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MODELS OF NUTRITION EDUCATION INTERVENTIONS FOR ADOLESCENT LIFESTYLE CHANGES: A SCOPING REVIEW

Model Intervensi Pendidikan Gizi untuk Perubahan Gaya Hidup Remaja: Scoping Review

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ABSTRAK

Masa remaja merupakan masa transisi yang menentukan pola makan sehat dan perilaku gaya hidup sepanjang hidup. Intervensi edukasi gizi memiliki peran strategis dalam mencegah pola makan tidak sehat pada remaja. Penelitian ini bertujuan menggambarkan dan mengevaluasi berbagai model intervensi pendidikan gizi yang efektif bagi remaja melalui identifikasi pola, hasil, hambatan, dan faktor pendukung yang komprehensif. Metode pada kajian ini menggunakan scoping review yang mengikuti panduan PRISM-Scr dan kerangka Arksey dan O'Malley. Pencarian literatur dilakukan pada database PubMed, Science Direct, dan Scopus menggunakan kata kunci: "remaja," "gizi," "intervensi," dan "hambatan" pada bulan Maret 2025. Studi dipilih berdasarkan kriteria inklusi dan eksklusi yang telah ditentukan sebelumnya. Hasil menunjukan bahwa *dari 1.936 artikel, sebanyak 10 artikel terpilih untuk dianalisis. Artikel yang dipilih berasal dari negara berkembang dan dikategorikan ke dalam tiga pendekatan utama: intervensi berbasis digital, intervensi berbasis tradisional, dan intervensi berbasis sekolah. Masing-masing menunjukkan efektivitas yang bervariasi dalam meningkatkan pengetahuan, sikap, dan perilaku gizi remaja. Faktor keberhasilan meliputi integrasi dalam sistem pendidikan, relevansi budaya, serta kolaborasi multisektoral. Beberapa hambatan meliputi keterbatasan durasi, pendekatan pasif, dan akses makanan sehat. Temuan ini menekankan pentingnya strategi yang multikomponen dan adaptif terhadap konteks lokal.*

Keywords: *negara berpenghasilan menengah ke bawah, pendidikan gizi, perubahan gaya hidup, remaja, tinjauan cakupan*

ABSTRACT

Adolescence is a transition period that determines healthy eating patterns and lifestyle behaviors throughout life. Nutrition education interventions play a strategic role in preventing unhealthy dietary habits among adolescents. This study aims to describe and evaluate various effective models of nutrition education interventions for adolescents by identifying patterns, outcomes, barriers, and supporting factors comprehensively. The method applied in this review is a scoping review guided by the PRISMA-Scr framework and Arksey and O'Malley's methodological framework. Literature was retrieved from PubMed, ScienceDirect, and Scopus databases using the keywords: "adolescents," "nutrition," "intervention," and "barriers" in March 2025. Studies were selected based on pre determined inclusion and exclusion criteria. The results show that out of 1,936 articles identified, 10 studies were selected for further analysis. The selected articles originated from developing countries and were categorized into three main intervention approaches: digital-based, traditional-based, and school based interventions. Each model demonstrated varying levels of effectiveness in improving adolescents' nutritional knowledge, attitudes, and behaviors. Key success factors included integration into the educational system, cultural relevance, and multisectoral collaboration. Several barriers were also identified, such as limited duration, passive delivery approaches, and limited

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access to healthy foods. These findings underscore the importance of multicomponent strategies that are contextually adaptable to local settings.

Keywords: adolescents, lifestyle change, low and middle income, nutrition education, scoping review

INTRODUCTION

In 2024, the global prevalence of obesity reached 3 billion individuals [1], while hypertension affected 19% of the population [2], and diabetes impacted 10.5% of the global population[3]. These health conditions are closely associated with poor dietary habits, physical inactivity, and the excessive consumption of fast food and sugar sweetened beverages, which are high in calories but low in nutritional value. The global rise in obesity and diet related non communicable diseases (NCDs) underscores the urgency of effective, targeted interventions.

