic foods (Supplementary Figure 1).

Two out of three (67.1%) thought that their patients had a low level of knowledge about the environmental impact of their diet. The majority of health professionals recognized that their own knowledge about the dietary environmental impact is not high: 37.9% valued their knowledge level as middling, and 32.4% said it was low or very low. Only 29.7% considered themselves to have a high or very high level of knowledge. A large proportion of them considered it relevant to broaden their knowledge of both the environmental impact of diets (60.7%) and their socio-economic aspects (60.9%). Around seven out of ten of the respondents stated that all health professionals, independently of their career background, should receive training on the impact—both environmental (70.8%) and social (68.7%)—of food and diet to transfer sustainable dietary habits to their patients (Table 2).

When asking participants if the frequency of consumption of several food groups is adequate from health and environmental perspectives separately, they reported that Spaniards should increase their consumption of fruits, vegetables, legumes, whole grains, nuts, olive oil, and fish, and decrease their consumption of refined grains, red and processed meats, and alcoholic and sugary drinks for a healthier diet. Similar results were reported when asking about dietary changes to reduce the dietary environmental impact (Figure 1).

3.3. Dietary recommendations

About half (46.6%) of the health professionals were not used to commenting on the environmental impact of diet when talking about food to their target population. This was due to a lack of knowledge (44.7%) or, to a lesser extent, because they were not in the habit of doing so (29.8%). Just 3% said that it was because they do not consider it relevant enough to be mentioned. Among those who were used to discussing this, half referred to the environmental impact of food choices often or always, and the other half occasionally (Figure 2). They expressed the view that the most relevant recommendations for following a sustainable diet would be (Figure 3): "increase the consumption of fresh food and reduce the consumption of industrial foods" (57.8%), "consume in-season fresh products" (48.1%), and "do not waste food" (40.5%). About one-third reported "follow the Mediterranean diet" (33.9%) and "consume local food" (30.8%) as the most effective strategies. They considered it less relevant to recommend "decrease the consumption of animal-sourced foods or follow a vegetarian diet" (4.6%), "buy directly from the producer" (3.9%), or "from co-ops" (1.3%), or "opt for fair-trade foods" (3.9%). Meal planning (80.6%) and the use of leftovers (72.5%) were the most important and recommendable actions to reduce food waste according to the health professionals surveyed (Supplementary Figure 2).

4. Discussion

This study is the first one aiming to assess the knowledge and attitudes toward sustainable diets, and the practice of recommending them, among health professionals in Spain. Our findings suggest that most of the professionals were not literate on dietary environmental and social dimensions. Nevertheless, they considered it important to promote sustainable diets when making dietary recommendations, and pointed out that all health professionals, independently of their career background, should be educated and trained on sustainable diets to provide dietary counseling considering not only on the healthiness, but also on the dietary environmental impact, social aspects, and economic considerations.

4.1. Ways to educate and train health professionals in sustainable diets

Our results show that, on one hand, one-fifth of the respondents recognized never having heard the term "sustainable diets" before, and on the other, that channels related to the healthcare profession (such as dietary guidelines, scientific conferences, continuous training programs, or during their formal education as a health professional) were not the main channel through which healthcare professionals were made aware about this topic. This fact points out the need in Spain to evolve promoting, educating, and training

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TABLE 1 Sociodemographic characteristics and professional trajectory of the surveyed health professionals.

	Percentage of the sample
Sex	
Woman	76.0
Man	23.2
Prefer not to disclose	0.8
Age	
Below 35 years old	13.7
Between 35 and 49 years old	39.3
Between 50 and 64 years old	39.4
65 years or above	7.5
Years working as a health professional	
5 or fewer years	7.7
Between 6 and 15 years	19.8
Between 16 and 25 years	31.1
Between 26 and 35 years	27.5
36 or more years	14.0
Highest academic degree	
Bachelor's degree	49.1
Postgraduate degree	11.9
Master's degree	26.5
PhD	12.5
Frequency of participation in continuous training courses or attendance at professional or scientific conferences	
Never	3.5
Once every 5 years	5.4
Once every 2 years	10.4
Once a year	29.5
More than once a year	51.1
Frequency of reading nutrition-related scientific papers	
Never	12.8
<2 papers per month	58.3
1 or 2 papers per week	19.0
Between 3 or 5 papers per week	5.9
6 or more papers per week	4.0

on nutrition and dietetics from a simplistic biological vision to a broader one.

Dietary guidelines, which are the basis for national food policies and public institutions' feeding programs, are one of the most relevant areas to leverage not only a large-scale adoption of sustainable diets but also literacy on nutrition and dietetics. Until now, environmental sustainability had not been a recurrent feature in dietary guidelines. Some even, such as the 2015–2020 Dietary Guidelines for Americans, stated that dietary recommendations should be based exclusively on the healthiness of food, showing a clear refusal to consider environmental sustainability aspects (18). Fortunately, things are changing; including in Spain. The Spanish Agency for Food Safety and Nutrition has very recently released new dietary guidelines not only considering the healthiness but the overall sustainability of dietary patterns (19). It should be noticed that our survey took place before the release of the new guidelines. By now, the new dietary recommendations may have reached a large number of health professionals. If the survey were to take place now, it is possible that the proportion of health professionals who report not having heard about sustainable diets would be lower, and the percentage of professionals aware of them through dietary guidelines higher.

On the other hand, while health professionals reported attending professional and scientific conferences or taking

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TABLE 2 Knowledge and attitude about sustainable diets of the surveyed health professionals.

	Percentage of the sample
Have you ever heard about the term "sustainable diet"?	
Yes, in channels not related to my healthcare profession (i.e., press, social media, informal conversations, etc.)	44
Yes, during my training as a health professional	11.7
Yes, in scientific papers	17.2
Yes, in conferences	11.6
Yes, in postgraduate programs or continuous training courses	12.1
Yes, in dietary guidelines	15.7
No	21.5
How relevant do you think it is for your clients, patients and society in general taking the broad concept of dietary sustainability into account in their dietary choices?	
Very important	60.6
Important	32.3
Neither important nor not important	4.5
Of little importance	1.9
Not important at all	0.7
Which of the following healthcare professionals do you think should be trained on the environmental impact of food and diet to translate that information when providing dietary counseling?	
Primary care physicians	31.6
Physicians of other specialties	2.2
Primary care nurses	31.3
Nurses of other specialties	2.9
Pharmacists	5
Dietitians and Nutritionists	27.9
All of them	70.8
Neither of them	0.7
What level of knowledge do you think your clients or patients have about the environmental impact of their diet?	
Very high	0.5
High	2.5
Medium	17.5
Low	43.1
Very low	24
I do not know	12.4
Which level of literacy do you feel you have about the environmental impact of diet?	
Very high	27.9
High	37.9
Medium	26.4
Low	6
Very low	1.8
Would you like to increase your knowledge of the environmental impact of food?	
Yes, I consider it relevant as a health professional	60.7
Yes, I consider it relevant from a personal point of view	51.2
Yes, I consider it relevant for me as a citizen	45.9

(Continued)

TABLE 2 (Continued)

	Percentage of the sample
No, it is not a relevant topic	2.8
When making dietary recommendations, do you consider it relevant to take social impact factors related to food production into account?	
Yes, I do	79.9
No, I do not	8.4
I do not know/I do not answer	11.7
Which of the following health professionals do you think should be trained on the social dimension of diet for routine management of their clients or patients?	
Primary care physicians	28.7
Physicians of other specialities	2
Primary care nurses	28.7
Nurses of other specialities	3.8
Pharmacists	6
Dietitians and Nutritionists	29
All of them	68.7
Neither of them	0.8
Would you like to increase your knowledge of the social impact of food?	
Yes, I consider it relevant as a health professional	60.9
Yes, I consider it relevant from a personal point of view	51.2
Yes, I consider it relevant for me as a citizen	46
No, it is not a relevant topic	2.9
When you provide dietary recommendations, what importance do you give to each of the following dimensions? Please, share 100 points between the three possible options.	
Human health	61.2
Environment	17.4
Socio-economical	21.4

continuous training courses often, only around 12% of our sample population indicated having heard about sustainable diets in conferences or courses. This is definitely a missed opportunity. More efforts should be made into the design and implementation of continuous training courses, and professional and scientific conferences, approaching a holistic view of diets. These would be a golden opportunity to disseminate about dietary sustainability, providing knowledge and tools to health professionals for encouraging the adoption of sustainable diets among the general population (20).

Of course, universities should expedite the incorporation of sustainable diets in their curriculum to also educate and train future health professionals that are potential key actors to sensitize the general population; our findings pointed out that still more than one-third of health professionals younger than 25 years have not been trained on sustainable diets during their professional training. Other educational formats, such as topic-oriented courses or workshops, could also be good resources for educating on sustainable diets from universities (20). Residency or professional practice programs should complement the theoretical knowledge acquired through the curriculum, as these periods would provide an opportunity for young professionals to acquire practical training to be applied later during their careers (20).

4.2. Health professionals' knowledge of sustainable diets comes from sources unrelated to their professional training

Health professionals recognized reducing food waste and buying local food among the most relevant actions to promote a sustainable diet, while buying directly from the producers or in cooperatives, or reducing the consumption of animal-based products were placed among the less relevant ones. It should be noticed, however, that the questionnaire only allows participants to select three options as the most relevant ones. It is possible that participants also consider those less popular options important, although to a lesser extent. These findings could be interpreted as a sign that the press and social media are their main sources of information, as they acknowledged.

Large campaigns focused on the promotion of local foods, including meats and dairy products, and the reduction of food

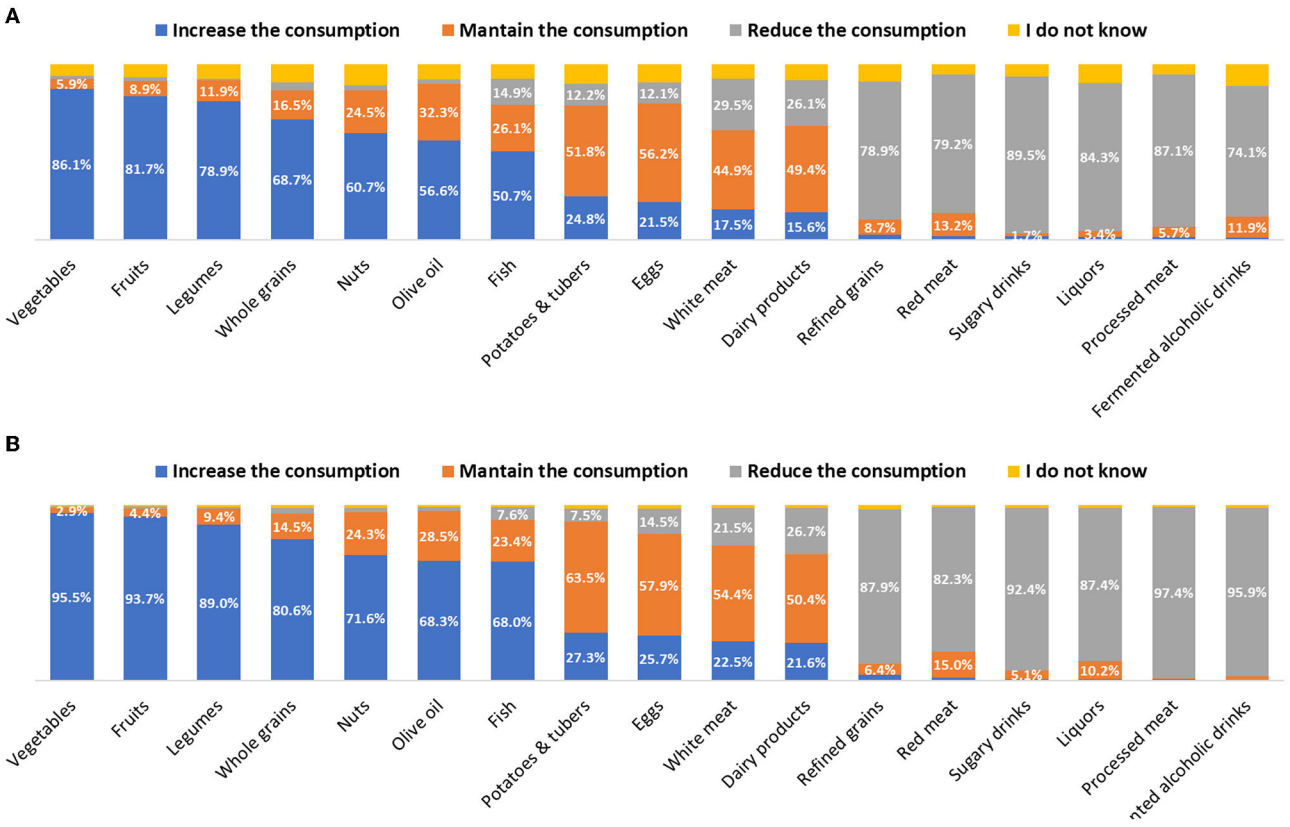

FIGURE 1
Dietary changes that the Spanish population should take for environmental **(A)** and health **(B)** reasons according to the surveyed health professionals.

