



Effectiveness of a School-Based Nutrition Education Programme on Knowledge of Vitamin D Deficiency and Preventive Practices Among Early Adolescents in Durg District, India

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Abstract

Vitamin D deficiency is highly prevalent among Indian adolescents and poses significant risks to skeletal development and long-term metabolic health. This study assessed the effectiveness of a structured Nutrition Education Activity Programme (NEAP) in improving knowledge related to vitamin D deficiency and its prevention among early adolescents. A quantitative pre-experimental one-group pre-test and post-test design was employed among 80 adolescents aged 11–14 years from selected government schools in Durg District, Chhattisgarh. Knowledge levels were measured using a structured questionnaire before and after a four-day educational intervention. However, at baseline, 55.0% of participants demonstrated poor knowledge, while only 1.25% exhibited good knowledge regarding vitamin D deficiency. Post-intervention assessment showed a substantial improvement, with 65.0% of adolescents achieving good knowledge and only 1.25% remaining in the poor knowledge category. Mean knowledge scores increased significantly from 6.52 ± 4.13 at baseline to 15.42 ± 2.53 after the intervention (mean difference = 8.9; $t = 2.36$; $p < 0.05$). Age and number of siblings were significantly associated with baseline knowledge, whereas gender, dietary pattern, parental education, and income showed no significant associations. Therefore, the findings indicate that targeted nutrition education can effectively address clinical nutrition knowledge gaps related to vitamin D deficiency during early adolescence.

Keywords: Vitamin D deficiency; Nutrition education; Early adolescents; School-based intervention; Knowledge assessment; Preventive nutrition

Introduction

Vitamin D is a group of structurally related, fat-soluble compounds that play a central role in maintaining calcium and phosphate homeostasis, thereby supporting bone mineralization and skeletal health. In humans, the biologically most important forms are vitamin D₃ (cholecalciferol) and vitamin D₂ (ergocalciferol). Beyond its classical role in bone health, vitamin D is increasingly recognized for its involvement in immune regulation, muscle function, and modulation of inflammatory processes (Holick, 2007; Bouillon et al., 2019). Unlike most other

vitamins, vitamin D is considered conditionally essential because endogenous synthesis occurs in the skin following exposure to ultraviolet B (UVB) radiation from sunlight. However, dietary sources such as milk, eggs, fish, and fortified foods, along with supplements, remain important contributors, particularly when sunlight exposure is inadequate.

Vitamin D deficiency is defined as a condition in which circulating levels of vitamin D fall below those required for optimal physiological functioning. According to the World Health Organization (2023),

deficiency commonly arises due to insufficient sunlight exposure, poor dietary intake, or both. Inadequate vitamin D levels impair intestinal calcium absorption, leading to reduced bone mineral density, skeletal deformities, and an increased risk of fractures. In children and adolescents, deficiency may manifest as bone pain, delayed growth, fatigue, muscle weakness, and increased susceptibility to infections (Misra et al., 2008; Palacios and Gonzalez, 2014). Given its long-term consequences on skeletal integrity and overall health, early identification and prevention of vitamin D deficiency are essential public health priorities.

Adolescence represents a critical developmental stage characterized by rapid physical growth, hormonal changes, and increased nutritional demands. Early adolescence (11–14 years) is particularly significant, as a substantial proportion of peak bone mass is accumulated during this period (Weaver et al., 2016). UNICEF (2019) describes adolescence as a “window of opportunity” for establishing healthy behaviors that persist into adulthood. However, modern lifestyle patterns, including reduced outdoor activity, prolonged screen time, and suboptimal dietary habits, have significantly increased the risk of vitamin D deficiency among adolescents, even in regions with abundant sunlight (Saggese et al., 2015; Cashman et al., 2016). These trends underscore the importance of targeted educational interventions during early adolescence to promote awareness and preventive practices.

India presents a paradoxical scenario wherein, despite ample sunlight throughout the year, vitamin D deficiency remains highly prevalent. National and regional studies consistently report that 70% to 100% of children and adolescents exhibit vitamin D insufficiency or deficiency (Ritu and Gupta, 2014; Aparna et al., 2018). The Indian Council of Medical Research (ICMR) has highlighted that more than 80% of Indian adolescents have serum vitamin D levels below recommended thresholds. Contributing factors include limited sun exposure due to cultural practices, urbanization, indoor lifestyles, air pollution, inadequate dietary intake, and poor awareness regarding the importance of vitamin D (Harinarayan et al., 2013; Sharma et al., 2020). These factors collectively emphasize the urgent need for preventive strategies focused on education and behavior modification.