Adolescence is a critical phase for establishing long term dietary and lifestyle habits, as nutritional needs increase significantly to support rapid physical and cognitive development [4], [5]. However, this period also presents heightened vulnerability to nutritional problems due to poor eating habits, sedentary behavior, and the easy access to processed, energy dense foods [6], [7], [8]. The behaviors formed at this stage such as food choices and meal patterns tend to persist into adulthood and significantly influence future health outcomes [9], [10]. Promoting healthy eating through education in adolescence therefore holds strategic value in the prevention of chronic diseases later in life.

To address adolescent nutrition issues, education is a key public health strategy. However, the methods, models, and contexts of nutrition education interventions vary widely due to differences in delivery mechanisms, socioeconomic conditions, and cultural factors. This scoping review aimed to map and evaluate types of Nutrition Education Intervention (NEI) models promoting healthy lifestyle changes among adolescents, assess their effectiveness in influencing behavior, and identify barriers and facilitators to implementation. The synthesis of existing evidence is expected to guide the development of more effective, sustainable, and context-appropriate strategies for improving adolescent nutrition and health outcomes.

METHODS

This study followed the scoping review guidelines provided by Arksey and O'Malley and suggestions from Levac et al and adhered to the PRISMA-Scr Reporting Checklis [11]. The checklist was employed to improve the transparency and thoroughness of the review, adhering to established best practices in systematic review methodologies [12]. The initial step in this scoping review involved conducting a comprehensive literature search across three major scientific databases: PubMed, ScienceDirect, and Scopus. The review followed the methodological framework proposed by Arksey and O'Malley, which includes the following stages: identifying relevant sources, selecting studies, charting the data, and finally compiling, summarizing, and reporting the results. The search strategy employed Boolean operators such as AND and OR to combine key concepts related to “adolescents,” “nutrition,” “interventions,” and “lifestyle related barriers.” The search was conducted in March 2025, and articles were limited to those published between January 1, 2019, and March 15, 2025. Only articles written in English were considered for inclusion in this review.

Eligible studies included original peer-reviewed research on nutrition education interventions targeting adolescents, conducted in Low and Middle Income Countries (LMICs). Studies were excluded if they were literature reviews, qualitative studies without experimental components, focused on non adolescent populations, involved adolescents with specific medical conditions, or were protocols or unpublished works still under review.

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The initial database search identified 1,936 articles (993 from PubMed, 527 from Scopus, and 416 from Science Direct). After removing three duplicates, 1933 articles were screened through a two-stage process consisting of title and abstract screening followed by full text review. Screening was conducted collaboratively by the research team to ensure consistent application of the eligibility criteria. From the 21 articles that underwent full-text review, 10 met all inclusion criteria and were retained for analysis. The selection process is illustrated in the PRISMA Flowchart (Figure 1), which, while primarily used for randomized trial reviews, also serves as a useful framework for documenting the screening and selection process in systematic and scoping reviews of intervention studies.