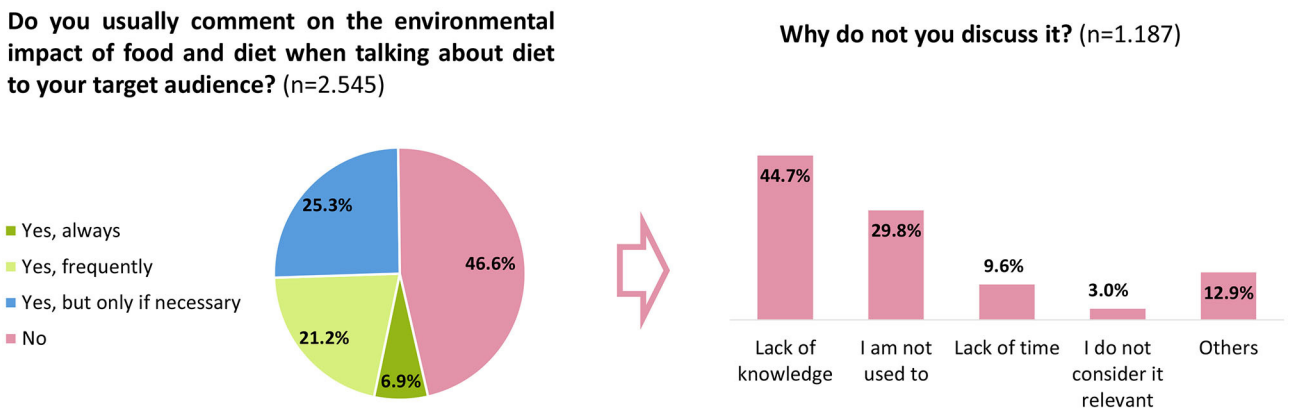

FIGURE 2
Habit of mentioning the environmental impact of food when talking about diet with health professionals' target audience.

waste has been launched during the last years in Spain (21, 22). In accordance, the general population—including health professionals, as our findings indicate—have got the idea that giving priority to local food and reducing food waste, are the most relevant strategies to advance toward a sustainable diet, while the high environmental impact of animal-based foods is not well-perceived (16). However, although it is true that tackling food waste is key in the transition toward a sustainable diet, people should be aware that not all local products are healthy, or socially or environmentally sustainable options (23), and that reducing the consumption of animal-based food is one of the best measures to reduce the dietary environmental impact (9). On the other hand, opting for buying food directly from producers or from cooperatives is a way of reconnecting with the production

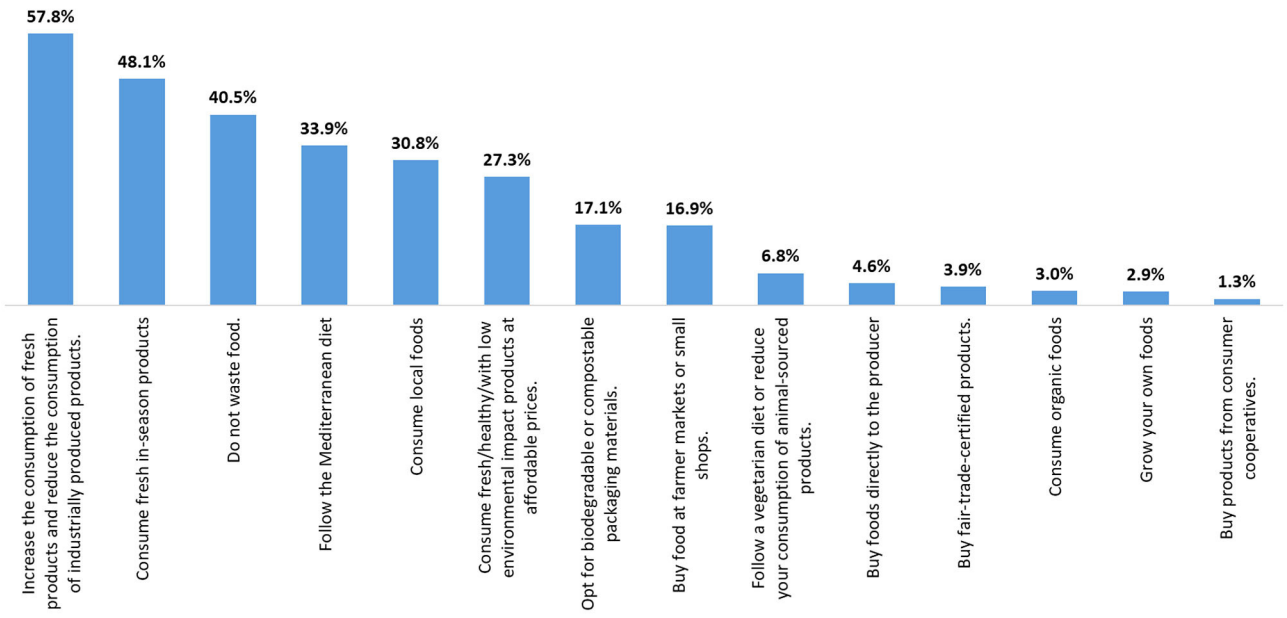

FIGURE 3
The most important recommendations to follow a sustainable diet according to the surveyed health professionals.

areas and their actors (24), strengthening the relations between consumers and producers toward a more equitable, and fairer food system (25), and supporting the maintenance of the job of those small producers, to stand up to the pressure of big food industries (7).

Massive campaigns have the power of disseminating knowledge and motivating receptors to change their behaviors. Honest campaigns promoting the adoption of healthy, environmentally sustainable, and socio-economically fair diets, and giving tips to follow such a diet, are urgently needed. Additionally, stricter regulation is needed in food industry advertising, to make sure that their message is aligned with public health and sustainability goals. Other public health strategies, such as food labeling, could be another soft policy measure to leverage knowledge regarding food sustainability among the general population (26).

4.3. Health professionals do not recognize tradeoffs between healthiness and the environmental impact of foods

The majority of the health professionals recognized having a medium or low level of knowledge on the environmental impact of food, being this the main barrier to discussing the environmental impact of food when providing dietary counseling. This lack of knowledge was evident when asking participants which changes the Spanish population would have to make to reduce their dietary environmental impact.

It seems that health professionals associate the effects of foods on the environment with those on human health. However, both dimensions are not necessarily aligned. For instance, participants responded that the population should increase their consumption of whole grains, while reducing the consumption of their refined version, because of environmental and health reasons. Although this replacement would provide health benefits, the environmental impact of both whole and refined grains is low (27). Thus, the reduction of refined grains makes sense for health reasons, but not for their environmental impact. The same happens with sugary drinks; although participants responded that their consumption should decrease for both environmental and health reasons, the fact is that their environmental impact is low (27). The case of dairy products is also striking. Besides the necessity of limiting the consumption of dairy products due to environmental reasons (28, 29), just a fourth of the sample indicated that their consumption should be reduced, and 15% even mentioned that should increase. Comparing these findings with those of a recent study aimed at the knowledge and attitude toward sustainable diets in the Spanish adult population (16), it seems that the knowledge of health professionals about the environmental impact of foods is similar to that of the general Spanish population. They also described a general association between healthiness and environmental sustainability, and a lack of awareness about the high environmental impact of dairy products, as we detected.

4.4. Health professionals prioritize human health effects over other sustainability dimensions

Besides most of the health professionals indicated that it is important to consider the environmental impact and socio-economic aspects when making dietary recommendations, they noted that the health dimension—both nutritional adequacy and safety—is much more relevant than the other aspects. This greater priority given to human health was shown by asking participants about the three most relevant measures to promote a sustainable diet. The recommendation they recognized as the most relevant was related to consuming more fresh products, which could be understood as a bias in favor of the health dimension. Fresh products may have been interpreted as healthy products such as vegetables and fruits, as seems to be understood by the Spanish population (16). This could be directly linked to the health dimension, but is not relevant from an environmental or socio-economical point of view. With regard to the environmental dimension, food processing is responsible for <5% of the greenhouse gas emissions derived from the food system (30) and even contributes to the reduction of food loss and waste. Most of the products that do not meet the standard "cosmetic" characteristics for being introduced in the market as fresh products are processed into preserved foods, minimizing their loss in fields (31). Additionally, waste from processed fruits and vegetables is lower than that of fresh fruits and vegetables (32). In parallel, a share of farmers' livelihoods and incomes depends on processed forms of fruits and vegetables, and they also contribute to food safety, security, and nutrition thanks to their longer shelf-life and year-round availability (31). Furthermore, it should be noticed that not all fresh products are healthy or environmentally sustainable options. For instance, high consumption of fresh red meat would lead to health problems while having a high environmental impact (27).

By definition, all dimensions should be of equal importance, as the ultimate goal of sustainable diets—i.e., contributing to nutrition and food security, and a healthy life for present and future generations—could not be achieved if not taking all dimensions into account (13). Indeed, back in 2008, the United Nations World Health Assembly already made a multilateral commitment to protect the health of the population from the fatal consequences of climate change (33). Climate change is increasingly undermining every pillar of good health, affecting physical and mental health directly and indirectly: threatening global food security, intensifying water scarcity, exacerbating the risk of infectious disease outbreaks, and negatively affecting livelihoods and the socioeconomic conditions on which physical and mental health rely on, among other effects (28). On the other hand, the direct link between socioeconomic aspects and health is well known (34). Altogether, health professionals should be aware that environmental and socio-economic problems directly and indirectly affect people's health, and should grant those dimensions the relevance they deserve when providing dietary counseling. A recent pilot study suggested that making the direct link between the environment and human health clear to health professionals could motivate them to engage in the promotion of sustainability actions (35). Presenting this narrow connection between food-health-environment-socioeconomic aspects when educating health professionals on sustainable diets could be an effective strategy for their commitment on their promotion.

4.5. Strengths and limitations

The major strength of this study is the large sample size, and the inclusion of health professionals from different areas, such as Nutrition and Dietetics, Medicine, Nursing, and Pharmacy. Some limitations should also be recognized. A selection and participation bias cannot be discarded; it is possible that those professionals more concerned about the topic were those who participated in the study, or even that the respondents were not as interested in sustainable diets as they reported. On the other hand, this would also indicate that the low level of knowledge detected in this study would be even more prominent. The interpretation of the results of the present study has to be done with caution. While the questionnaire was designed and externally checked by experts on nutrition, sociology, and communication, it has not received proper validation, and would be susceptible to improvements. Additionally, it has not been designed to deeply assess the knowledge of health professionals but to have a broad perspective.

5. Conclusions

This study, aimed at the assessment of the knowledge and attitudes toward sustainable diets among health professionals in Spain, shows that their knowledge in this area is not very high. Nevertheless, they would like to receive education and training to promote sustainable diets among their patients/clients. Due to the urgency of the general adoption of sustainable diets, the key role of health professionals in such a dietary transition, and their willingness to promote sustainable diets in their daily practices, efforts should be stressed on implementing specific guidelines for these health professionals, but also training courses, at university level but also as continuous practical training, providing to them the necessary tools to be agents of change in the general adoption of sustainable diets.

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 authors.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

UF, MV-C, and JS-S participated in the online meeting with the representatives of the councils of health professional colleges. UF wrote the first draft. All authors contributed to the design of the questionnaire, participated in the interpretation of the data, reviewed the draft, and have read and approved the final 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.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2023.1182226/full#supplementary-material

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Food literacy competencies in youth – a mini-review

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Introduction: Young people's transition into adulthood is an opportunity in the life course to establish adequate eating behaviors, hence exploring food literacy competencies in this period of life is especially important. Food literacy has recently gained increased attention in adults, adolescents, and younger children, but less is published about youth. This paper aims to summarize what tools have been used to measure food literacy and the sub-competence nutrition literacy in youth aged 16–24 years in the previous 5 years.

Methods: A mini-literature review was conducted in MEDLINE and EMBASE via Ovid, in September 2022. Study eligible criteria; had to be an original article, using a tool to quantitatively assess food literacy and/or nutrition literacy, including participants between 16–24 years, full text available in English, published between 2017–2022.

Results: A total of 958 articles were identified, of which 385 duplicates were removed. Thus, 573 articles were screened by title/abstract. Finally, nine articles were eligible for data extraction of which four proposed a tool to measure food literacy and five proposed a tool to measure nutrition literacy.

Discussion and conclusion: Although four studies claimed to measure food literacy, none of these used tools comprehensive enough to measure all aspects of food literacy, and only one was validated in young people. This study shows that only few tools exist for the measurement of food literacy in youth, and those available are scant. Further work is needed to develop a food literacy tool for youth.

KEYWORDS

food literacy, nutrition literacy, critical nutrition literacy, nutrition knowledge, food skills, youth, public health

Highlights

- This mini-review aims to summarize what tools have been used to measure food literacy and the sub-competence nutrition literacy in youth aged 16–24 years in the previous five years.
- A mini-literature review was conducted in MEDLINE and EMBASE via Ovid, in September 2022 and the literature search revealed that comprehensive tools measuring food literacy in youth are lacking.
- Continued effort to achieve consensus on how to measure food literacy in youth is needed.

1. Introduction

Youth is a period in life where many become more responsible for what to eat, when to eat, and how to eat (1). At the same time, the food landscape is complex and rapidly evolving, which makes it a challenge for the individual consumer to make food choices that ensure a healthy diet. Unhealthy eating habits and poor diet quality over time can increase the risk of malnutrition and later in life increase the risk of non-communicable diseases. Hence it is crucial to establish healthy eating habits early in life and during the life course, especially in the transition to adulthood (2). The concept of food literacy is increasingly applied in the academic literature, especially in adults (3–6), and several definitions of food literacy exist (3, 5–10).

The food literacy definition proposed by Vidgen & Gallegos is the most cited definition for measuring food literacy; it consists of 11 components within the competencies of planning and managing, selecting, preparing, and eating foods (10, 11). Vidgen & Gallegos define food literacy as "a collection of interrelated knowledge, skills and behaviors required to plan, manage, select, prepare and eat foods to meet needs and determine food intake" and as "the scaffolding that empowers individuals, households, communities or nations to protect diet quality" (5). Nutrition literacy is suggested as a sub-competence of food literacy (8). Nutrition literacy is a construct consisting of three sub-levels derived from the health literacy framework by Nutbeam (12). Nutrition literacy is based on the same three sub-levels as health literacy but is used in a nutritional context (8, 13). In a previous study, it was reported that experts in the field have agreed upon the definition of food literacy by Vidgen & Gallegos for measuring food literacy in adults (11). A new tool for measuring food literacy in adults has been proposed based on the definition by Vidgen & Gallegos, however, there is still disagreement on which items should be included to capture the food literacy competencies in an international context, e.g., cultural considerations (14). More work is also needed to establish a tool for measuring food literacy in youth. Slater and coworkers (1) have proposed an even broader food literacy framework for youths than the Vidgen & Gallegos definition, and suggested that youth require much more than basic nutrition knowledge and food skills to navigate the complex food environment. Currently, no tool exists based on the suggested food literacy framework by Slater et al. According to Slater et al., and Vettori, et al., food literacy involves not only individual abilities, but also social, environmental, political, cultural, and economic aspects of food behavior (1, 9).

Previous reviews have summed up which aspects of food literacy are measured in the literature and what tools are being used in children (2–12 years), adolescents (13–18 years) (4) and adults (3, 8, 15). However, no previous review has emphasized tools used to measure food literacy in youth (16), which is the period between adolescence and adulthood. Thus, an overview of what tools have been used to measure food literacy in youth is lacking. This mini-review responds to this and aims to summarize tools used to measure food literacy and nutrition literacy (sub-competence of food literacy) in youths 16–24 years in the previous five years.