Nutrition education has been identified as an effective approach for preventing micronutrient deficiencies and promoting healthy dietary behaviors. The Nutrition Education Activity Programme (NEAP) is a structured educational intervention designed to improve nutrition-related knowledge and facilitate positive health behaviors through interactive teaching methods such as lectures, demonstrations, group discussions, visual aids, role play, and quizzes. According to Krause and Mahan (2018), nutrition education empowers individuals to make informed food choices and adopt sustainable health-promoting practices. Previous studies have demonstrated that school-based nutrition education programs significantly improve adolescents’ knowledge, attitudes, and practices related to micronutrient intake and lifestyle behaviors (Contento, 2016; Sharma and Singh, 2019). Evidence from recent literature further supports the role of awareness in preventing vitamin D deficiency. A large cross-sectional study conducted by Bohsas et al. (2024) in Syria reported that although general awareness of vitamin D’s role in bone health was high, significant knowledge gaps persisted regarding risk factors and preventive strategies. The study also identified age and occupation as significant predictors of adequate knowledge, highlighting the influence of education and life stage on awareness levels. Similar findings have been reported in studies conducted across Asia and the Middle East, emphasizing that improved knowledge is closely associated with healthier sun exposure practices and dietary behaviors (Al-Delaimy et al., 2021; Khan et al., 2022).

Given the high prevalence of vitamin D deficiency among adolescents and the modifiable nature of its key determinants, there is a growing emphasis on preventive, school-based educational interventions. Nutrition education, when delivered during early adolescence, has the potential to improve knowledge, shape health-promoting behaviours, and reduce long-term nutritional deficiencies (Contento, 2016; Krause & Mahan, 2018). Despite this, empirical evidence evaluating structured nutrition education programmes targeting vitamin D awareness among Indian adolescents remains limited, particularly in semi-urban and rural settings.

In this context, the present study was designed to systematically evaluate the role of a Nutrition Education Activity Programme (NEAP) in enhancing

early adolescents' understanding of vitamin D deficiency and its prevention. Specifically, the study aimed to assess baseline knowledge levels related to vitamin D deficiency among early adolescents studying in selected government schools of Durg District, Chhattisgarh, and to examine changes in knowledge following the implementation of the educational intervention. In addition, the study sought to explore whether pre-interventional knowledge levels were associated with selected demographic characteristics, acknowledging that socio-demographic factors often influence nutritional awareness and health literacy (UNICEF, 2019; Sharma *et al.*, 2020).

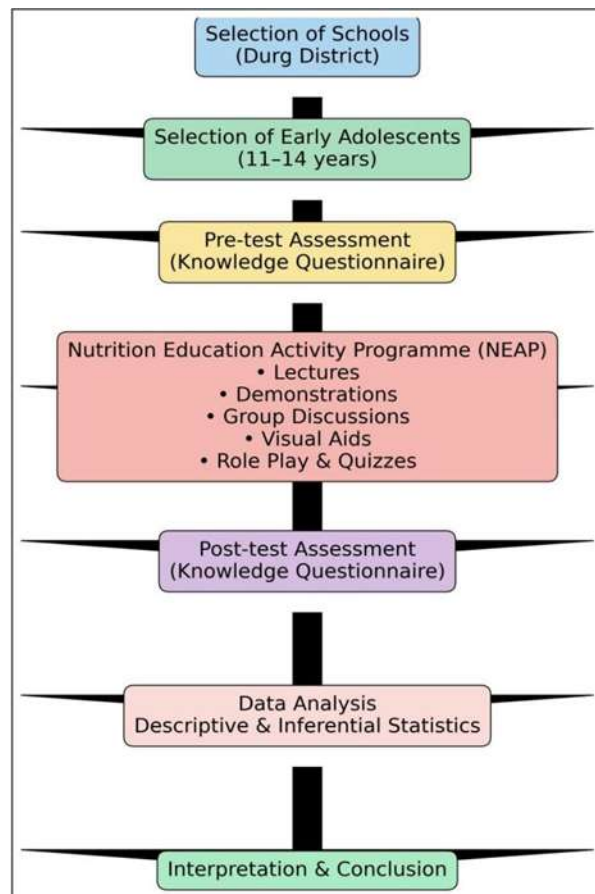
The study was guided by the underlying hypothesis that a structured and interactive nutrition education programme would result in a statistically significant improvement in adolescents' knowledge regarding vitamin D deficiency and its preventive measures. It was further hypothesised that baseline knowledge levels would vary according to demographic variables

such as age, gender, dietary pattern, and sun exposure practices. By empirically testing these assumptions, the study contributes to the growing body of evidence supporting nutrition education as a feasible and effective public health strategy for addressing micronutrient deficiencies during early adolescence.