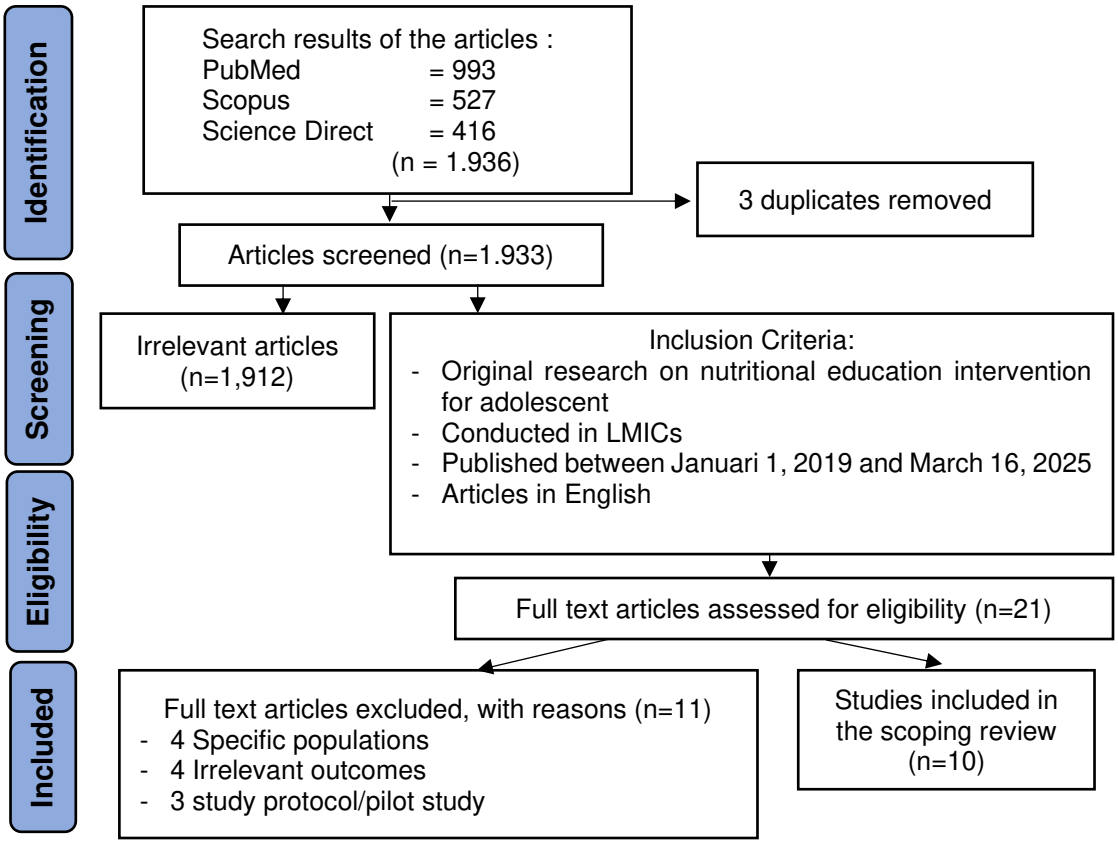

Figure 1. PRISMA Flowchart. Article Selection Process

A standardized charting form was used to extract key data, including authorship, year, location, objectives, design, sample size, intervention type and duration, outcomes, and barriers or facilitators. Two reviewers conducted independent extraction and cross-checking to ensure consistency. Studies were then categorized into three intervention models: digital-based, traditional-based, and school-based. Given the methodological diversity, a narrative synthesis was applied to map intervention characteristics, evaluate outcomes, analyze implementation contexts, and identify evidence gaps.

RESULT

Data from ten selected studies were organized in a standardized charting table detailing study location, objectives, design, intervention type, sample size, duration, and outcomes. Article quality was evaluated through critical appraisal, and thematic analysis was used to identify patterns and research gaps. The findings were classified into three main intervention models—digital-based, traditional-based, and school-based—each summarized in a separate table for clarity and comparison.

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1. Digital-based Intervention

Based on the analysis of the selected studies, two articles were identified that applied digital-based intervention models. These interventions utilized technological platforms such as mobile applications and digital games to improve nutritional knowledge, attitudes, and behaviors among adolescents. Differences were observed in the types of platforms, duration, and outcome effectiveness (Table 1).

Table 1. Data Charting Digital-based Intervention

No	Author(s), Year, Study Location	Objective(s)	Study Design	Intervention Type	Outcomes
1.	Chagas et al (2020), Brazil	Assessing the impact of a game-based nutrition intervention on food consumption, nutrition knowledge, and self-efficacy in implementing healthy eating practices.	This cluster randomized controlled trial involved 319 adolescents from eight randomly selected private schools, with 117 in the intervention group and 202 in the control group.	The Rango Cards digital game is played over a period of 7 to 17 days.	There was no significant increase in knowledge and efficacy, but the digital intervention encouraged perceptions and plans for healthy eating behavior change.
2.	Mahmudiono et al. (2025), Indonesia	Designing and assessing the effectiveness of an application based on the Traffic Light Diet System in encouraging adolescent dietary behavior, knowledge, and attitudes regarding sugar, salt, and fat.	Quasi-experimental research design involved 110 university students, randomly assigned with 55 people to the intervention group and 55 people to the control group, without any intervention	The traffic light diet system was delivered through an android application over an 8 week period.	Increased knowledge and attitudes in both groups, and the control group were greater.