2. Method

For this mini-review, the following eligibility criteria were used to evaluate articles for data extraction. To be included, the article had to be an original article, presenting separate data in the age group 16–24 years, using a tool to quantitatively assess food literacy and/or nutrition literacy (sub-competence of food literacy), available in full text in the English language, and published between 2017–2022. The previous five years were used as eligibility criteria to give an insight into the tools currently being used. Articles were excluded if being qualitative studies due to lack of a tool that quantitatively assesses food literacy and/or nutrition literacy. Further, studies were excluded if they lacked information concerning the tool/questionnaire used to measure food literacy or nutrition literacy. Additionally, articles being part of the school curriculum or measuring general nutrition knowledge/sports nutrition knowledge or measuring nutrition knowledge related to a specific food/or behavior were excluded.

2.1. Literature search and screening process

The literature search and screening process is presented in Figure 1. A systematic search and a comprehensive review of the literature were performed on September 26, 2022, in MEDLINE and EMBASE via Ovid. The following keywords were used: (1) "(youth OR juvenile OR adolescen* OR young* OR teenage* OR teens OR student*).ti. (2) ((nutrition* OR food* OR diet*) adj3 (knowledge* OR competence* OR literac*).ti,ab. (3) limit 6 to yr. = "2010-Current" (4) (nutrition* OR food* OR diet*) and knowledge* OR competence* OR literac*).ti. (5) NOT (review* OR meta-analys* OR systematic review.ti. Google Scholar was searched on September 26, 2022, using similar keywords to ensure that all published articles on the topic were screened.

The authors discussed and agreed on the eligibility criteria prior to the literature search, and the literature search was performed by the first author, with the assistance of a librarian. The first author performed all parts of the screening.

In the study by Liao et al. (17) mean age of the participants was not reported. However, the authors reported to include first, second, third- and fourth-year Taiwan university students. This study was included based on the reported age of Taiwan university students in another included study by Lai et al. (mean (SD) age of 20 ± 2) (18). Hence, we assume that the participants in the study by Liao et al., are in our target group (16–24 years).

3. Results

The literature search resulted in 958 articles, of which 385 were duplicates and removed. In total, 573 articles were screened by publication year, of which 306 articles were excluded due to being published before 2017. For the second screening, 267 articles were screened by title and abstract, of which 164 articles were excluded based on eligibility criteria. For full-text screening, 103 articles were screened and read to confirm study eligibility, out of which nine articles were eligible for data extraction in this mini-review (Figure 1).

The data extraction from the included literature in this mini-review is presented in Table 1. The studies included describes tools published between 2017–2022, in which four studies (three different tools) measured food literacy (19, 21, 23, 24) and five studies measured nutrition literacy or sub-dimensions of nutrition literacy (17, 18, 25,

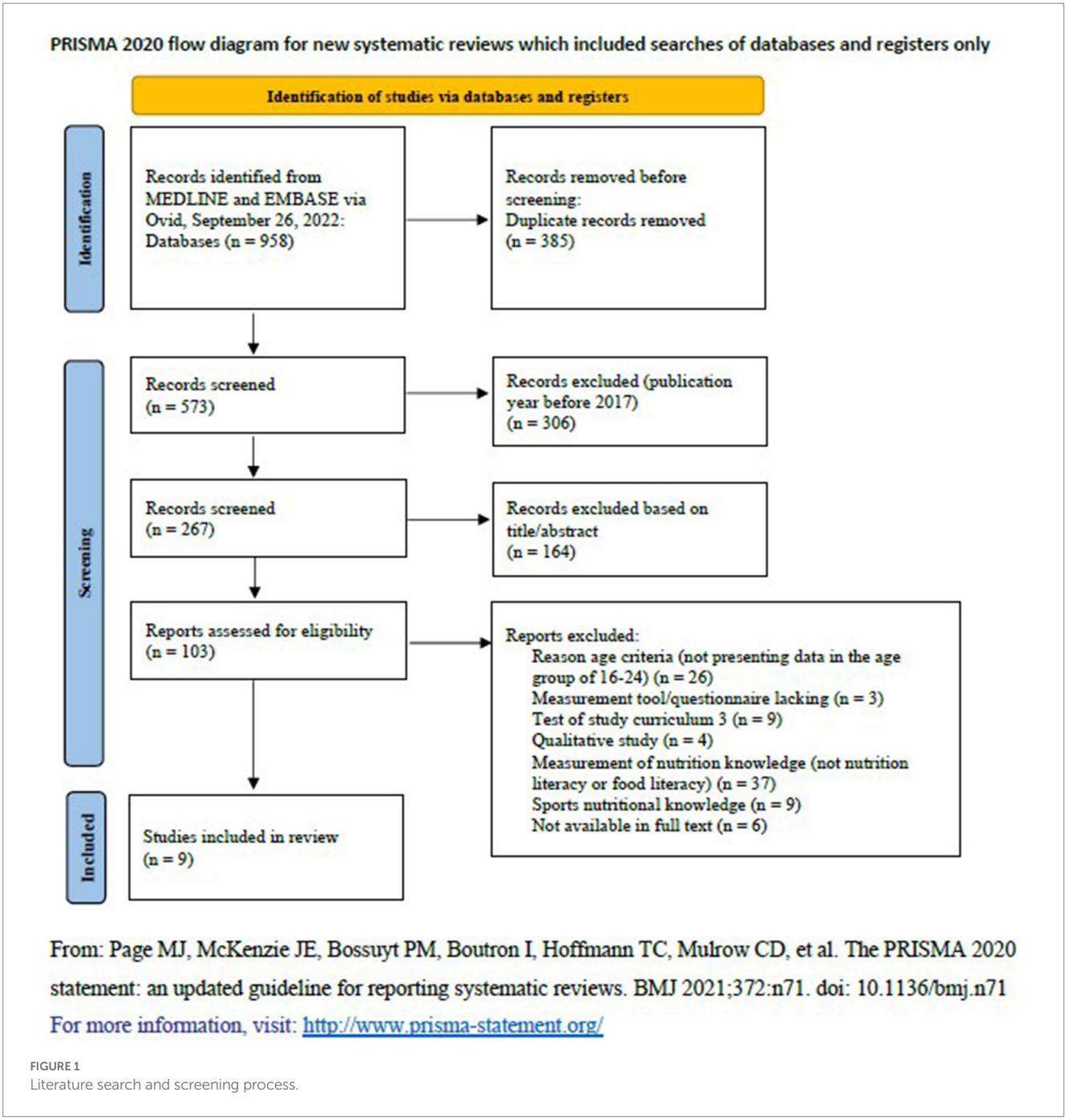

FIGURE 1
Literature search and screening process.

26, 28). The mean age in the included studies ranged from 17–24 years, except for one previously mentioned study that did not report mean age (17). The purpose of most of the studies was to either assess the level of food literacy or nutrition literacy of young people with already existing tools, while four of the studies had the purpose to develop and test the validity and/or reliability of a newly developed tool (21, 23, 25, 28).

3.1. Tools used to measure food literacy

In the study by Ashoori, M. et al., food literacy was measured using a previously validated tool for youths consisting of 60 items, the Food and Nutrition Literacy Assessment Tool (FNLAT) (19, 20). The FNLAT tool used by Ashoori, M, and coworkers is based on the health literacy definition by Nutbeam (12, 20). The FNLAT tool is divided into two domains, knowledge, and skills. The FNLAT tool also assesses sub-competencies within these two domains (food and nutrition knowledge, functional skills, interactive skills, advocacy, critical analysis of information, and food label reading skills) (19).

Two of the included studies that intended to measure food literacy aimed to test the reliability and validity of a food literacy tool in the target population 16–24 years (21, 23). The study by Durmus et al. (21) intended to adapt and validate the short food literacy questionnaire (SFLQ) tool developed by Krause et al. (22). The SFLQ tool focuses on individual skills and abilities needed for

TABLE 1 Literature list used for data extraction.

Authors/ years	Study population	Measurement tool	Concept to be measured
Ashoori et al. (19)[a]	Iranian senior high school students, mean ± SD age, 17.8 ± 0.4 (n = 621).	• The food and Nutrition Literacy assessment tool (FNLAT) consists of 60 items (20) of which 30 items with dichotomous answering and 30 items with Likert-type statements. • The FNLAT tool is divided into six dimensions: Food and nutrition knowledge (27 items), functional skills (11 items), interactive skills (7 items), advocacy (7 items), critical analysis of information (5 items), and food label reading skills (3 items). • FNL score ranged from 0–100.	• Food and nutrition literacy
Durmus et al. (21)[b]	Harran University School, mean ± SD age, 19.9 ± 2.4 (n = 308).	• Short Food Literacy Questionnaire (SFLQ) developed by Krause et al. (22). • The SFLQ tool consists of twelve items arranged on a four-or five-point Likert type scale. • SFLQ score ranged from 7–52.	• Food literacy
Na and Cho. (23)[b]	Young Korean people, mean ± SD age, 24.0 ± 2.6 (n = 435)	• Food literacy tool developed for adult Korean people based on eleven food literacy. Components in a scoping review (6) (knowledge, food skills, food choice, self-efficacy, meal management, food safety, food security, food systems, food resource management, emotions, and sociocultural context). • The final tool consisted of 50 items divided into two domains (food and nutrition knowledge and meal management) with 25 items assessing each domain.	• Food literacy
Itzkovitz et al. (24)[a]	Canadian adults, people living with type 1 diabetes (n = 236) mean ± SD age 24.3 (3.3), and the control group 22.5 ± 3.4 (n = 191)	• Short Food Literacy Questionnaire (SFLQ) developed by Krause et al., (22). • The SFLQ tool was adapted to the 2007 Canadian Food guideline. • The SFLQ tool consists of twelve items arranged on a four-or five-point Likert type scale. • SFLQ score ranged from 7–52. • Cooking skills were assessed by one item regarding the ability to cook with six answer options: - "I do not know where to start when cooking" - "I can do things such as boil an egg or cook a grilled cheese - "I can prepare simple meals but nothing too complicated. - "I can prepare most dishes" - "I can cook most dishes if I have a recipe to follow" - "I frequently prepare sophisticated dishes"	• Food and nutrition literacy • Cooking skills (not included in the SFLQ tool)
McNamara et al. (25)[b]	Students from the University of Maine and Rutgers. Between the age of 18–24 mean ± SD age of 19.9 ± 1.8 (n = 672).	• Nutrition literacy tool consisting of 67 items divided into three subsections (functional, interactive, critical) based on emerging themes in focus groups and on a previously validated critical nutrition literacy tool (13). • The items were arranged on a five-point Likert scale ranging from strongly disagree to strongly agree.	• Nutrition literacy - Functional - Interactive - Critical skills
Lai et al. (18)[a]	University students in Taiwan, mean ± SD age at 20.12 ± 1.8 (n = 412).	• Eighth-item nutrition literacy tool. • Likert-type statements. • Divided into five dimensions, obtaining nutritional information (2 items), understating basic nutrition information (2 items), analyzing different types of nutrition information (1 item), apprise and ability to judge and assess nutritional information (2 items) and the capacity to apply nutrition information (1 item).	• Nutrition literacy - Functional - Interactive - Critical skills
Liao and Chang (17)[a]	University students in Taiwan (n = 119). Separate data was presented for first, second, third- and fourth-year university students.	• Self-rated nutrition literacy tool. • Divided into five domains of nutrition literacy: obtain nutrition information (2 items) understand nutrition information (2 items), analyze nutrition information (1 item), apprise nutrition information (1 item), and apply nutrition information (2 items). • The response options were based on a four-point Likert-type scale.	• Nutrition literacy - Functional - Interactive - Critical skills
Yilmazel and Bozdogan (26)[a]	Turkish adolescents. The total study sample consisted of 307 participants in the age range of 14–19. Separate results are presented for the age group 17–19 (n = 173).	• The nutrition literacy scale was based on a previously developed tool (27), consisting of 22 items. • Divided into three sub-dimensions (functional 7 items, interactive 6 items, and critical literacy 9 items). • Items were arranged on a five-point Likert-type scale. • The score ranged from 22–110 as the maximum.	• Nutrition literacy - Functional - Interactive - Critical skills
Bedoyan et al. (28)[b]	US college students between 18–24, mean ± SD age at 18.4 ± 1.0 (n = 50).	• Critical Nutrition Literacy Tool (CNLT-R) based on a previously validated tool by Guttersrud et al., (13). • The CNLT-R tool consisted of seven items. • Arranged on a five-point Likert scale ranging from strongly disagree to strongly agree.	• Nutrition literacy - Critical skills

[a]Study design: cross-sectional.
[b]Study design: validation study.

making healthy food choices and the tool is based on the definition of health literacy by Nutbeam (12). The authors that developed the SFLQ tool underline that the tool does not capture all aspects of food literacy (22) and refer to the definition by Vidgen et al. (5), and emphasize that the SFLQ tool is intended to be a rapid and practical tool for measuring food literacy in adults. The SFLQ tool consists of 12 items divided into two domains (food and nutrition knowledge and meal management). The SFLQ tool was used in two of the included studies for measurement of food literacy (21, 24). In the study by Itzkovitz et al., the SFLQ tool was used to measure the nutrition, health, and food literacy in adults living with type 1 diabetes compared to a healthy control group (24).

In the study by Na and Cho (23), a three-phase process was conducted to develop a tool for measuring food literacy in Koreans. The final tool consisted of 50 items divided into two domains, food, and nutrition knowledge (25 items) and meal management (25 items). The items were based on the 11 components of food literacy identified in a previous scoping review (6).

3.2. Tools used to measure nutrition literacy (sub-competence of food literacy)

Most of the studies referred to nutrition literacy as a construct with three sublevels (functional, interactive, and critical nutrition literacy) (18, 25, 26, 28) and considered to be a subset of health literacy (12). Four of the nine included studies in this mini-review used a tool that measured all three sublevels of nutrition literacy (17, 18, 25, 26), while one of the included studies measured only two subset of nutrition literacy (functional and critical nutrition literacy) (28).

Tools used to measure all three sublevels of nutrition literacy differed. One tool consisted of eight items divided into five domains (obtaining, understanding, analyzing, assessing, and applying nutrition information). The eight-item nutrition literacy tool was used in two of the included studies (17, 18). One of the other included studies that measured all three sublevels of nutrition literacy consists of 22 items divided into three subsections (functional, interactive, critical) (26) and referred to the definition by Guttersrud et al. (29) and Velardo (7). Both the eight-item tool and the 22-item tool referred to nutrition literacy as a subset of health literacy based on the definition by Nutbeam (12). In contrast, one of the other included studies that measured all three sublevels suggested using a more comprehensive tool consisting of 67 items divided into three sublevels (functional, interactive, critical) (25) and the study referred to the definition by Velardo (7).