Methodology

A quantitative pre-experimental research design with a one-group pre-test and post-test approach was adopted to evaluate the effectiveness of the Nutrition Education Activity Programme. The study was conducted in selected government schools of Durg District, Chhattisgarh, among early adolescents aged 11–14 years (Figure 1). The study population comprised school-going early adolescents who met the inclusion criteria and were selected using a non-probability convenience sampling technique. Baseline data were collected using a structured knowledge questionnaire developed to assess understanding of vitamin D, its sources, deficiency, symptoms, consequences, and preventive strategies.

Figure 1. Methodology flow chart of the study design and data collection process.



Following the pre-test, the Nutrition Education Activity Programme was administered. The intervention included interactive lectures, demonstrations, group discussions, visual aids, role play, and quizzes, designed to enhance comprehension and encourage positive health behaviours such as adequate sunlight exposure and consumption of vitamin D-rich foods. After the completion of the educational intervention, a post-test was conducted using the same structured questionnaire to assess changes in knowledge levels. The collected data were analyzed using descriptive statistics (frequency, percentage, mean, and standard deviation) and inferential statistics to evaluate the effectiveness of the intervention and to identify associations between knowledge levels and demographic variables. Statistical significance was tested at the 0.05 level.

Operational Definitions

1. **Vitamin D Deficiency:** A condition characterized by insufficient levels of vitamin D in the body, leading to impaired calcium absorption and potential adverse effects on bone growth and overall health. In the present study, it refers to the knowledge and awareness of early adolescents regarding causes, symptoms, consequences, and preventive measures of vitamin D deficiency.
2. **Early Adolescents:** Students aged 11–14 years studying in selected government schools of Durg District, Chhattisgarh, who participated in the study.
3. **Nutrition Education Activity Programme (NEAP):** A structured, planned educational

intervention designed to enhance knowledge regarding vitamin D deficiency and its prevention through interactive teaching strategies such as lectures, demonstrations, group discussions, visual aids, role play, and quizzes.

4. **Knowledge:** The level of understanding of early adolescents regarding vitamin D, including its sources, functions, deficiency, symptoms, consequences, and preventive strategies, as measured by a structured knowledge questionnaire.
5. **Pre-interventional Knowledge:** The baseline level of knowledge assessed before administering the Nutrition Education Activity Programme.
6. **Post-interventional Knowledge:** The level of knowledge assessed after the completion of the Nutrition Education Activity Programme.
7. **Effectiveness:** The extent to which the Nutrition Education Activity Programme improves knowledge scores on vitamin D deficiency and its prevention, determined by comparing pre-test and post-test scores.

Variables of the Study

The variables included in the present study were identified based on the objectives and hypotheses. The independent variable focused on the educational intervention, while the dependent variable measured the outcome of interest. Selected demographic variables were included to examine their association with baseline knowledge levels. The detailed classification of variables is presented in Table 1.

Table 1. Variables of the Study.

Type of Variable	Variables
Independent Variable	Nutrition Education Activity Programme (NEAP)
Dependent Variable	Knowledge regarding vitamin D deficiency and its prevention
Demographic Variables	Age, gender, class/grade, type of family, parental education, parental occupation, dietary pattern, duration of sun exposure, participation in outdoor activities

Tools Used for Data Collection

Data were collected using a structured and validated questionnaire designed specifically for early adolescents. The tool enabled systematic assessment of demographic characteristics and knowledge related to vitamin D deficiency and its prevention. The components of the data collection tool and their purpose are summarized in Table 2.

Table 2. Tools Used for Data Collection

Section	Tool Description	Purpose
Section A	Demographic data sheet	To collect background information of early adolescents
Section B	Structured knowledge questionnaire on vitamin D deficiency and its prevention	To assess knowledge regarding sources, functions, deficiency, symptoms, consequences, and preventive measures of vitamin D

Statistical Plan

Both descriptive and inferential statistical techniques were employed to analyze the data in accordance with the study objectives. Descriptive statistics were used to summarize demographic variables and knowledge scores, while inferential statistics were applied to test the effectiveness of the intervention and associations between variables. The statistical methods adopted are outlined in Table 3.

Table 3. Statistical Plan.