Both studies had the same objective, which was to improve adolescent nutrition knowledge and behavior using digital-based approaches. However, different platforms and study designs were used. Mahmudiono et al. developed an Android-based application utilizing a food scanning feature called the Traffic Light Diet System [13], while Chagas et al. developed the Rango Cards Game, an interactive digital game application [14]. Chagas et al. applied a cluster randomized controlled trial design, where the control group did not receive any intervention. Meanwhile, Mahmudiono et al. used a quasi-experimental study design, in which the control group was only given a PPT presentation.

In the study using the Rango Cards Game, no significant improvement was found in nutrition knowledge, and only a slight but not significant increase was observed in self-efficacy scores [14]. However, there was a significant improvement in the perception of the benefits of fruits and vegetables, the intention to reduce salt consumption, and the intention to prepare healthy meals. In Mahmudiono et al.'s study, both groups showed significant improvements in knowledge; however, the control group showed a greater increase. Regarding attitudes, the intervention group showed a modest but significant improvement, while the control group demonstrated a greater change [13].

Both studies had advantages in utilizing digital technology to support nutrition education interventions. However, there were several limitations that could serve as input for future studies to achieve better outcomes in nutrition interventions. The Traffic Light Diet System study had limitations in terms of the control group having a higher number of respondents due to the specific use of Android devices, which led to selection bias and limited sample representation. Furthermore, participants with

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diverse educational backgrounds might interpret nutrition education differently [13]. Additionally, there were facilitators such as the integration of a food database customized with local food in online ordering applications, making it closely related to daily life and easier to implement [13]. The Rango Cards Game study had limitations in terms of the short intervention duration, a limited number of game phases, and the lack of incorporation of local food culture preferences or local health priorities, relying only on national guidelines. Nevertheless, it had the advantage of being player-centered in its game design, resulting in a stronger relationship between the player and the technology [14].

2. Traditional-based Interventions

Based on the analysis of the selected articles, three studies were identified that evaluated traditional-based interventions. However, five different intervention models were found within these three studies. This was due to the studies in India [15] and Indonesia [7], which each evaluated two different intervention approaches within a single study, namely the comparison between a complete intervention package and a pamphlet in India, and the comparison between individual and group approaches in Indonesia. Meanwhile, the study in Mexico [16], compared two intervention groups, but only the group that received lecture-based food education was categorized as a traditional intervention. In terms of study design, one study used a Cluster Randomized Controlled Trial (RCT) design [15] while the other two studies used a quasi-experimental design [7], [16]. (Table 2).

Table 2. Data Charting Traditional-based Interventions

No	Author(s), Year, Study Location	Objective(s)	Study Design	Intervention Type	Outcomes
1.	Figueroa Piña (2021), Mexico	Improving students' nutritional literacy and knowledge through food education that combines various disciplines such as health, food science, agriculture, and the environment.	This quasi-experimental study involved 64 adolescents selected through convenience sampling, with 34 assigned to the intervention and 30 assigned to the control group without any intervention.	Food education program implemented over a 12-week period.	Increase consumption and frequency of eating fruit and vegetables, and significantly improve nutritional attitudes and awareness.
2.	Mallick et al. (2024), India	To assess and compare the effectiveness of health education packages through nutritional knowledge interventions, practices, and physical activity levels in group 1 which received the complete package (Health education with flip chart and pamphlet)	A cluster randomized controlled trial involved 116 students from four schools selected using cluster random sampling	Health education using a flip chart and pamphlet over 4 weeks.	Significant decrease in screen time for studying. There was an increase in nutritional knowledge and sleep duration, although not significant.
3.	Mallick et al. (2024), India	To assess and compare the effectiveness of health education packages through	Cluster randomized controlled trial involved 110	Pamphlet distributed over a 4 week period.	There was no significant increase in nutritional knowledge and physical activity.