The study by Bedoyan et al. (28) used a critical nutrition literacy tool by Guttersrud et al. (13) and aimed to establish the criterion validity of a revised version of the critical nutrition literacy tool in a US population. The study referred to both the definition by Velardo and Nutbeam (7, 12). The original tool consisted of two scales (engagement scale and claims scale). The revised critical nutrition literacy tool included the claims scale of which seven of the 11 items were included.

4. Discussion and conclusion

The understanding of the concept of food literacy is evolving (1, 5–7, 10, 11). Tools used to measure food literacy or sub-competencies of food literacy have previously been emphasized among children (3–6 years) (4), adolescents (9–18 years) (4) (10–19 years) (30) and adults (8, 14, 15, 31). To our knowledge, this mini-review is the first to summarize existing tools used to evaluate food literacy and nutrition literacy targeting youth (16–24 years). Out of the nine included studies in this mini-review, four tools measured food literacy, and five tools measured nutrition literacy or sub-dimensions of nutrition literacy.

Measurement of food literacy was assessed in four of the included studies (19, 21, 23, 24), in which two of the studies used the SFLQ tool based on the health literacy definition by Nutbeam (21, 24). The SFLQ tool was originally developed by Krause (22) as a feasible and reliable tool for the assessment of food literacy in adults, and the authors emphasize that the tool did not intend to measure all suggested aspects of food literacy by Vidgen and Gallegos. The SFLQ tool is only able to indicate key elements of food literacy and may be used in public health surveys wanting to increase the food literacy focus, however, this tool cannot be used to measure the whole concepts of food literacy as described by Vidgen and Gallegos (5). Thus, several of the competencies within the areas 'functional competencies', 'relational competencies' and 'system competencies' in the food literacy framework suggested for youth (1) is underrepresented in the SFLQ tool.

More comprehensive food literacy tools were also identified, the FNLAT tool consisting of 60 items (19), and a food literacy tool developed for Korean adults, consisting of 50 items (23). The FNLAT tool is based on the Nutbeam framework for health literacy (functional, interactive, and critical skills). Food and nutrition knowledge was included in the FNLAT tool in addition to the skills section, as having basic nutrition knowledge was reported to be an important component of food and nutrition literacy in the literature (8). The original authors who developed the FNLAT tool underline that the FNLAT tool is not designed to measure all aspects of food literacy, especially not food skills (20). Thus, the FNLAT tool might not sufficiently cover aspects of the 'functional competencies' as 'food preparation skills', 'food budgeting skills', 'food & hygiene knowledge' and 'be able to think critically about and act on food and nutrition issues', and the areas 'relational competencies' and 'system competencies is lacking', which are areas in the suggested food literacy framework for youth by Slater et al. (1).

The 50-item food literacy tool developed for Korean adults was the only tool based on food literacy aspects identified in a scoping review and not based on the health literacy definition by Nutbeam. The 50-item tool includes the food literacy aspects food knowledge, food safety, food systems, sociocultural context, food skills, food choices, food resource management, and self-efficacy. However, several of the items are related to Korean food practices, which may not apply to other countries with other food practices, and it is developed for assessing food literacy in adults. Therefore, it is possible that this tool may not adequately encompass critical aspects of the 'functional competencies' suggested for youth by Slater, including 'have a healthy food relationship' and 'be able to think critically about and act on food and nutrition issues', 'food skills' and 'basic nutritional knowledge'.'Relational competencies' is also lacking in the tool (1).

To adapt a food literacy tool for a new population, it is crucial to consider cultural sensitivity and to conduct pilot testing and validation for accuracy and suitability for the target population. Moreover, researchers who develop a new tool should provide information on how others can adapt the tool to different cultures, e.g., using national dietary guidelines to assess general nutritional knowledge. Additionally, future research should prioritize making tools available

in both the original language and English to enhance transparency and accessibility for other researchers.

None of the identified tools can be used in an international context nor are they comprehensive enough to capture and measure the whole concept of food literacy in youth. It has previously been emphasized that youth may require more basic nutrition knowledge and food skills compared to adults (1), as they are in a transition phase to adulthood. The transition phase into adulthood requires more responsibilities in regard to education, family, employment, living agreement and securing a healthy diet. Having sufficient food literacy competencies is important for youth to be able to secure a diet in alignment with the dietary guidelines, and to avoid a diet that will inflict implications over the life course (1). Adapting existing food literacy tools validated in an adult population to a youth population may pose potential challenges. When adapting a tool to a new target population, several aspects must be considered, such as age-specificity, language-appropriateness, and cultural sensitivity, to ensure its suitability. It is also crucial to pilot test and assess the validity of the adapted tool to ensure its accuracy for the new target population. The SFLQ tool and the 50-item food literacy tool for Koreans were developed for adults, only the FNLAT tool was developed for younger people. Most tools measuring nutrition literacy included in this mini-review were originally developed for adults, despite being used in younger age groups.

A consensus on how to define and measure the concept of food literacy in youths is needed, including the sub-competencies described in the comprehensive food literacy framework by Slater (1). However, given that the framework comprises 16 broad competencies areas and 59 specific competencies, it may be challenging to develop a single tool that covers all aspects of food literacy as defined by the framework. This is evident by the fact that none of the identified studies in this mini– review used a tool covering the framework. Continued work and effort are therefore needed to develop a tool that assesses food literacy in youth, as there is still a substantial gap between how food literacy currently is being assessed in youth today and the competencies covered by the broader framework suggested for this age group (1).

Findings from this mini-review are limited to food literacy tools published after 2017 to give a brief up-to-date on tools currently being used. We may therefore not have identified all available tools measuring food literacy in the target population. Another limitation is that only articles available in the English language were included, which may have resulted in excluding relevant tools available in other languages. Another limitation was that the screening process was not blinded and performed by one person, however the eligibility criteria were discussed by the authors prior to the screening process. Overall, these limitations need to be considered when interpreting the findings of this mini-review, consequently, we do not achieve a full-overview of the literature to develop a new tool. However, this mini review is useful to identify gaps in the knowledge for future research, e.g., the need for a youth specific food literacy tool. A strength is that the literature search was assisted by a librarian. This mini-review was carried out to provide an overview of tools used to measure food literacy and nutrition literacy as a sub-competence of food literacy in young people aged 16–24 years in the previous 5 years. This mini-review underlines that there is a need for continued effort to make comprehensive tools that measure the complete concept of food literacy in youth. However, this is challenging, as there is currently no clear consensus on how to measure food literacy in a youth population.

Author contributions

SG-J and AM contributed to the conception and design of the study. SG-J performed the literature search and screening and wrote the first draft of the manuscript. AM wrote sections of the manuscript and supervised. All authors contributed to the manuscript revision, and read, and approved the submitted version.

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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Dietary practice and nutritional status and the respective effect of pulses-based nutrition education among adolescent girls in Northwest Ethiopia: a cluster randomized controlled trial

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Background: Thinness and stunting are the most severe public health problems among adolescent girls in Ethiopia. An inadequate intake of protein-source foods is the most critical cause, mainly due to the non-affordability of animal-origin foods. However, research into what extent improving pulses-based food consumption could contribute to decreasing the magnitude of protein-energy undernutrition is limited.

Objective: This trial aimed to evaluate the effectiveness of pulses-based nutrition education in reducing the proportion of thinness among adolescent girls.

Methods: A two-arm cluster randomized controlled trial was conducted among adolescent girls in Northwest Ethiopia from December 2021 to June 2022. A total of 602 adolescent girls from four schools were enrolled in the trial. Schools were assigned to intervention and control groups using the stratified cluster randomization method. Pulses-based nutrition education was the intervention, whereas the usual dietary practice of adolescent girls was the comparator. The education was delivered over 4 weeks on a 45–60-min session per week basis. Thinness was the primary outcome of the trial, measured by anthropometry. An intention-to-treat analysis method was used. A log-binomial regression model was fitted to the data. Relative risk with the respective confidence interval and value of p was calculated. A value of $p < 0.05$ was used to declare statistical significance. Stata 16 software was used for the analysis.

Results: About 89.37% of the participants in the intervention group and 92.36% in the control group completed the trial. The pulses-based nutrition education intervention did not show a significant difference in reducing the proportion of thinness among the participants in the intervention group compared to the participants in the control group even though a significant difference was observed in terms of the consumption of pulses-based food.

Conclusion: The present trial was statistically non-significant in reducing thinness among adolescent girls. Similar studies that utilize objective methods for ascertaining pulses-based food consumption need to be conducted.

Clinical trial registration: https://pactr.samrc.ac.za/Search.aspx, the trial was registered in the Pan African Clinical Trials Registry (PACTR202111605102515) on November 12, 2021.

KEYWORDS

cluster randomized trial, nutrition education, adolescent girls, adolescents, pulses, legumes, thinness, underweight

Introduction

Adolescent girls' protein undernutrition remains one of the most critical public health burdens in low- and middle-income countries (LMICs) (1–4). For instance, an analysis of worldwide trends in body mass index (BMI), underweight, overweight, and obesity from 1975 to 2016 showed the mean BMI estimates for youths aged 10–19 years old in South Asia, South-East Asia, East Africa, West Africa, and Central Africa were <20. According to the report, Ethiopia is among countries such as Niger, Senegal, India, Bangladesh, Myanmar, and Cambodia, where the lowest BMIs in the world were recorded (5). The Ethiopian Demographic and Health Survey (EDHS) also reported that 29% of adolescent girls in Ethiopia were underweight in 2016 (6). There are also similar recent studies in the country that reported underweight and stunting prevalences ranging from 13.6–29% (7–12) and 11.9–47.4% (9, 10, 12–15), respectively.

Although protein-energy undernutrition is known to cause significant morbidity and mortality among adolescent girls, its intergenerational consequences on their reproductive outcomes are the most serious. For instance, underweight adolescent girls are more likely to be underweight mothers, making them give birth to small babies (16). In turn, the low birth weight baby is more vulnerable to several risks of illness, death, and developmental problems (17, 18). These lead to poor educational achievement, school attendance, and concentration, perpetuating the cycle of undernutrition across generations and heavily affecting the productivity of a given nation (19, 20). However, adolescence is, fortunately, the second opportunity to correct the nutritional deficiencies experienced during early childhood, thereby breaking the intergenerational cycle (21).

Several factors are responsible for adolescent girls' protein undernutrition. However, inadequate energy and protein intake is believed to be the most critical cause of teenage girls' thinness and stunting in LMICs, mainly due to the inaccessibility of protein-source foods and poor knowledge and attitudes about nutrition. Specifically, animal-origin food intakes, such as meat, eggs, and milk, are low in most low-income countries, including Ethiopia, and these foods are not affordable for most of their populations (1, 8, 22–25). However, it is strongly recommended that people consume pulses rich in quality protein and minerals, such as iron, calcium, and zinc, as an alternative protein source food when accessing animal-origin foods is a chronic problem. Pulses such as chickpeas, lentils, peas, and broad beans are much more accessible and affordable in many low-income countries (26–28). Pulses are the most commonly produced crops in Ethiopia, which is among the top 10 pulses crop producer countries globally, and they are relatively more affordable than animal-origin foods for most Ethiopians (26, 29). However, studies, including our baseline survey, showed poor preparation and low consumption of pulses-based food due to the lack of knowledge about the benefits and preparation of pulses (30, 31). Therefore, this study evaluated the effectiveness of pulses-based nutrition education in reducing the proportion of thinness among adolescent girls in Northwest Ethiopia.

Abbreviations: BMI, Body mass index; BAZ, Body mass index-for-age z-score; CONSORT, Consolidated standards of reporting trials; EDHS, Ethiopian demographic and health survey; FAO, Food and agriculture organization; HAZ, Height-for-age z-score; HPM, Health promotion model; CRT, Cluster randomized trial; IG, Intervention group; CG, Control group; LMICs, Low and middle-income countries; PHPM, Pender's health promotion model.

Methods

Trial design

A stratified cluster randomized controlled trial was conducted among adolescent girls. In the present trial, clusters were schools, and the study units were adolescent girls from the respective schools. The study had two groups, an intervention group (IG) and a control group (CG). A total of four clusters were identified and assigned to the intervention group and the control group using the stratified cluster randomization method. Adolescent girls from the respective schools were enrolled into the groups using a systematic random sampling method. In the present trial, the intervention was pulses-based nutrition education, while the comparator was the usual dietary practice of adolescent girls.

Participants

A total of 602 adolescent girl participants, 301 for each arm, from four schools in Central Gondar Zone, Northwest Ethiopia, were enrolled in the trial. The participants were girls between 15 and 19 years old, attending grades 9–12. Only adolescent girls who were willing to participate were included in the trial. Those participants who could not communicate and planned to leave the study area/school before the study completion were excluded from the trial. On the other hand, schools found in areas where pulse crop production is prevalent were included. Whenever schools were considered close to each other, the one situated between those schools was excluded and then used as a buffering zone to avoid information contamination. Participant recruitment was conducted in the 1st week of December 2021.

Study setting

This study was conducted among adolescent girls in the Central Gondar zone, located 726 km away from Addis Ababa, in northwest Ethiopia. The area has 15 districts and 29 schools serving about 46,340 students. There are two climatic conditions in the Central Gondar Zone, highland and lowland; thus, there are different states of pulse crop production. Pulse crop production is high in the northern and southern parts of the zone, while there is little in the eastern part, and rare in the western part. However, common in the north and the south, the pulses produced differ due to the difference in climatic conditions. The most prevalent pulse crop grown in the south is chickpea, while pea and broad bean are harvested in the north (communications with Central Gondar Zone Education and Agriculture offices).

Intervention

The intervention was pulses-based nutrition education and the comparator was the usual dietary practices of adolescent girls. Adolescent girls in the intervention group received weekly lessons for 4 weeks on a one 45–60 min session per week basis.

The first session was about the definition and short and long-term consequences of undernutrition for adolescent girls. The second session overviewed the food groups' sources and functions. The third and fourth sessions were about pulses such as broad beans, peas, chickpeas, and lentils, which are accessible in the study area and relatively affordable for the trial participants. To be more specific, the third session was about the recommended daily quantity of pulses intake and pulses processing (cleaning, washing, soaking, germination, and boiling). The benefits of further processing of pulses in terms of removing anti-nutrients and improving test and digestibility, mixing pulses with cereals to enhance the quality of their protein, and the different pulses-based recipes were also discussed in this session. The fourth session was a demonstration of selected pulses-based recipes.