Objective	Statistical Technique
Describe demographic characteristics	Frequency and percentage
Assess pre-test and post-test knowledge levels	Mean and standard deviation
Evaluate effectiveness of NEAP	Paired <i>t</i> -test
Determine association between pre-test knowledge and demographic variables	Chi-square test
Level of significance	$p < 0.05$

Protocol of the study

Intervention Schedule and Implementation

The Nutrition Education Activity Programme (NEAP) was implemented over four consecutive days using a combination of interactive and participatory teaching strategies. The structured progression from lectures to activities, demonstrations, and quizzes was designed to reinforce learning, encourage engagement, and enhance knowledge retention among early adolescents. The detailed day-wise intervention plan is presented in Table 4.

Table 4. Day-wise Intervention Details of the Nutrition Education Activity Programme.

Day	Intervention Method	Description of Student Response
Day 1	Lecture cum discussion	Students listened attentively, showed interest in the topic, actively asked questions, and demonstrated a clear understanding of the basic concepts of vitamin D deficiency.
Day 2	Lecture cum activity session	Students actively participated in group-based activities, displayed enthusiasm, collaborated effectively with peers, and engaged positively in the learning process.
Day 3	Lecture cum demonstration	Students carefully observed the demonstration, followed the steps systematically, and showed improved clarity in understanding preventive practices related to vitamin D deficiency.
Day 4	Quiz competition and interactive session	Students were highly motivated and enthusiastic, responded confidently to questions, and exhibited excellent participation and recall of previously discussed content.

The stepwise implementation of the Nutrition Education Activity Programme facilitated progressive learning and active engagement among early adolescents. The initial lecture cum discussion session helped establish foundational knowledge and encouraged students to clarify misconceptions through interaction, which is essential for effective nutrition education (Contento, 2016). Active questioning observed on the first day indicated a high level of interest and cognitive involvement.

The incorporation of activity-based learning on the second day further strengthened engagement by promoting peer interaction and experiential learning. Such participatory approaches have been shown to enhance comprehension and retention of health-related information among adolescents (WHO, 2020). The demonstration method used on the third day enabled students to visually and practically understand preventive strategies, reinforcing abstract concepts through step-by-step observation. The final day's quiz competition and interactive session served as both a reinforcement and evaluation strategy. High levels of enthusiasm and accurate responses suggested effective knowledge consolidation and recall. Interactive assessments such as quizzes are widely recognized for improving motivation and reinforcing learning outcomes in school-based health education programmes (UNICEF, 2019). Overall, the multi-modal structure of the intervention contributed to sustained student interest and effective knowledge transfer, as reflected in improved post-intervention outcomes (Table 4).

Inclusion and Exclusion Criteria

Clearly defined inclusion and exclusion criteria were established to ensure the selection of participants who could meaningfully engage with the intervention and provide reliable data. Such criteria are essential in educational and interventional studies to enhance internal validity, minimize bias, and ensure that observed outcomes can be attributed to the intervention rather than participant-related confounders (Polit and Beck, 2021).

Inclusion Criteria

Participants were eligible for inclusion in the study if they met the following conditions. Early adolescents who expressed a willingness to participate were included, ensuring voluntary involvement and ethical compliance. Only those who were present at the time of data collection and intervention were considered, as full participation in both pre-test and post-test assessments was necessary to evaluate the effectiveness of the Nutrition Education Activity Programme. In addition, adolescents who were physically and mentally fit to attend and comprehend the education sessions were included, as active engagement with the learning activities was central to achieving the study objectives. These criteria ensured that participants had the cognitive and physical capacity to understand

the educational content and respond meaningfully to the assessment tool, thereby strengthening the reliability of knowledge-related outcomes (Creswell and Creswell, 2018).

Exclusion Criteria

Adolescents were excluded from the study if they were unwilling to participate, in keeping with ethical principles of autonomy and informed consent. Those who were absent during the period of data collection or intervention were also excluded, as incomplete exposure to the programme could compromise the accuracy of post-intervention comparisons.

Furthermore, adolescents identified with learning disabilities that could significantly affect comprehension of the educational programme were excluded. This decision was made to maintain uniformity in participants' ability to engage with the intervention content and assessment process, as variations in cognitive processing could influence knowledge outcomes independent of the intervention itself. Similar exclusion practices have been recommended in educational intervention studies to avoid measurement bias and ensure valid interpretation of results (Fraenkel *et al.*, 2019). By applying these inclusion and exclusion criteria, the study ensured a homogeneous sample of early adolescents capable of benefiting from the intervention, thereby enhancing the methodological rigor and interpretability of the findings.