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No	Author(s), Year, Study Location	Objective(s)	Study Design	Intervention Type	Outcomes
		interventions on nutritional knowledge, practices and physical activity levels in group 2 who only received pamphlets.	students from four schools selected using cluster random sampling		However, it showed positive behavioral changes in the form of a significant increase in healthy food consumption practices.
4.	Kamsiah et al. (2023), Indonesia	Evaluating the impact of nutrition education on knowledge, attitudes and consumption patterns in preventing KEK in adolescent girls through an individual approach.	Quasi-experimental study involved 30 students, selected through cluster random sampling.	Individual based nutrition education using lectures, discussions,and booklets over a 3 week period.	There was a significant increase in knowledge, attitudes, and energy and protein intake.
5.	Kamsiah et al. (2023), Indonesia	Evaluating the impact of nutrition education on knowledge, attitudes and consumption patterns in preventing KEK in adolescent girls through a group approach.	Quasi-experimental study involved 30 students, selected through cluster random sampling.	Group based nutrition education using lectures, discussions,and booklets over a 3 week period.	There was a significant increase in knowledge, attitudes, and energy and protein intake.

All traditional-based interventions demonstrated positive effects on improving knowledge, attitudes, and behaviors, though results varied across studies. In India, pamphlet-only interventions had a greater impact on promoting healthy eating practices compared to those combining flip charts and pamphlets. Conversely, the combined flip chart and pamphlet intervention significantly reduced screen time for studying but did not produce significant improvements in nutrition knowledge or sleep duration. Both intervention and control groups showed inconsistent changes in physical activity. [15]. The study in Mexico reported that lecture based food education was able to significantly increase the frequency of fruit and vegetable consumption and improve nutrition attitudes and awareness. However, its impact was still lower compared to interventions that combined it with direct practice [16]. In contrast, the study in Indonesia found significant improvements in knowledge, attitudes, as well as energy and protein intake using the booklet and group discussion approach compared to individual mentoring [7].

Several barriers were identified in studies using traditional-based interventions. In India and Indonesia, limitations included short intervention durations, socioeconomic complexities, and the delivery of education models that were passive, leading to a lack of practical integration in learning, which became obstacles in sustainable behavior change [7], [15]. The study in Mexico found that the group receiving only food education showed cognitive improvements but lacked practical engagement [16]. However, some factors facilitated success, such as access to and support from the home environment for behavior change[16], various and easily accessible visual and printed information sources[15], and social interaction support in group approaches[7].

3. School Based Intervention

Five studies were identified in the category of school based interventions. One study used a qualitative exploratory approach through in depth interviews and focus group discussions [17], while the other four studies applied a cluster randomized

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controlled trial design [18], [19], [20], [21]. In these five analyzed studies, seven intervention models were identified, showing a diversity of approaches. Some studies implemented nutrition education and multi component healthy lifestyle programs [18], [20], as well as interventions integrating the school curriculum [20]. Other studies developed interventions based on school integration with meal programs and gardening or using only school gardens combined with nutrition education and community workshops [19]. In addition, there were interventions in the form of training school canteen and shop operators [17], as well as culinary nutrition education based on direct practice [21]. The target groups of interventions in these five studies also varied, including students, parents, and the school community who were actively involved in the implementation of the programs. (table 3).