The selection considered the relative ease of accessing the pulses and other inputs and the ease in terms of time and skill to prepare them. As a result, only pulses-based recipes, such as recipes for soup and pulses mixed with rice and vegetables, were demonstrated. Pulses and rice were the main components used in the demonstration, while vegetables, spices, and oil were included to enhance the flavor of the food. Broad beans were used for the demonstration conducted in the North, while chickpeas were used in the South. The investigators delivered the theoretical sessions while a chef conducted the demonstration. The maximum number of participants per training session for the theoretical sessions was 50, while all the participants in the intervention group attended the demonstration and were served the recipe at a time.

To enhance adherence to the nutrition education sessions, participants who were unwilling to participate after explaining the purpose, risks, and benefits of participating in the intervention were excluded. We also excluded participants who had planned to leave the school during the study duration. A nutrition education manual was developed and strictly followed.

The nutrition education manual was developed by reviewing the Food and Agriculture Organization's (FAO) materials related to general dietary knowledge, attitude and practice assessment guidelines, and guidelines specific to pulse processing and pulses-based food preparation (26, 27, 32). Pender's Health Promotion Model (HPM) manuals and procedures were also used (33–35). The manual was presented to experts, and their feedback was received and incorporated. The nutrition education was delivered from the 4th week of December 2021 to the 3rd week of January 2022.

The outcome of the intervention

Thinness was the primary outcome of the current trial, while pulses-based food consumption and knowledge, beliefs, perceptions, and experiences about pulses-based food were the secondary outcomes. Thinness was categorized based on z-scores calculated using the WHO AnthroPlus software. Accordingly, adolescent girls with a body mass index-for-age (BMI-for-age) Z-scores of < -2 were classified as thin (36, 37).

Pulses-based food consumption was dichotomized into 'yes' or 'no' levels and was based on 24-h dietary recall. The consumption was regarded as 'yes' when the participant reported consuming pulses-based food in the past 24 h in one or more of the following forms: roasted, boiled, germinated, or bread mixed with cereals and vegetables. The pulse quantity alone was a cup or a handful to an approximate amount of 100–120 g or a cup of cooked pulses consumed in the past 24 h (26, 28).

Furthermore, the knowledge, beliefs, perceptions, and experiences about pulses-based food were organized based on Pender's Health Promotion Model domains (35). The domains relevant for this particular trial were: (1) commitment to prepare and consume pulses-based food, (2) pulses taste-related barriers to consuming pulses-based food, (3) self-efficacy beliefs to consume pulses-based food, (4) perceived benefit of consuming pulses-based food, (5) interpersonal influence to consume pulses-based food, and (6) knowledge/skill/accessibility-related barriers to consume pulses-based food. The domains were measured using 28 questions with a 5-point Likert scale. The domains were dichotomized as favorable and unfavorable using the sum of the middle value "3" as the cutoff point. Thus, when a participant's items sum score for a given domain was greater than the sum score of the middle value of that domain, then that participant was categorized as having favorable behavior and if otherwise, as having unfavorable behavior.

Finally, the dietary diversity score was categorized as good if the trial participant reported consuming five or more of the 10 food groups. The food groups included cereals/roots/tubers, pulses, nuts and seeds, dairy food, meat and poultry, egg, green leafy vegetables, other vitamin A-rich fruits and vegetables, other vegetables, and other fruits. A food group was considered consumed in the past 24 h if the serving of food items in that group was one tablespoon size or about a fistful, which is equivalent to 15 g (38). Baseline data were collected in the 3rd week of December 2021, and end-line data were collected in the first week of June 2022. The time gap from the last nutrition education session to the post-intervention outcome measurement was 4 months and 1 week.

Randomization

Schools were the units of randomization into intervention and control groups. Four schools were randomized using the stratified

cluster randomization method. Stratification was based on climatic conditions, and thus two geographic areas were formed. Two schools were purposively selected from each geographic area stratum. The schools were chosen so that they were reasonably far apart. The two schools from each stratum were finally randomized into the intervention and control groups using an envelope. Therefore, each stratum/geographic area was made to have one intervention and one control school/cluster. Adolescent girls were then recruited using systematic random sampling from each school. Study participants from the intervention schools were the intervention recipients, and study participants from the control schools were left without the intervention and continued with their usual dietary practices.

Allocation concealment and blinding

Consent and recruitment of the schools and individual study participants were conducted before the schools were randomized into intervention and control groups. Baseline data were collected from the study participants before the schools were randomized. The personnel facilitating the self-administered questionnaire and measuring the weight and height were also unaware of which participants or schools were part of the intervention group and which were not. One academic staff in the Department of Epidemiology and Biostatistics at the University of Gondar conducted the randomization procedure.

Sample size estimation

The sample size was calculated using proportions of the outcome (BMI-for age) before and after the intervention based on an individually randomized trial. The previous study showed that the prevalence of thinness among adolescent girls was 13.6% before and 3% after the intervention (39). The sample size, considering an individually randomized trial by assuming 0.9 power and a 5% level of significance, was 274 in total, 137 for each group. After multiplying by a design effect of 2 and adding a 15% loss to follow-up, the final sample size was 602 participants, 301 for each arm.

Data collection procedure

Baseline and end-line anthropometric data were collected using a digital weight scale and stadiometer. Data relating to dietary practice, including consumption of pulses-based food and knowledge, beliefs, perceptions, and experiences about pulses-based food, and sociodemographic variables were collected using a self-administered questionnaire.

Weight was measured using an electronic SECA scale after the participants removed their shoes and heavy clothing, and the measurement was recorded to the nearest 0.1 kg. Height was measured using a stadiometer with a sliding headpiece. The value was registered to the nearest 0.1 cm. The measurement was conducted after the participant removed her shoes and anything on her head, stood on the basal part of the stadiometer with feet together, the shoulders, buttocks, calves, and heels touched the vertical stand, and eyes in the Frankfort horizontal plane. The digital weight scale and the stadiometer were placed on a hard-flat table. All the procedures were aligned with the Food and Nutrition Technical Assistance (FANTA) 2018 anthropometry guide (40).

Data on the consumption of pulses-based food were collected using the past 24-h pulses-based food consumption history adopted from the 24-h recall dietary practice assessment approach. Thus, the questions were the FAO's six close-ended questions, with 'yes' or 'no' options, followed by six probing questions (32). The probing questions were used to list the various forms of pulses-based food consumed at a particular point in time in the past 24 h. The questions had explicit instruction for the students that they should choose the 'yes' option if the pulses they consumed in the past 24 h were about the size of a handful or a cup, which is assumed to be equivalent to 100–120 g (26, 28). In addition, the pulses should be consumed after mixing with cereals.

Concerning data collection on the knowledge, beliefs, perceptions, and experiences about pulses-based food, a tool of 29 items with an acceptable item consistency (Cronbach's alpha = 0.72) was used and organized based on Pender's Health Promotion Model domains (35). The domains with the respective number of items were (1) commitment to prepare and consume pulses (5 items, e.g., – I am committed to preparing and eating pulses-based food in boiled forms mixed with cereals), (2) pulse taste-related barrier to consuming pulses (9 items, e.g., – I do not eat pulses food in boiled form since I do not like its taste), (3) self-efficacy beliefs to consume pulses (6 items, e.g., – I can plan to prepare and eat pulses in a germinated form mixed with cereals), (4) the perceived benefit of consuming pulses (2 items, e.g., –Eating pulses combined can help increase growth and development), (5) interpersonal influence to consuming pulses (4 items, e.g., – My friends encourage me to consume pulses foods), and (6) knowledge/skill/accessibility barriers to consuming pulses (3 items, e.g., – Since I do not know, I cannot prepare and consume pulses mixed with rice). The items were designed to be on a 5-point Likert scale. In addition to Pender's Health Promotion Model (HPM) manual, other related guidelines were also used to develop the items (33–35).

Data related to general dietary practice focused on the details of dietary intake in the past 24 h. Six FAO's dietary practice assessment close-ended questions with a 'yes' or 'no' response option were used. The questions were about any food or drink, except water consumed in the past 24 h at six different time points and between (early in the morning, late in the morning, noon, afternoon, evening, and before going to bed). Each close-ended question was followed by a probing question with adequate space to write details of what was eaten and drunk, provided that the answer for the close-ended question was 'yes'. These dietary practice assessment questions had an explicit instruction for the participants that they should choose the 'yes' option if the food they consumed was roughly about the size of a tablespoon or a fistful, which is assumed to be equivalent to 15 g (32, 38, 41).

Quality control

Several data quality assurance activities were undertaken at the different steps of the study. Participants were enrolled in the trial after being well introduced to the trial objective and how much time they could spend answering the questions. The data were collected whenever the participants had free classes, at break time, before the day's class began, or after class ended, considering their preferences. When the filled

questionnaire was returned, corrections for completeness, consistency, and accuracy was done on the spot before the student left the room.

There was an attempt to make pre-and post-test data collection contexts (timing and place) as similar as possible. The digital weight scale was regularly calibrated at a 10 kg weight. The variables were measured by trained personnel using an anthropometric data collection protocol, and the overall data collection was closely supervised. Finally, this report was prepared using the Consolidated Standards of Reporting Trials (CONSORT) statement for cluster randomized trials (42).

Statistical analysis

Intention-to-treat was the method of analysis. The Chi-square test was used to examine the baseline socio-demographic characteristic differences between the intervention and control groups and examine the changes between the pre-test and post-test measurements of the primary and secondary outcome variables. A Log-binomial regression model was fitted to the data, and the relative risk with the corresponding confidence interval and value of p was then produced to determine the strength, precision, and significance of the effect of the intervention on the outcome variable. A value of $p < 0.05$ was considered statistically significant. Sensitivity analysis was also conducted to examine the influence of loss to follow-up, non-adherence, and confounding variables on the effect of the intervention on the outcome variable. Stata version 16 was used for data analysis.

Sensitivity analysis

Sensitivity analysis was conducted to examine the influence of the loss to follow-up, non-adherence, and confounding variables on the effect of the intervention. The effect of the intervention, excluding those losses to follow-up, was compared to the effect of the intervention keeping losses to follow-up or imputing the missing anthropometric data. The lost data imputation method was multiple imputations by assuming missing at random (MAR). However, we assessed statistically whether the missingness was missing completely at random (MAR), missing at random (MAR), or missing not at random (MNAR). Accordingly, thinness and other variables at baseline were compared between non-responders and responders and between non-responders of the intervention and control groups.

The influence of non-adherence was assessed by comparing the effect of the intervention on the participants who attended the four training sessions with the participants enrolled in the trial. Similarly, the influence of the baseline characteristics was assessed by conducting a multivariable analysis. All the sensitivity analyses were conducted to examine if the deviations could have affected the conclusion of the trial.

Results

Participant flow diagram

A total of 602 participants, 301 from each arm, were enrolled in the study from the four schools, and 269 participants in the intervention arm and 278 participants in the control arm completed the trial, with 89.37 and 92.36% response rates, respectively. School dropout was the cause of the trial participants' loss to follow-up (Figure 1).

Baseline socio-demographic characteristics

Of the participants who completed the trial, most of the intervention participants, 82 (30.50%), were aged 18 years, and of the control participants, 68 (24.46%) were 17 years old, while the least frequent ages were 15 years old, 35 (13.00%), and 19 years old, 41 (14.75%), among intervention and control participants, respectively. In total, 28% of the intervention and 39.93% of the control participants were in grade 9, while 22.32% of the intervention and 14.75% of the control participants were in grade 12. The majority were rural dwellers, 181 (67.33%) of the intervention participants and 235 (84.53%) control participants. Concerning the participants' history of school club participation, 189 (70.31%) of the participants in the intervention group and 218 (78.41%) of the participants in the control group reported that they had ever participated in the school club activity (Table 1).

Dietary diversity and meal frequency

The dietary practice was similar between the intervention and the control groups at the baseline and end-line of the intervention across eight of the 10 food groups. There was a difference for other vegetables and other fruits at the baseline of the intervention and other fruits at the end-line of the intervention. Similarly, the dietary diversity score was different at the baseline but similar at the end-line of the intervention between the intervention and the control groups. Regarding meal frequency, no difference was observed between the intervention and control groups at both the baseline and end-line of the intervention (Table 2).

Knowledge, beliefs, perceptions, and experiences about pulses-based food

All six domains were not significantly different between the intervention and the control groups at the baseline of the intervention. However, one of the six domains showed a statistically significant difference between the groups at the end-line of the intervention. That is, interpersonal influence to consume pulses-based foods changed from a statistically insignificant difference (value of $p = 0.49$) at baseline to a statistically significant difference (value of $p = 0.02$) at the end-line between the IG and CG (Table 3).