Ethical Considerations

Ethical principles were rigorously followed throughout the conduct of the study to safeguard the rights, dignity, and well-being of all participants. Prior to initiation, formal approval was obtained from the appropriate Institutional Ethics Committee, and administrative permission was secured from the concerned school authorities. The study was conducted in accordance with internationally accepted ethical guidelines for research involving human participants, including respect for autonomy, beneficence, non-maleficence, and justice (World Medical Association, 2013).

Participation in the study was entirely voluntary, and no form of coercion or undue influence was used at any stage. Participants were assured that their decision to participate or withdraw from the study would not affect their academic standing or access to school resources. Confidentiality of information was strictly maintained by anonymizing participant data and restricting access to collected information solely to the research team. The educational intervention posed minimal risk, as it focused on health promotion and knowledge enhancement without any invasive procedures or psychological stress. Similar ethical safeguards have been recommended for school-based educational interventions involving adolescents (Alderson and Morrow, 2020).

Informed Consent

Informed consent was obtained from all participants prior to data collection. Considering the involvement of minors, written informed consent was obtained from parents or legal guardians, and assent was obtained from the adolescents themselves. Participants and their guardians were provided with clear and age-appropriate information regarding the purpose of the study, the nature of the intervention, the procedures involved, potential benefits, and the right to withdraw at any point without penalty. Adequate time was given for participants and their guardians to seek clarification before providing consent. All explanations were delivered in a language easily understood by the participants to ensure true comprehension. This process ensured transparency and upheld ethical standards related to informed participation, which are considered essential in research involving children and adolescents (CIOMS, 2016; Polit and Beck, 2021).

Results

Distribution of Pre-test and Post-test Knowledge Levels

The assessment of knowledge levels among early adolescents revealed a substantial improvement following the implementation of the Nutrition Education Activity Programme. Prior to the intervention, most participants demonstrated poor knowledge regarding vitamin D deficiency and its prevention. Specifically, 55% of early

adolescents had poor knowledge, 43.75% had moderate knowledge, and only 1.25% demonstrated good knowledge. This distribution highlights a considerable baseline knowledge deficit among the study population.

Table 5. Distribution of Early Adolescents According to Pre-test and Post-test Level of Knowledge (N = 80).

Level of Knowledge	Pre-test n (%)	Post-test n (%)
Poor	44 (55.00)	1 (1.25)
Moderate	35 (43.75)	27 (33.75)
Good	1 (1.25)	52 (65.00)
Total	80 (100)	80 (100)

Following the educational intervention, a marked shift in knowledge levels was observed. In the post-test, only 1.25% of adolescents remained in the poor knowledge category, while 33.75% attained moderate knowledge and a substantial 65% achieved good knowledge. This significant redistribution clearly indicates the effectiveness of the Nutrition Education Activity Programme in enhancing awareness and understanding of vitamin D deficiency and its preventive measures (Table 5). The improvement observed aligns with findings from previous school-based nutrition education studies, which report significant gains in micronutrient-related knowledge following structured educational interventions (Contento, 2016; Sharma and Singh, 2019).

The findings illustrated in Figure 2 clearly demonstrate substantial deficiencies in baseline knowledge regarding vitamin D deficiency among early adolescents prior to the nutrition education intervention. Before the programme, more than half of the participants (55%) were classified as having poor knowledge, while 43.75% exhibited only a moderate level of understanding. Only a very small proportion (1.25%) demonstrated good knowledge related to vitamin D deficiency and its prevention. This distribution highlights a pronounced knowledge gap within the study population and underscores the limited awareness of vitamin D-related health issues among early adolescents.

The dominance of poor and moderate knowledge categories prior to intervention, as depicted in Figure 2, suggests that adolescents possess fragmented or superficial understanding of vitamin D, often restricted to isolated facts rather than comprehensive awareness of sources, health consequences, and preventive measures. Similar patterns have been reported in earlier studies, which indicate that adolescents frequently underestimate the importance of vitamin D despite its critical role in bone development and immune function (Ritu and Gupta, 2014; Aparna et al., 2018). The minimal proportion of students with good knowledge further reflects insufficient emphasis on micronutrient education within routine school curricula.