Table 3. Data Charting School Based Intervention

No	Author(s), Year, Study Location	Objective(s)	Study Design	Intervention Type	Outcomes
1.	Azizan et al. (2021), Malaysia	Evaluating the implementation of a school based intervention that promotes healthier eating habits in the school environment.	Quasi-experimental study involved 76 adolescents selected through purposive sampling, with 38 assigned to the intervention group and 38 to the control group.	Training school canteen and shop operators to sell healthier food combined with subsidization of healthy food over a 3 month period.	Changes in food preferences, increased consumption of fruits and vegetables, acceptance of healthy foods and the availability of a healthy canteen environment.
2.	Kim et al. (2023), Ethiopia	Evaluating the feasibility and effectiveness of a nutrition education intervention through 4 school based components.	Cluster randomized controlled trial involved 183 students selected using cluster sampling.	Routine activities (flag ceremony, class lessons, school clubs), peer mentoring, BMI measurement and counseling, and parent teacher meetings over a 12 month period.	Significant decrease in candy consumption, increase in food diversity and meal frequency of students, nutritional knowledge of students and parents. However, no significant change in junk food consumption was shown.
3.	Kim et al. (2023), Ethiopia	Assessing the feasibility and effectiveness of delivering health education interventions included in the standard school curriculum.	Cluster randomized controlled trial involved 180 students selected using cluster sampling.	The school curriculum on health and nutrition is similar to that already available in Ethiopian public schools over a 12 month period	Consumption of sweet foods such as candy was found to be still high. Getting significantly lower scores in food diversity, meal frequency, and nutritional knowledge compared to the group given additional nutritional education intervention.
4.	Wang et al. (2022), Tanzania	Implementing and evaluating a full intervention package through four components of school based interventions on nutritional intake,	Cluster randomized controlled trial involved 180 students, selected using cluster sampling	School Meals, School Gardens, Nutrition Education, Community Workshops over a 12 month period	There was an increase in students' self-efficacy and preference for healthy foods. There was a significant increase in vegetable consumption, total energy, protein and micronutrients. No

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No	Author(s), Year, Study Location	Objective(s)	Study Design	Intervention Type	Outcomes
		consumption patterns, and eating behavior of elementary school students.			significant differences were found in anthropometric indicators (BMI).
5.	Wang et al. (2022), Tanzania	Implementing and evaluating a partial intervention package through three components of school based intervention on nutritional intake, consumption patterns, and eating behavior of elementary school students.	Cluster randomized controlled trial involved 180 students, selected using cluster sampling	School Gardens, Nutrition Education, Community Workshops over a 12 month period	There were no significant increases in energy or micronutrient intake. However, there were increases in vegetable consumption, self-efficacy and preference for healthy foods, although the results were not as strong as in the group receiving the full interventions.
6.	Barbosa Filho (2019), Brazil	Assessing the effectiveness of the Fortaleça sua Saúde program in promoting healthy lifestyle behaviors among adolescents with low Human Development Index.	Cluster randomized controlled trial involved 1,256 students selected using cluster sampling	Fortaleça sua Saúde Program (Training of subject teachers and sports teachers, Changes in the School Environment, Education for students & parents), over a 7 month period.	There was a significant increase in physical activity. Increased healthy behavior related to reduced screen time on TV and Computer/games. And a significant decrease in the behavior of consuming sweet foods was found.
7.	Ng et al. (2024), Malaysia	Evaluating the effectiveness of a culinary nutrition education program at a 3 month follow up, in terms of children's dietary practices and variations.	Quasi-experimental study involved 21 parent child dyads, selected using cluster sampling, without a control group.	Culinary nutrition education based on direct practice (1 parentchild session about the home food environment + 5 hands on healthy meal preparation sessions), over 6 weeks.	The intervention had a significant impact on increasing children's consumption of whole grains, fruits and vegetables, and decreasing their consumption of processed foods and sugary drinks. Helped improve the variety of foods at dinner.