Pulses-based food consumption

There was no statistically significant difference between the intervention group and the control group in terms of the consumption of five of the six pulses-based food forms, which included roasted, boiled, germinated, soup, bread, and mixed with cereals and/or

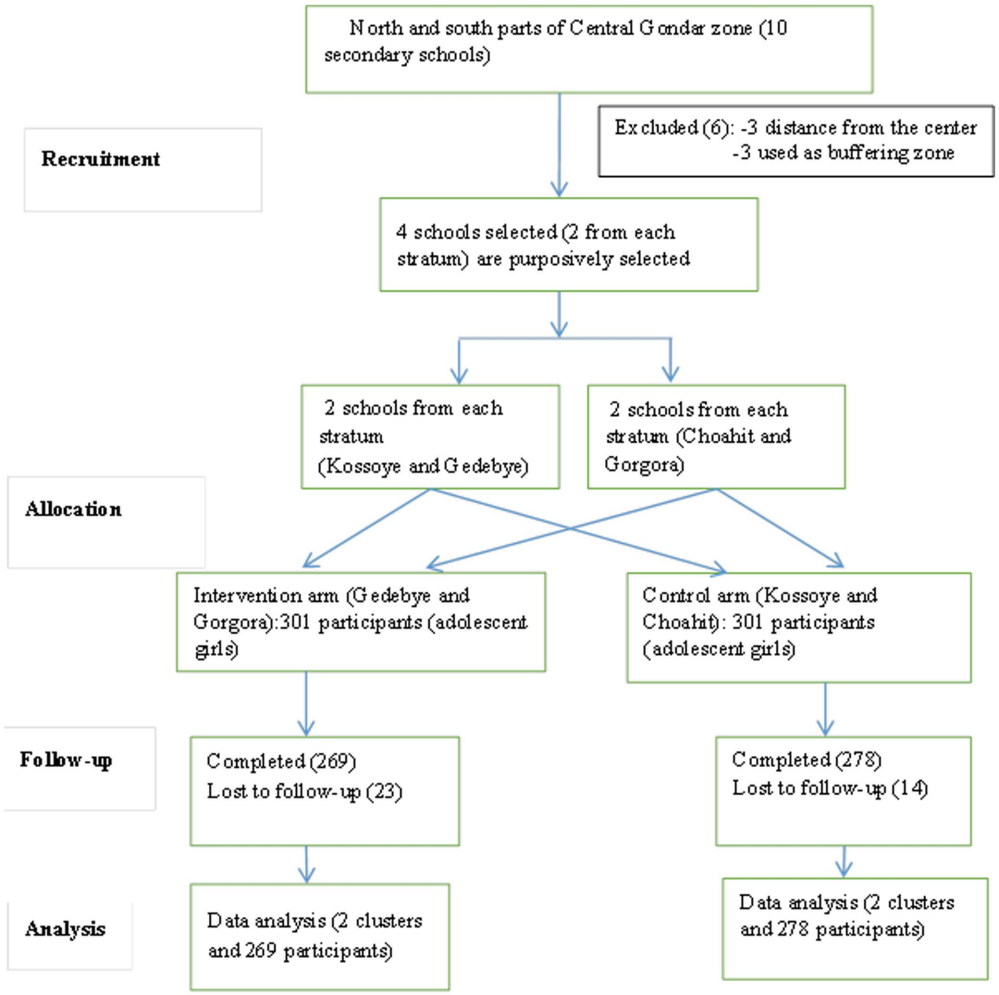

FIGURE 1
Flow diagram of pulses-based nutrition education compared to usual dietary practice among adolescent girls in Northwest Ethiopia, 2022.

vegetables at the baseline of the intervention in the past 24 h. The form of pulses-based food that showed a significant difference at baseline among the groups was bread ($p = 0.008$). Conversely, a statistically significant difference was observed between the intervention group and the control group at the end-line of the intervention in four of six pulses-based food forms. The changes in the Chi-square *p*-values of 0.14–0.001, 0.57–0.01, 0.008–0.0001, and 0.68–0.007 were for the boiled, germinated, bread, and vegetable forms, respectively. The pulses-based foods that remained insignificant were the soup and roasted forms. Regarding the overall pulses-based food consumption, a statistically significant difference was observed between the intervention and the control groups both at the baseline ($p = 0.004$) and end-line ($p = 0.000$) of the intervention (Table 4).

The effect of pulses-based nutrition education in reducing thinness

The primary analysis showed that the pulses-based nutrition education intervention did not significantly reduce thinness among the intervention group participants compared to the control group [CRR;95%CI: 0.56 (0.21, 1.50)]. The conclusion remained the same after the baseline outcome variable, thinness, was included in the analysis model [ARR; 95%CI: 1.32 (0.60, 2.92)] (Table 5).

Sensitivity analysis

The sensitivity analysis revealed that the loss to follow-up and non-adherence did not result in a considerable change in the effect sizes of the intervention, as witnessed by the comparison of the effect sizes obtained from the per-protocol and intention-to-treat analyses. In addition, the conclusion regarding the effect of the intervention remained the same between the primary analysis and the analysis adjusted by baseline characteristics, including the baseline outcome variable (Table 5).

Discussion

The present trial aimed to examine the effectiveness of pulses-based nutrition education in reducing the proportion of thinness

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TABLE 1 Baseline socio-demographic characteristics of adolescent girls in Northwest Ethiopia, 2022 (n = 547).

Characteristics	IG Freq (%)	CG Freq (%)	χ^2 p-value
Age (years)			0.005
15	35 (13.00)	52 (18.70)	
16	48 (17.86)	63 (22.66)	
17	51 (18.97)	68 (24.46)	
18	82 (30.50)	54 (19.42)	
19	53 (19.72)	41 (14.75)	
Grade			0.003
9	77 (28.64)	111 (39.93)	
10	65 (24.18)	78 (28.06)	
11	67 (24.92)	48 (17.27)	
12	60 (22.32)	41 (14.75)	
Religion			0.05
Orthodox Christian	261 (97.09)	276 (99.28)	
Muslim	8 (2.98)	2 (0.72)	
Permanent residence			0.000
Rural	181 (67.33)	235 (84.53)	
Urban	88 (32.74)	43 (15.47)	
Temporary residence			0.000
Rural	101 (37.57)	148 (53.24)	
Urban	168 (62.50)	130 (46.76)	
School club participation			0.03
Yes	189 (70.31)	218 (78.41)	
No	80 (29.76)	60 (21.58)	

IG, intervention group; CG, control group; Freq, frequency.

TABLE 2 Dietary diversity among adolescent girls in Northwest Ethiopia, 2022.

Food groups	Baseline			End-line		
	IG Freq (%)	CG Freq (%)	χ^2 p-value	IG Freq (%)	CG Freq (%)	χ^2 p-value
Cereals and roots	269 (100.00)	276 (99.28)	0.163	267 (99.26)	278	0.15
Pulses	238 (88.48)	245 (88.13)	0.9	259 (96.28)	263 (94.60)	0.35
Nuts and seeds	0 (0.00)	0 (0.00)	–	0 (0.00)	0 (0.00)	–
Diary food	25 (9.29)	40 (14.39)	0.08	11 (4.10)	11 (3.96)	0.9
Meat, poultry, and fish	107 (39.78)	104 (37.41)	0.57	43 (16.04)	52 (18.71)	0.41
Egg	14 (5.22)	18 (6.47)	0.534	4 (1.53)	6 (2.21)	0.56
Dark green leafy vegetables	4 (1.50)	2 (0.72)	0.391	1 (0.38)	1 (0.36)	0.98
Other vitamin A-rich fruits and vegetables	2 (0.74)	1 (0.36)	0.550	1 (0.40)	0 (0.00)	0.3
Other vegetables	4 (1.5)	0 (0.00)	0.044	2 (0.75)	1 (0.36)	0.54
Other fruits	13 (4.8)	37 (13.36)	0.001	13 (4.8)	37 (13.36)	0.001
Dietary diversity score	24 (8.92)	42 (15.11)	0.03	8 (3.00)	9 (3.24)	0.86
Meal frequency (≥3)	249 (92.57)	261 (93.88)	0.539	245 (91.08)	254 (91.36)	0.91

IG, intervention group; CG, control group; Freq, frequency.

TABLE 3 Knowledge, beliefs, perceptions, and experiences about pulses foods among adolescent girls in Northwest Ethiopia, 2022.

Barriers and facilitators	Baseline			End-line		
	IG Freq (%)	CG Freq (%)	χ^2 *p*-value	IG Freq (%)	CG Freq (%)	χ^2 p-value
Commitment to prepare and consume pulses	153 (56.88)	156 (56.12)	0.86	208 (77.32)	201 (72.30)	0.18
Pulses taste-related barrier to consume pulses	44 (16.36)	59 (21.22)	0.15	45 (16.73)	57 (20.50)	0.26
Self-efficacy beliefs to consume pulses	197 (73.23)	185 (66.55)	0.09	218 (81.04)	231 (83.09)	0.53
Perceived benefit of consuming pulses	190 (70.63)	192 (69.06)	0.69	239 (88.85)	240 (89.22)	0.37
Interpersonal influence to consuming pulses	93 (34.57)	104 (37.41)	0.49	101 (37.55)	79 (28.42)	0.02
Knowledge/skill/and accessibility barriers to consume pulses	70 (26.02)	58 (20.86)	0.15	70 (26.02)	59 (21.22)	0.15

IG, intervention group; CG, control group; Freq, frequency.

TABLE 4 Pulses-based food consumption among adolescent girls in Northwest Ethiopia, 2022.

Pulses-based food	Baseline			End-line		
	IG Freq (%)	CG Freq (%)	χ^2 *p*-value	IG Freq (%)	CG Freq (%)	χ^2 *p*-value
Boiled form	21 (7.81)	13 (4.74)	0.14	27 (10.04)	8 (2.89)	0.001
Germinated form	11 (4.09)	14 (5.11)	0.57	16 (5.95)	5 (1.81)	0.012
Bread form	32 (11.90)	15 (5.49)	0.008	35 (13.01)	6 (2.17)	0.000
Soup form	12 (4.48)	5 (1.83)	0.078	5 (1.86)	3 (1.09)	0.454
Mixed with vegetable	16 (5.95)	8 (2.88)	0.08	19 (7.06)	2 (0.720)	0.000
Overall pulses consumption	68	43	0.004	69	20	0.000

IG, intervention group; CG, control group; Freq, frequency.

TABLE 5 The effect of school-based pulses-based nutrition education in reducing thinness among adolescent girls in Northwest Ethiopia, 2022 (*n* = 547).

Characteristics	Thinness		CRR (95%CI)	ARR (95%CI)
	Yes	no		
Baseline thinness				
Yes	13	26	48 (14.48, 123.70)	33.39 (11.30, 98.72)
No	4	504	1	
Intervention				
Nutrition education	6	263	0.56 (0.21, 1.50)	1.32 (0.60, 2.92)
Control	11	267	1	

CRR, crude relative risk; ARR, adjusted relative risk.

among adolescent girls in Northwest Ethiopia. The trial revealed that the intervention was effective neither in the primary analysis [CRR; 95%CI: 0.56 (0.21, 1.50)] nor in the analysis adjusted by the baseline characteristics, including thinness at baseline, [ARR; 95%CI: 1.32 (0.60, 2.92)], in reducing the proportion of thinness among adolescent girls. The finding remained the same after the sensitivity analysis or when considering the influence of intervention adherence and loss to follow-up on the effect of the intervention. This finding is different from the findings of trials conducted among adolescent girls (44) and breastfeeding children (48–50) in the South Nations Nationalities and People's Regional State (SNNPR), Ethiopia, which reported a significant reduction in the proportion of those underweight among the participants who received the pulses-based nutrition education as compared to those participants who did not receive the education. However, this finding is similar to the above previous findings (44, 48–50) in terms of the consumption of pulses-based food in that a statistically significant difference was observed in the consumption of the pulses-based food from the baseline to the end-line of the intervention between the participants in the intervention group and the participants in the control group. More specifically, the change in the consumption of pulses-based food in the current trial was a tiny increase among the participants in the intervention group, while there was a decrease among the participants in the control group from baseline to the end-line of the intervention. The deviation is because the baseline data were collected in December, one of the months in the harvesting season, while the end-line data were collected in June, one of the months in the non-harvesting season. In Ethiopia, June is one of the non-harvesting months in which most of the population in

the area enters into a state of food stress and nutrition depletion (51, 52).

Therefore, the difference in the effectiveness of the intervention between the present study and the previous studies might be attributed to the difference in the data collection dates. In addition, the failure to account for the baseline variability in the analysis by the previous studies might, in part, have contributed to the difference. However, both the present and the previous studies applied objective assessment of the consumption of pulses-based food.

The limitation of the present trial is that data about the consumption of pulses-based food were collected by self-report, which might have resulted in an overestimation of the pulses-based food consumption proportion among the participants in the intervention group compared to the participants in the control group. However, the trial has the following strengths: an effort was made to make the trial participants represent different geographic areas, and thinness and other baseline characteristics were accounted for in the analysis.

Conclusion

The present study revealed that pulses-based nutrition education intervention did not significantly reduce the proportion of thinness among adolescent girls in Northwest Ethiopia. However, this non-significant reduction of thinness is contrary to the favorable behavior observed toward the consumption of pulses-based food among the intervention group compared to the control group. Thus, a similar study using an objective measure of the consumption of pulses-based food needs to be conducted in the future. The future trial should not underestimate the influence that study participants' baseline characteristics could have on the effect of the intervention.

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 Institutional Review Board of University of Gondar. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

FM: conception, formulation of aims, data acquisition, analysis and interpretation of data, drafting and approval of article for publication and agreement to be accountable for all aspects of the work. GB, TA, and NM: formulation of aims and interpretation of data, revising and approval of article for publication and agreement to be accountable for all aspects of the work. All authors read and approved the final manuscript and met the ICMJE criteria for authorship.

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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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Improving child nutrition in disasters by developing a modeled disaster preparedness nutrition education curriculum

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In contemporary global society, largely because of climate change and other natural and human-induced hazards, disasters are an almost daily occurrence. The nutritional impact of disasters on children results in long-term physical and mental health problems. As children are one of the most vulnerable demographic groups, they must be empowered with disaster preparedness nutrition knowledge, and the skills and motivation to survive, prevent/reduce malnutrition, and maintain good health during disasters. A disaster preparedness nutrition education program (DPNEP) was developed in this study to improve children's nutrition in daily life and during disasters through student-centered education. A consultative approach was used to synthesize the knowledge of a diverse group of four experts in disaster medicine and management, public health, education, and food and nutrition sciences to reach a consensus through discussion. A model DPNEP was developed by targeting grade 4 and 5 students and using interactive teaching methods. This can lead to the implementation of continuous nutrition education to empower children to make healthy food choices in daily life and reduce the risk of disaster-nutrition-related morbidity and mortality. Furthermore, once children acquire the necessary information, they are likely to share this knowledge with their families and communities, thereby enhancing society's resilience.

KEYWORDS

disasters, disaster preparedness nutrition education, malnutrition, student-centered curriculum, elementary school, pupils

1 Introduction

In contemporary global society, disasters are an almost daily occurrence, largely because of climate change and other natural and human-induced hazards. These disasters cause much misery, especially in non-resilient societies. The average frequency of disasters due to natural hazards worldwide was 13% higher in 2021 compared to that in 1991 (1), causing substantial economic losses. The Emergency Event Database recorded 387 global disasters, accounting for 30,704 deaths and affecting 185 million people, with economic losses amounting to approximately USD 223.8 billion (2). According to the World Health Organization, as of May 2023, over 766

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TABLE 1 Global disaster trends and impacts, 2001–2020 vs. 2021 and 2022.