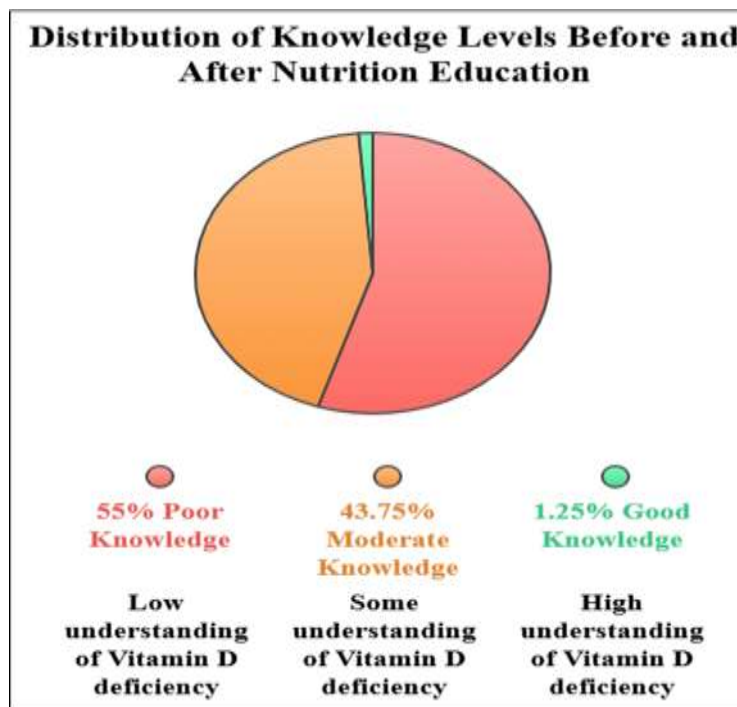
The high percentage of adolescents with poor knowledge shown in Figure 2 is particularly concerning given that early adolescence is a crucial period for skeletal growth and peak bone mass acquisition. Inadequate awareness during this stage may contribute to prolonged vitamin D insufficiency and increase the risk of long-term musculoskeletal complications (Misra et al., 2008; Weaver et al., 2016). Moreover, the coexistence of moderate knowledge among a sizable proportion of participants indicates partial awareness without adequate depth, which may limit the translation of knowledge into effective preventive behaviours such as optimal sunlight exposure and dietary intake.

A comparison of the baseline knowledge distribution presented in Figure 2 with post-intervention outcome data demonstrates a marked and statistically significant improvement in adolescents' understanding of vitamin D deficiency following the Nutrition Education Activity Programme. While Figure 2 shows that only 1.25% of participants initially possessed good knowledge, post-test findings revealed a substantial shift toward higher knowledge levels. The proportion of students classified under poor knowledge declined dramatically, whereas those demonstrating good knowledge increased considerably. This improvement was further corroborated by the significant rise in mean knowledge scores from pre-test to post-test, with the observed mean difference achieving

statistical significance ($p < 0.05$). The contrast between pre-intervention knowledge deficits depicted in Figure 2 and post-intervention outcomes highlights the effectiveness of structured, school-based nutrition education in addressing critical knowledge gaps. Importantly, the observed gains reflect not only increased awareness but also improved conceptual understanding of vitamin D sources, health consequences, and preventive measures.

From a public health and nursing perspective, the findings underscore the potential of nutrition education interventions as practical, cost-effective, and scalable strategies for improving adolescent nutritional literacy. Previous research has similarly demonstrated that targeted educational programmes can significantly enhance micronutrient-related knowledge and foster healthier behaviours among school-going adolescents (Harinarayan *et al.*, 2013; Sharma *et al.*, 2020). Collectively, the evidence suggests that integrating structured nutrition education into school health programmes may contribute meaningfully to the prevention of vitamin D deficiency and support long-term adolescent health outcomes.

Figure 2. Baseline knowledge levels on vitamin D deficiency.



Comparison of Mean Pre-test and Post-test Knowledge Scores

Further analysis was conducted to compare the mean knowledge scores before and after the intervention. The mean pre-test knowledge score was 6.52, indicating a low baseline level of awareness. After the Nutrition Education Activity Programme, the mean post-test score increased substantially to 15.42, with a mean difference of 8.9 points. The calculated t-value (2.36) exceeded the corresponding table value at the 0.05 level of significance, confirming that the observed improvement in knowledge was statistically significant. This finding supports the rejection of the null hypothesis and the acceptance of the research hypothesis (H_1), demonstrating that the Nutrition Education Activity Programme was effective in improving knowledge regarding vitamin D deficiency and its prevention (Table 6). These results are consistent with earlier studies indicating that interactive nutrition education significantly enhances adolescents' knowledge and promotes health-protective behaviours (Krause and Mahan, 2018; Misra *et al.*, 2008).