In general, school based interventions had a positive impact on adolescent lifestyle changes. This was reflected in changes in eating behaviors such as increased consumption of fruits, vegetables, and other healthy foods. Several interventions reported changes in vegetable consumption [17], [19], [21]. Some studies also reported a significant reduction in the consumption of sugary foods or beverages [18], [20], [21]. However, in the intervention model reported by Kim, one model that only provided nutrition education through the school curriculum still reported high consumption of sugary foods and beverages [20]. Multi component interventions involving students, teachers, parents, and communities [18], [19], [20] showed improvements in physical activity, meal frequency, reduction in consumption of sweets and ultra processed foods,

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and dietary diversity. However, reductions in junk food consumption and anthropometric indicators were not significant [18], [19], [20].

The limitations identified in several studies included the use of self reported measurement methods and relatively short intervention durations [18], [21]. In addition, the lack of components for changing the school food environment was a consistently reported barrier in several studies [18], [20], [21]. Specifically, in the study by [19] the absence of school meal support was a significant differentiator between the partial and full intervention groups. Other barriers included established preferences and habits [17], [20], resistance to change from the school environment [17], [18], and challenges in accessing healthy food at home and in the community [19], [21]. On the other hand, several facilitating factors found in the intervention models were stakeholder, teacher, family, and community support, which served as driving factors in the effectiveness of the interventions [18], [19], [20], [21]. Support from trained facilitators, peer monitoring involvement, and logistical support also contributed positively to program implementation [17], [19], [20], [21]. All studies emphasized the importance of program sustainability, cross sectoral integration, and local context adaptation.

DISCUSSION

This scoping review identified ten studies from low- and middle-income countries (LMICs) implementing nutrition education interventions (NEIs) for adolescents, categorized into digital-based, traditional-based, and school-based models. All interventions improved adolescents' knowledge, attitudes, and behaviors, with school-based programs showing the most comprehensive effects, especially when using multicomponent approaches. Digital interventions were attractive and innovative but varied in effectiveness depending on content quality and cultural adaptation, while traditional methods remained effective in group-based, culturally tailored contexts.

This review has several limitations. First, evidence from LMICs remains scarce and is generally of low quality. Second, the review only included peer-reviewed and published articles, excluding gray literature, theses, and program evaluations that may offer valuable insights. Furthermore, heterogeneity in study design, intervention duration, and measured outcomes limited direct comparisons across studies and precluded meta-analysis. Nevertheless, this review makes a meaningful contribution by mapping nutrition education interventions for adolescents in LMICs and highlighting key strategies and critical gaps. This review aligns with previous findings showing that nutrition interventions are effective in improving healthy eating behaviors and physical activity, particularly through school based, digital, and behavior change theory integrated approaches [22].

1. Digital-based Interventions

Digital-based interventions in this review reflect the diversity of approaches in delivering nutrition education to adolescents. This phenomenon aligns with the growing use of digital media as an educational tool to improve nutrition knowledge and behaviors among the general population, including adolescents [23]. Adolescents are now often categorized as digital natives a generation that has grown up in the digital era and thus possesses a high level of familiarity and interest in digital media [24]. Therefore, the use of digital media is particularly promising for adolescent targets. The two identified studies, *Traffic Light Diet* [13] and Rango Cards [14] although utilizing different platforms, shared a common goal of promoting changes in dietary behavior. However, the outcomes revealed variations in effectiveness. These differences suggest that the success of interventions is not solely determined by the type of technology used, but also by content quality, cultural relevance, the underlying behavior change theory, and the level of user engagement. These findings are consistent with other studies indicating that the effectiveness of digital interventions

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tends to increase when peer support, user responsive design, and adaptation to sociocultural context are incorporated [25].