Disaster trends and impacts		Year	Total	Asia	Americas	Africa	Europe	Oceania
Frequency of disasters		2001–2020 (annual average)	347	-	-	-	-	-
		2021	432	174	129	57	56	16
		2022	387	137	118	79	43	10
Human Impacts	No. of deaths	2001–2020 (annual average)	61,212	62.7%	21.2%	3.7%	12.2%	0.2%
		2021	10,492	48.7%	43.2%	5.1%	2.9%	0.1%
		2022	30,704	24.7%	5.4%	16.4%	53.4%	0.1%
	Population affected in millions	2001–2020 (annual average)	193.4	84.5%	7.0%	8.0%	0.3%	0.2%
		2021	101.8	65.5%	4.6%	29.4%	0.4%	0.1%
		2022	185	34.6%	5.5%	59.6%	0.1%	0.2%
Economic losses (billion USD)		2001–2020 (annual average)	153.8	42.5%	45.5%	0.9%	8.4%	2.8%
		2021	252.1	18.9%	58.9%	0%	20.7%	1.4%
		2022	223.8	21.8%	69.6%	3.8%	0.1%	3.8%

The global disaster trends and impact data are sourced from the Emergency Events Database (EM-DAT) of the Centre for Research on the Epidemiology of Disasters (CRED), United States Agency for International Development (USAID), Université Catholique de Louvain. 2021, 2022 Disasters in Numbers (2, 5). This table represents disasters related to natural hazards, excluding biological and extra-terrestrial origins.

million people had contracted COVID-19, with over 6.9 million fatalities (3). In addition to the costs associated with rising poverty, human costs have impacted global economic growth, disrupted lives and careers, and increased social unrest (4). The global disaster trends and impacts, 2001–2020 vs. 2021 and 2022, are summarized in Table 1.

The challenges of ending hunger, food insecurity, and child malnutrition in all its forms continue to grow. Additionally, governments worldwide support food production and agriculture with an estimated USD 630 billion annually, but they have failed to deliver healthy diets to children and other vulnerable populations (6). In addition to other numerous accompanied hardships, disasters compound these difficulties for children, highlighting the global inequalities they face; moreover, they affect children's nutritional status, dietary intake, and long-term development and cause general anthropometric failure (7). A longitudinal study in rural Nepal (8) demonstrated that despite a decrease in other infectious diseases during the COVID-19 pandemic, the pandemic exacerbated food insecurity and child malnutrition because of reduced employment opportunities, household income, and accessibility to and affordability of nutritious food, which further increased child vulnerability. The study emphasized the need for disaster preparedness with a focus on adequate nutrition, access to water, sanitation, hygiene, and healthcare supplies. Studies have indicated that undernutrition, particularly stunting, wasting, and underweight conditions, is rampant among children in flood-affected areas in low- and middle-income countries (9, 10). Effective preparedness for improving children's nutrition during disasters must consider, respect, and leverage customs, cultural practices, religion, individual tolerance, psychological norms, education, and values. Cultural humility, awareness, and sensitivity are important in addressing the trauma that disasters inflict on children and young people (11, 12).

Abbreviations: DPNEP, Disaster preparedness nutrition education program.

2 Rationale for disaster preparedness nutrition education

Damage from disasters can be worse when people lack preparedness and the ability to cope with hazards. Increased exposure to natural and human-induced hazards threatens people's livelihoods and sustainable development efforts. Subsequently, the United Nations International Children's Emergency Fund (UNICEF) and United Nations Educational, Scientific and Cultural Organization (UNESCO) have argued that education has an important role to play in preparing communities, saving lives, and building disaster-resilient societies (13). The Sendai Framework for Disaster Risk Reduction 2015–2030 emphasizes embedding disaster preparedness in daily life. It defines the goal of disaster education as the development of individual capacity based on the concept of the "three helps": self-help, mutual help, and public help (14, 15). Torani et al. (16) also demonstrated that disaster education is a functional, operational, and cost-effective tool for risk management.

Nutrition security is a human right. Food and nutrition are important in fostering humanity in children and helping them acquire life skills (17). To stay healthy, people require basic knowledge of what constitutes a nutritious diet and how to best meet their nutritional needs from the available resources, including unhealthy food- and nutrition-related practices (18). Maintaining a healthy diet is essential in childhood because the eating habits that children learn early in life are often carried forward into adulthood. Providing an effective nutrition education program will help children build strong, healthy eating habits (19) and consider the concept of food security in daily life and during emergencies. Preparedness is the key to successful evacuation and is the most effective way to minimize damage during a disaster (20). Strong nutrition and disaster preparedness require the active participation of children and youth; food security should be a part of disaster preparedness to build children's resilience and nutritional health and prevent/reduce negative long-term impacts of disasters (12, 21, 22).

Schools are crucial systems, play a pivotal role in helping students establish healthy eating behaviors (23), and are often designated to function as evacuation centers as well. Formal education can enhance disaster preparedness and reduce disaster vulnerability (24). Studies have indicated that school-based nutrition education programs increase children's nutrition knowledge and promote healthy eating habits (25–30). Despite the effectiveness of nutrition education in promoting a healthy diet and the role of disaster education in increasing survival among children during disasters, malnutrition and malnutrition-related morbidity and mortality remain prevalent among children during disasters. This could be attributed to the absence of school-based education programs/interventions that integrate and simulate disaster-nutrition-related issues for children. According to Pérez-Rodrigo and Aranceta (31), nutrition education should be designed according to the needs and interests of students, teachers, and the school. Nutrition education that focuses on the younger generation, incorporates various lifestyles, extends healthy life expectancy, and considers the food cycle and environment to pass down healthy food culture to younger generations constitutes the essential basic policy for food and nutrition (32) as well as disaster preparedness. Children who are nutritionally disadvantaged and facing food insecurity during normal times will have further opportunities to understand nutritional scenarios through disaster preparedness nutrition education; therefore, this knowledge will also help prevent their worsening malnutrition.

Disaster preparedness nutrition education can be incorporated flexibly at different times in a regular school day, allowing schools to use strategies tailored to specific settings, daily schedules, and resources (23). Nutrition education is effective only when it is based on an adequate analysis of nutritional problems and provides a clear and concise definition of the objectives and methods of communication (18). In a review, Torani et al. (16) noted that planning and designing a comprehensive education program is necessary to cope with disasters, especially for children, pregnant women, older adults, and people with disabilities. An intervention study involving a participatory activity for primary school pupils, aimed at building community resilience, showed that children had a more positive view of their health and community food afterward (33). Similarly, following the August 2018 earthquake in Lombok Island, Indonesia, an integrated nutrition rehabilitation intervention, including health, nutrition, education, and care, positively impacted the growth and development of children under 5 years in post-disaster conditions (34). The soaring cases of infectious diseases, mental health issues, and malnutrition-related morbidity and mortality among children in disaster contexts, occasioned by food insecurity, pre-disaster malnutrition, sociocultural factors, and organizational challenges, emphasize the need for disaster preparedness nutrition education for children's empowerment (12). This education creates awareness of the importance of prevention and preparedness, thereby bridging the gap between knowledge and action (35). It is also important to establish an education program and activities that enable children to adapt to and simulate expected nutritional challenges during disasters and devise a coping strategy for optimal health.

3 Study objective

This study aimed to develop a modeled educational program focused on improving children's nutrition in daily life and during disasters, to enhance and provide schoolchildren with essential knowledge and practical skills vital for addressing and overcoming the nutritional challenges during disasters.

4 Principles underlying disaster preparedness nutrition education program (DPNEP)

Developing a pedagogical framework for children's disaster preparedness nutrition education necessitates a combination of experiential learning and holistic strategies. Central to this framework lies experiential learning theory (36), which emphasizes active engagement through direct experiences and reflective practices. In the context of disaster preparedness and nutrition, this translates into hands-on activities, real-life simulations, and scenario-based role-playing. For instance, children can actively practice rationing and selecting nutritious food sources, followed by reflective discussions on their choices and potential outcomes. This approach deepens their comprehension of nutrition during disasters. Additionally, ecological systems theory (37) highlights the interconnectedness of various factors, urging educators to incorporate diverse environmental contexts into their teaching methods. Therefore, DPNEP should integrate considerations from the family, community, and broader society. This inclusive perspective ensures that children can apply their nutrition knowledge to different disaster scenarios and adapt effectively.

The whole child approach enriches this multifaceted perspective by emphasizing the importance of addressing a child's physical, cognitive, and emotional domains (38, 39). This holistic approach encompasses nutritional choices, mental health, hygiene, and basic first aid to help learners internalize the multifaceted nature of disaster scenarios, ensuring that they not only survive but also thrive in post-disaster environments. Moreover, technology integration into the educational framework enhances the learning experience and promotes the understanding of complex concepts, especially for children. Interactive apps and simulations breathe life into abstract nutrition principles, allowing children to visualize and apply their knowledge to real-world disaster situations. A multifaceted approach rooted in experiential learning and extended by ecological understanding and technological integration provides a solid foundation for children's disaster nutrition education in a student-centered manner. In addition, Sphere Project's handbook, titled *Humanitarian Charter and Minimum Standards in Humanitarian Response* (40), can guide the program's nutritional standards, ensuring practicality and adherence to global best practices.

5 Learning environment for DPNEP

Establishing an effective learning environment for a DPNEP entails integrating practical knowledge, interactive engagement, and emotional support. This unique program requires a setting that combines practical knowledge with engaging activities to ensure retention and application. The ideal environment prioritizes safety, active engagement, and relevance. Safe and comfortable spaces enhance learning (41). Active learning through hands-on activities, simulations, and role-playing can replicate real disaster situations and

improve comprehension, aligning with the experiential learning advocated by Kolb (36). The use of visual aids, such as charts, videos, and diagrams, can simplify complex nutritional concepts and aid retention. This approach is consistent with multimedia learning theory (42), which highlights the benefits of synergies between visual and verbal information processing. Furthermore, ensuring that content is culturally appropriate is crucial for creating a familiar learning environment. The UNESCO Guide on Education for Sustainable Development Goals advocates context-relevant education, especially for disaster preparedness, empowering learners to address challenges by taking appropriate action (43).

Through the DPNEP, children will understand the significance of nutrition in maintaining optimal health, energy, and well-being, especially during emergencies. They will also recognize the essential nutrient-rich foods within and outside the community, which can be safely stored for long durations; understand the role of water and hygiene; and become familiar with the basic principles of food safety during and after a disaster. In addition, through hands-on activities and practical scenarios, they will be empowered to make healthy food choices in daily life and undertake safety decisions that will benefit them and their families, ensuring resilience and well-being during disasters. Lastly, beyond providing mere knowledge and teaching practical skills, the program will instill a sense of responsibility and empowerment in the children. They will be encouraged to advocate for proper nutrition at home and in their communities, understanding that their choices have a profound impact on not only their own health, but also the well-being of those around them during a disaster. Through this holistic approach, children will acquire important knowledge and be inspired to become proactive agents of change in their communities.

5.1 Monitoring and evaluation framework for DPNEP

The implementation of a "Monitoring and Evaluation Framework" is crucial for determining the effectiveness of DPNEP. At its core, the program's goal is to endow students with actionable knowledge and practical skills to navigate nutritional challenges during disasters. The objectives of this program are multifold, aiming to enhance students' understanding of safe food and nutrition and good hygiene practices; improve their ability to make informed food choices in daily life and during disasters; and instill essential food preparation and rationing skills while embedding a culture of preparedness. The program also seeks to influence the broader community culture of schools. Key performance indicators have been established to track and measure program outcomes, which have been categorized into knowledge, skill, behavioral, and cultural indicators. Knowledge indicators, for instance, include the ability of students to identify locally sourced safe food items and evacuation sites, and recognize good hygiene practices, while skill indicators focus on students' proficiency in handwashing, food handling, and meal planning with emergency and limited supplies. Behavioral and cultural indicators assess student-led initiatives and the impact of the program on a community's disaster preparedness measures. To gather relevant data, a combination of pre- and post-program surveys, skill demonstrations, parent questionnaires, and teacher observations are utilized, ensuring a robust and comprehensive data collection process.

The sources of data are diverse, ranging from student assessments and teacher feedback to parental insights on their child's behavioral changes, and school records detailing participation and outcomes. This robust collection of data points enables a multi-dimensional evaluation of the effectiveness of DPNEP. Evaluations are strategically phased, with short-term evaluations assessing immediate program impact, intermediate evaluations monitoring knowledge retention and skill application after 3 months, and long-term evaluations analyzing sustained behavioral change and cultural integration on an annual basis. The framework emphasizes the importance of feedback for continuous improvement. Evaluation findings are disseminated to stakeholders, including school administrators, teachers, students, and parents, fostering a collaborative environment for program enhancement. Adjustments to the DPNEP are guided by this feedback, aiming to refine and optimize the program in accordance with the observed needs and success rates. Through such iterative refinement, the framework not only assesses the immediate impact of DPNEP but also ensures its long-term efficacy in preparing students with the critical knowledge and skills needed to handle nutritional challenges during disasters. The Monitoring and Evaluation Framework for DPNEP is illustrated in Figure 1.

6 Result to date/assessment process

Guided by the results from previous studies (12, 30), curricula for school-aged students were drafted for a DPNEP. A consultative approach was used to synthesize the knowledge of a group of diverse experts through discussion. The team consisted of four experts in disaster medicine and management (SE), public health (SE, RN), education (AAA), and food and nutrition sciences (ASA) with more than 5 years of professional practice/research experience. A draft of the "DPNEP for Daily Life and Emergencies," containing the basic components listed in Table 2, was presented to each expert to comment on, modify, or make recommendations. After careful consideration and integration of the experts' contributions, an updated version was developed. Subsequently, the team coordinator (AAA), an education expert, facilitated one or more live discussions via videoconferencing software and face-to-face sessions with individual participants for clarification, re-assessment, and consensus. The final version was developed and sent to each expert for confirmation and approval. The proposed "Disaster Preparedness Nutrition Education Program for Daily Life and Emergencies" is illustrated in Table 2.