Table 6. Comparison of Mean Pre-test and Post-test Knowledge Scores of Early Adolescents (N = 80).

S. No.	Test	Mean Score	Mean Difference	Standard Deviation	<i>t</i> -value
1	Pre-test	6.52	8.9	4.13	2.36
2	Post-test	15.42	—	2.53	—

Association Between Pre-test Knowledge and Demographic Variables

The association between pre-intervention knowledge levels and selected demographic variables was examined using the chi-square test. A statistically significant association was found between age and number of siblings with baseline knowledge levels ($p < 0.05$).

Table 7. Association of Pre-test Knowledge Levels with Selected Demographic Variables (N = 80).

Demographic Variable	χ^2 Value	df	Table Value	Level of Significance ($p < 0.05$)
Age	70.14	6	12.59	Significant
Gender	0.34	2	5.99	Not Significant
Type of family	1.01	4	9.49	Not Significant
Father's education	10.21	10	18.31	Not Significant
Mother's education	3.58	10	18.31	Not Significant
Father's occupation	1.12	8	15.51	Not Significant
Mother's occupation	1.76	6	12.59	Not Significant
Dietary pattern	0.58	4	9.49	Not Significant
Number of siblings	14.78	6	12.59	Significant
Family monthly income	5.18	6	12.59	Not Significant

Older adolescents demonstrated comparatively better baseline knowledge, possibly due to greater exposure to academic content and life experiences. Similarly, adolescents from larger families exhibited varying levels of awareness, which may reflect differences in parental attention and information sharing. However, no statistically significant association was observed between pre-test knowledge and variables such as gender, type of family, parental education, parental occupation, dietary pattern, or family monthly income ($p > 0.05$). These findings suggest that knowledge deficits related to vitamin D deficiency are widespread and relatively independent of socio-economic background (Table 7).

Discussion

The present study investigated the effectiveness of a structured Nutrition Education Activity Programme (NEAP) in enhancing early adolescents' knowledge of vitamin D deficiency and its prevention. The results demonstrated a significant improvement in post-intervention knowledge, indicating that targeted educational strategies can substantially elevate awareness levels among school-aged adolescents. This discussion interprets the findings considering existing literature, explores possible explanations for observed patterns, and highlights implications for practice and future research.

Baseline Knowledge of Vitamin D Deficiency

Prior to the intervention, most participants displayed inadequate knowledge regarding vitamin D

deficiency. More than half (55%) had poor understanding of key concepts, such as sources, symptoms, and preventive measures. This aligns with patterns observed in similar age groups globally. For instance, Bohsas et al. (2024) reported substantial gaps in vitamin D knowledge among young adults, with only a minority demonstrating accurate understanding of deficiency symptoms and risk factors. Likewise, Ritu and Gupta (2014) observed pervasive knowledge deficits regarding vitamin D status among Indian adolescents, despite the country's abundant sunlight.

The widespread baseline deficiency in awareness may be attributed to several factors, including limited inclusion of micronutrient education in regular school curricula and inadequate emphasis on preventive nutrition within family and community contexts (Aparna et al., 2018). This underscores the need for enhanced health education frameworks that specifically address micronutrient literacy at early developmental stages.

Impact of the Nutrition Education Activity Programme

A key finding of the study was the statistically significant increase in knowledge following the NEAP intervention. The mean post-test score (15.42) was substantially higher than the pre-test score (6.52), supporting the hypothesis that structured education can produce measurable improvements in understanding. The reduction in the proportion of adolescents with poor knowledge (from 55% to 1.25%) and the increase in those with good knowledge (from 1.25% to 65%) demonstrate the intervention's effectiveness.

These results are consistent with previous research indicating that interactive, participatory learning approaches enhance nutrition knowledge more effectively than didactic instruction alone. Contento (2016) found that child-centred and discussion-based nutrition education significantly elevated understanding of dietary concepts. Similarly, Sharma and Singh (2019) reported remarkable improvements in micronutrient knowledge following school-based nutrition education, suggesting that active engagement and practical demonstrations are crucial for knowledge retention.

The NEAP's combination of lectures, group activities, visual aids, and quizzes likely contributed to improved

cognitive engagement and comprehension. These methods resonate with principles of constructivist learning theory, which emphasises learning through active involvement and contextual relevance (Felder and Brent, 2005). Therefore, the intervention's design may be as important as its content in achieving effective learning outcomes.

Association with Demographic Characteristics

The association between baseline knowledge and selected demographic variables provided nuanced insights. A significant association was observed between knowledge levels and both age and number of siblings. Older adolescents demonstrated relatively better baseline understanding, possibly reflecting developmental progression and greater cumulative exposure to health information through formal education and informal sources.