2. Traditional-based Interventions

Traditional-based nutrition education interventions—such as lectures, group discussions, pamphlets, and flip charts—remain effective in improving adolescents' knowledge, attitudes, and nutritional behaviors. These results show that even in the digital era, conventional methods can still yield positive outcomes when culturally and contextually adapted. Furthermore, creative and engaging media design enhances students' comprehension and retention of nutritional information[26]. The five traditional-based intervention models demonstrated varying levels of effectiveness, which may be influenced by differences in intervention design, delivery approaches, and participant engagement. Interventions in two study groups reported that the pamphletbased approach was more effective than multicomponent interventions involving additional visual graphics [15]. The simplicity of direct communication is often easier for adolescents to understand, as they tend to have shorter attention spans and be more selective in processing information [27]. In the Indonesian study, the group based intervention approach proved more effective than individual guidance [7]. This finding aligns with Bandura's social learning theory, which emphasizes observation, imitation, and social interaction in the process of behavior formation [28]. Socioeconomic factors also influenced the effectiveness of the interventions provided [7], [15]. This supports previous findings that educational interventions in low and middle income countries often fall short when not supported by a well coordinated multisectoral approach [22]. In Mexico, nutrition education interventions combined with direct practice were found to be more effective than lecture based approaches alone. This is consistent with the principle of experiential learning, which posits that behavioral change is more likely to occur when participants are actively engaged in real life experiences [28]. Therefore, traditional approaches remain highly relevant, particularly when integrated with other media as part of a multicomponent strategy, and should be accompanied by longer intervention durations to achieve sustainable behavior change.

3. School-Based Interventions

The findings from the review of school based nutrition intervention approaches revealed generally positive effectiveness, particularly in influencing adolescents' dietary behavior. This was reflected in increased consumption of fruits and vegetables, as well as reduced intake of sugary foods and beverages. The effectiveness was strengthened when the interventions were multicomponent, involving not only students as the primary target but also parents, teachers, canteen operators, and the school community. Similar effectiveness was also found in other studies implementing multicomponent school based interventions [29]. However, such effectiveness tends to diminish when changes in school policy and the school food environment are not supported. For instance, the limited access to healthy food due to the absence of internal school policies. This is supported by studies showing that combining a supportive food environment and the availability of healthy food options can enhance the effectiveness of school based nutrition programs [30]. Differences in intervention outcomes may also be influenced by the involvement of local context, such as cultural factors, food preferences, and access to healthy foods at home and in the community. We found that multicomponent nutrition education interventions that integrate elements surrounding adolescents such as nutrition education, parental involvement, environmental modification, and the use of digital technology tend to be more effective in improving knowledge and changing healthy lifestyle behaviors among adolescents [22], [31].

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This review has the advantage of specifically mapping nutrition education interventions in low and middle income countries (LMICs), a region that remains underrepresented in the global literature. The classification of interventions into three categories (digital, conventional, and school based) facilitates policymakers in selecting strategies that align with the characteristics and needs of the target population. The implications of this review suggest that future studies should prioritize the development of context specific interventions grounded in behavioral theory, while also considering cultural factors, multisectoral collaboration, and multicomponent strategies that address various aspects influencing the target audience. The findings of this review may serve as a foundation for designing more effective and sustainable nutrition intervention programs, particularly in LMICs settings.

CONCLUSION

This review aimed to describe and evaluate models of nutrition education interventions for adolescents in low and middle income countries (LMICs), focusing on patterns, outcomes, barriers, and supporting factors. Ten eligible studies were identified and categorized into three main intervention approaches: digital-based interventions, traditional-based interventions, and school-based interventions, each demonstrating varying levels of effectiveness in improving adolescents' nutritional knowledge, attitudes, and behaviors.

1. **Digital-based Interventions**

   Digital interventions, although innovative in utilizing technology, need to consider a longer intervention duration, which should also be strengthened by the integration of local food culture.

2. **Traditional-based Interventions**

   The effectiveness of traditional-based intervention models depends on the educational methods used and the period of implementation, which impact long-term behavior change.

3. **School Based Interventions**

   In contrast, multi component and participatory approaches involving schools, families, and communities have shown good effectiveness in improving dietary diversity, reducing unhealthy food consumption, and promoting supportive environments. In conclusion, future interventions should adopt multisectoral, culturally tailored, and theory-driven approaches, with sustained implementation to ensure long-term behavioral change in adolescent nutrition across LMIC contexts.

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