7 Discussion on the practical implication

The means to achieve sustainable solutions to child malnutrition in all its forms and circumstances is to educate and empower children and expand their life opportunities. When a child is nutritionally prepared through education to deal with multiple scenarios and complex emergencies, a ripple effect catalyzes far-reaching impacts on the community. The program content involves simple, understandable, and well-integrated disaster-nutrition messages and can be taught by academic staff in elementary schools with little or no training required. A student-centered curriculum considers learners' needs, experiences,

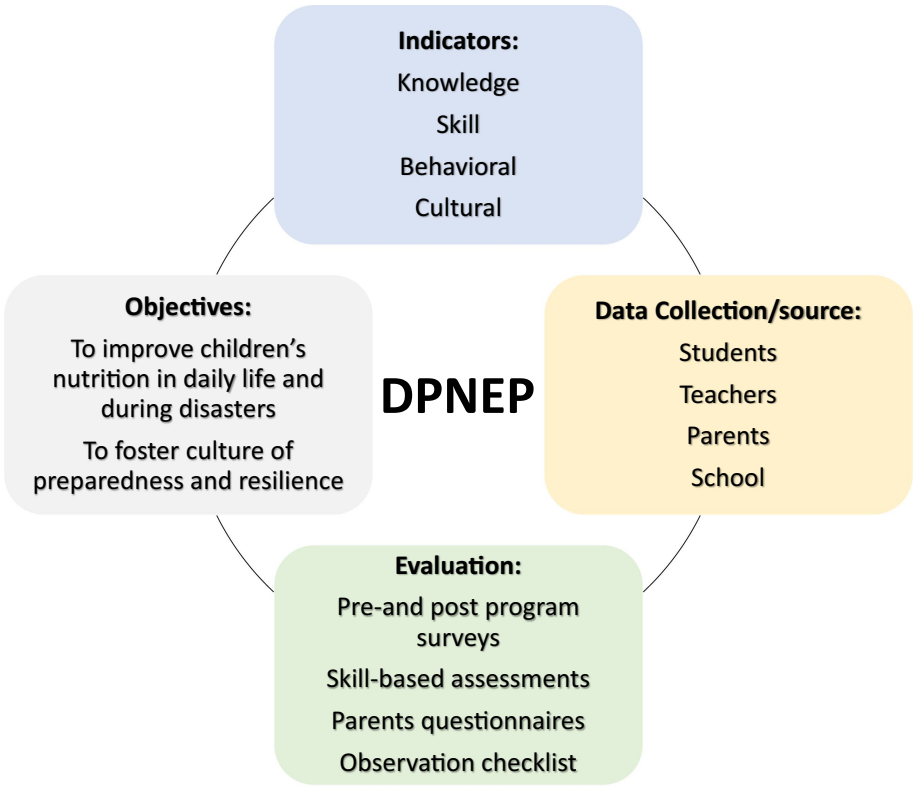

FIGURE 1
Monitoring and evaluation of framework for DPNEP.

perspectives, abilities, interests, and backgrounds (44–46). Further, student-centered instruction enhances cooperative learning and enables students to make necessary decisions and develop independent problem-solving skills (47). The target population in this study consisted of students in grades 4 and 5 of elementary school. Students at this age are both young/cognitively flexible and old/cognitively sophisticated enough to prevent and reduce malnutrition in daily life and during disasters through acquired knowledge and skills actively and passively.

Moreover, they are not faced with the challenge of preparing for secondary school; therefore, targeting this group could encourage implementation in practice. Previous studies (30, 48) have demonstrated that the inclusion of 30 min of nutritional education per week in elementary school schedules is effective in improving healthy eating behavior; thus, it is important to provide nutrition education that integrates disaster preparedness into the formal education system to develop children's abilities and preparedness for disasters. This will improve children's understanding of nutrition in daily life and during disasters and provide opportunities for them to share what they have learned with their families, thereby promoting family and community understanding.

Our educational tool integrates disaster preparedness and nutrition education, increasing children's motivation and skills and the opportunities for them to make informed decisions and engage in health-promoting actions, particularly regarding food choices and safety before, during, and after disasters. However, readers and practitioners should recognize that, while this program was developed based on experts' recommendations and common best practices, it has not yet undergone a comprehensive validation process. As a result, the overall effectiveness, adaptability, and long-term impact of this program in real-world scenarios remains uncertain. This DPNEP may occasionally be validated in real disaster scenarios, but pre- and post-measurements of students' knowledge, attitude, and practice can evaluate its value. The student-centered curriculum encourages active learning and increases content retention by providing practical, hands-on learning on healthy eating while promoting disaster preparedness. A special unit within a school health program can be employed alone or as part of subjects such as physical and health education, social studies, basic science, or agricultural science, depending on each school's environment and resources. Schools can implement the model according to the needs of the school and the community. For instance, it could be an integral part of a camping activity to make it more attractive and fun for students or a picnic incorporating their families and the community. Schools should also identify and secure the available materials and resource persons such as the firefighters, waste management personnel, nutritionists, clinics, disaster management and public health experts, psychologists, gardens, chefs, market leaders, and experienced older adults within the community to facilitate learning, allowing students to become familiar with key facilities, equipment, locations, food, and persons in the community. During a disaster, this will allay or reduce fear and anxiety and help children maneuver their way to safety without

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TABLE 2 Proposed Program for the Disaster Preparedness Nutrition Education Program for Elementary Schools.

Target Students: Students in grades 4–5 in elementary school Style: Special subject with simulation play Duration: 30 min/class					
Topics/Contents	Objective	Methods	Key Message	Instructional Materials	Evaluation
Introduction: food, adequate diet, nutrients, safety, variety, enjoyable, social acceptance, household, community, and disaster	At the end of the class, participants should be able to give meaning to or get used to keywords.	Discussion	We need a variety of foods to grow and be healthy	Graph/audiovisual material illustrating food charts	What is food? What are nutrients?
Why we need food: To be healthy and well-nourished; for energy, growth, physical activity, and basic body functions	At the end of the class, participants should be able to establish what constitutes a good diet	Play/discussion	We need a variety of foods to grow and be healthy	Graph/audiovisual material illustrating the stages of child development	Why do we need food?
Nutrients and their functions: Carbohydrates, proteins, vitamins and minerals, fats, and oil	At the end of the class, participants should be able to explain the functions of the main nutrients	Discussion	Different groups have different dietary needs	Graph/audiovisual material illustrating the major classification of food	What are the functions of proteins? What are the functions of carbohydrates?
Food sources: Cereals (rice, wheat), root and tuber (carrots, sweet potato), pulses (beans, groundnuts), fruits (bananas, apples), meats, poultry, fish, milk, oil, fats (vegetable oil), and others (e.g., sugar)	At the end of the class, participants should be able to state the nutrient content of common foods	Storytelling	Different foods provide different nutrition	Graph/audiovisual material illustrating the major classification of food	Mention the food sources that you know
Dietary needs: The need for variety. Different groups have different dietary needs	At the end of the class, participants should be able to appreciate the need for variety in a diet and recognize individual dietary needs	Discussion and storytelling	A healthy diet can be simple and inexpensive	Graph illustrating the wide variety of locally available food	Mention the dietary needs of children
How to plan a mixed and balanced diet: Dietary guidelines (lifestyle, hygiene, and sanitation). Local and common diets (e.g., rice, wheat, maize, potatoes, and its accompaniments – fish, vegetables, soup or stews, and water)	At the end of the class, participants should know how to enrich a meal	Demonstration/ project-based	A healthy diet can be simple and inexpensive	Graph illustrating the major classification of food and audiovisual materials	What is a balanced diet?
Malnutrition: Bad diet, malnutrition, undernutrition, overnutrition, hunger, and illness	At the end of the class, participants should be familiar with the keywords	Discussion and play	Malnutrition puts children at risk during disasters and affects learning	Graph illustrating a group of children suffering from nutrition-related diseases	What is malnutrition?
The causes of malnutrition: Poverty, food insecurity, disaster, poor health and sanitation, lack of knowledge and care	At the end of the class, participants should be able to recognize the causes of malnutrition	Storytelling/ discussion	Malnutrition has numerous causes	Graph illustrating a group of children suffering from nutrition-related diseases	What are the causes of malnutrition?
Disasters and examples: A disaster is a sudden accident or natural tragedy that causes great damage or loss of life (e.g., earthquakes, typhoons, tsunamis, pandemics, wildfires, drought, thunderstorms)	At the end of the class, participants should be able to understand and list examples of disasters	Discussion/ storytelling	A disaster causes great damage and loss of life	Graph illustrating examples of disasters. Disaster video clip	State examples of a disaster

(Continued)

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TABLE 2 (Continued)

Target Students: Students in grades 4–5 in elementary school Style: Special subject with simulation play Duration: 30 min/class					
Topics/Contents	Objective	Methods	Key Message	Instructional Materials	Evaluation
Basic emergency survival kit: For example, water, food, flashlight, blanket, whistle, first aid kits, toiletries, waterproof case, and battery-powered radio	At the end of the class, participants should be able to identify emergency survival kits	Demonstration	Adequate preparedness saves lives	Graph and/or audiovisual materials illustrating an emergency survival kit	List the emergency kit items
Symbols of evacuation: Evacuation sites, evacuation centers, tsunami sites, evacuation routes, and basic school map (e.g., sports building, playground, cafeteria, toilet, school gate, signage, surrounding environment)	At the end of the class, participants should be able to recognize basic evacuation symbols (universal signage)	Excursion	Knowledge of evacuation symbols reduces danger and stress	Cards/audiovisual material illustrating evacuation symbols	Identify the evacuation symbols in your community
Strategies for fighting malnutrition during disasters: Action by communities and individuals and the role of nutrition education and school with emphasis on identification, innovation, and improvisation using locally available materials	At the end of the class, participants should be able to recognize strategies for fighting malnutrition during disasters, particularly the role of nutrition education	Discussion/ project-based	Appropriate application of nutrition education can fight malnutrition in daily life and during disasters	Graph illustrating a group of children suffering from nutrition-related diseases	What is the role of the individual in fighting malnutrition?
Role of children during emergencies: For example, stay with, listen, and respond adequately to instructions from your guardian; inform your guardian of your needs, including food and allergies; maintain proper hygiene; advise/remind guardians of basic survival kits; raise the alarm if you suspect any danger; if alone, follow the evacuation route to the nearest evacuation center/sites; have consideration/empathy for others	At the end of the class, participants should be able to state their role during emergency	Discussion/ roleplay	We must show empathy and respond adequately during emergencies	Audiovisual material illustrating emergencies	State the roles of children during a disaster

compromising their nutritional health; this will make them better equipped to make informed decisions about food and water safety, potentially preventing illness or malnutrition during critical post-disaster periods.

Children's knowledge can also serve as a safeguard against long-term health issues stemming from sustained food insecurity, ensuring they choose foods that provide essential nutrients. This knowledge becomes an invaluable asset in a landscape where malnourished children are increasingly susceptible to various diseases and developmental setbacks. Moreover, instilling such knowledge at a young age fosters a broader culture of preparedness within communities. This cascading effect reduces the immediate burden on relief agencies and strengthens community resilience, bolstering psychological well-being, fostering community cohesion through collective initiatives, promoting collective well-being, and promoting resource management. As these children mature, they carry this culture forward, ensuring that future generations are better prepared. While lack of empirical evidence, time factors, and school workload may affect the program's implementation, it is intended to motivate students rather than merely serve as an evaluation tool. Through the precision education of the DPNEP for children, a more resilient, healthy, and sustainable future society is expected to emerge.

7.1 Limitations

Although built on a robust foundation of previous research on nutrition education for fourth- and fifth-grade students (30) and a scoping review of child nutrition during disasters (12), this study is not without its limitations. First, despite extensive background research, the current program did not have a specific pilot study tailored to its content and target population. This raises concerns about potential cognitive and developmental misalignments that may not adequately address the unique needs and levels of understanding of fourth- and fifth graders in the context of disaster preparedness. Second, although the program integrates instructional strategies that

have proven effective in previous research, the specific level of interest and engagement of the target demographic in the context of disaster preparedness is untested. Their perceptions of this new content in terms of interest and internalization may differ from previous research findings on nutrition education in general.

Third, while the program is designed with flexible curriculum integration in mind and offers schools the adaptability to implement it based on their specific needs and that of the associated communities, the specific and logistical aspects of integration in a variety of school settings have not been empirically evaluated. This adaptive design acknowledges the importance of community- and school-specific requirements, but the nuances and unforeseen challenges of integration in diverse educational settings remain untested. In addition, this study may inadvertently introduce cultural and socioeconomic assumptions. Even with insights from prior research, the lack of specific pilot study implies that it remains an area of uncertainty whether this program will resonate with the diverse backgrounds and life experiences of all fourth- and fifth-grade students. Future iterations of this program and subsequent studies will benefit from direct empirical testing and feedback from the target population to further refine and optimize its effectiveness.

8 Conclusion

The DPNEP can lead to the implementation of continuous nutrition education to empower children to make healthy food choices in daily life and reduce the risk of disaster-nutrition-related morbidity and mortality. Furthermore, once children acquire the necessary information, they are likely to share this knowledge with their families and communities, thereby enhancing society's resilience.

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.

Author contributions

AA: Conceptualization, Funding acquisition, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. SE: Conceptualization, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing. ASA: Conceptualization, Methodology, Resources, Validation, Visualization, Writing – review & editing. RN: Funding acquisition, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

ASA is an employee of Kerry Ingredients Nigeria Limited, Ikeja, Lagos State, Nigeria.

The remaining 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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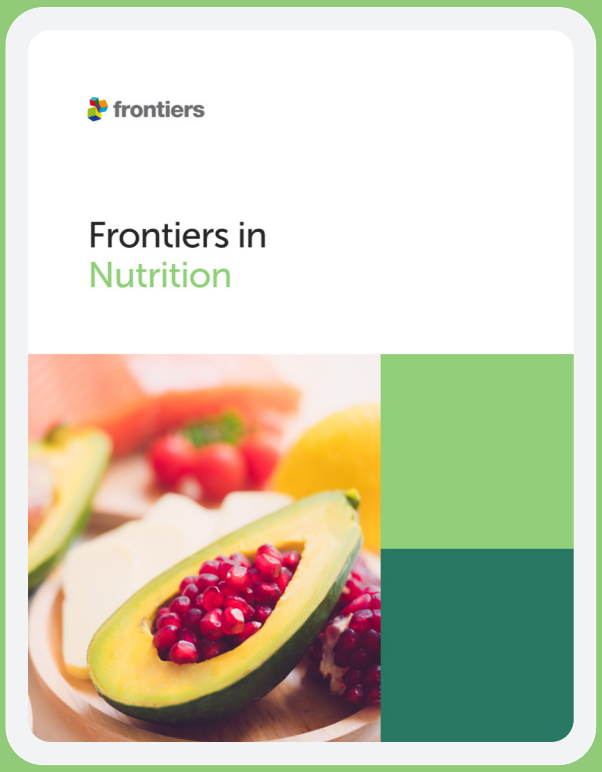

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