In contrast, variables such as gender, family type, parental education, and income showed no statistically significant associations with initial knowledge levels. This suggests that, within this cohort, socio-economic and family characteristics did not substantially influence awareness of vitamin D deficiency. These findings differ from some earlier studies, which identified maternal education and socio-economic status as predictors of nutrition knowledge (Misra et al., 2008; Palacios & Gonzalez, 2014). This discrepancy may be due to the relatively homogeneous socio-demographic composition of the study sample, as most participants came from similar backgrounds within the same district.

The lack of association with dietary pattern and parental occupation further suggests that vitamin D knowledge deficits are widespread and not confined to specific demographic strata. This reinforces the rationale for universal rather than targeted interventions in similar school settings.

Comparison with Existing Literature

The observed effectiveness of education aligns with international literature on nutrition interventions among adolescents. A meta-analysis by Weiss et al. (2017) highlighted that structured health education improves both knowledge and behaviours related to micronutrient intake. Likewise, a study by Al-Delaimy et al. (2021) found that adolescents who participated in tailored educational programmes reported

significant increases in knowledge about vitamin D sources and preventive behaviours.

However, some studies have noted that improved knowledge does not always translate into sustained behavioural change without ongoing reinforcement and environmental support (Story *et al.*, 2008). While the present study focused on immediate post-test knowledge, future research should examine whether improved awareness persists over time and leads to tangible behaviour modifications, such as increased sun exposure and dietary changes.

Public Health and Educational Implications

The study's findings have important implications for public health and educational practice. First, the demonstrated effectiveness of NEAP suggests that integrating structured nutrition modules into school curricula could be a feasible strategy for addressing micronutrient knowledge gaps. Schools provide a controlled environment where large numbers of adolescents can be reached systematically, and interactive teaching methods can be applied effectively.

Second, the lack of association between knowledge and socio-economic variables highlights the need for broad-based educational campaigns that transcend demographic boundaries. Public health agencies may consider multi-sectoral collaboration with the education sector to institutionalise regular nutrition education and ensure consistent messaging.

Nursing Implications

The findings of the study emphasize the pivotal role of nurses in health promotion and disease prevention among adolescents. Nursing education should prioritize preventive health strategies and equip future nurses with the skills necessary to identify knowledge deficits and implement effective educational programmes. Active involvement of nursing students in school-based health education can significantly contribute to improving adolescent health literacy, particularly regarding preventable nutritional deficiencies such as vitamin D deficiency.

Limitations and Future Directions

While the present study provides valuable insights, certain limitations should be acknowledged. The study design did not include a long-term follow-up to assess retention of knowledge or changes in behaviour.

Additionally, the sample was limited to a specific geographic district, which may limit the generalisability of findings to other regions with different cultural or educational contexts. Future research should incorporate longitudinal designs, behavioural assessments, and potential biological markers (e.g., serum vitamin D levels) to gauge the sustained impact of educational interventions. Moreover, comparative studies across diverse regions could clarify how contextual factors influence intervention effectiveness.

Recommendations

Based on the findings of the present study, future research should consider adopting experimental designs with control groups to strengthen causal inference and enhance the robustness of outcome evaluation. The Nutrition Education Activity Programme (NEAP) demonstrated clear effectiveness and therefore holds strong potential for wider application. Its implementation may be extended beyond school settings to community environments and health institutions, where it can serve as a cost-effective and scalable educational intervention for improving awareness of vitamin D deficiency and its prevention. In addition, future studies may explore the effectiveness of diverse teaching modalities, including video-based instruction, digital applications, and interactive learning modules, to assess their comparative impact on knowledge retention and behavioural change. Integrating technology-driven approaches may further enhance engagement, accessibility, and sustainability of nutrition education among adolescents and broader population groups.

Conclusions

This study provides clinical evidence that a structured nutrition education programme significantly improves adolescents' knowledge of vitamin D deficiency and preventive strategies. The magnitude of improvement observed in post-intervention knowledge scores suggests that educational interventions may serve as an essential adjunct to nutritional deficiency prevention strategies, particularly in settings where biochemical screening is not routinely feasible. Early adolescence represents a critical period for optimizing bone health, and improved awareness of vitamin D may contribute to healthier dietary and lifestyle choices that support optimal growth and development. Incorporating structured nutrition education into

routine school health services could enhance early preventive care and reduce the long-term burden of vitamin D-related disorders.

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