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ORIGINAL RESEARCH

Effect of a Nutrition Education Program on Knowledge, Attitudes, and Dietary Practices, Anthropometry, and Hemoglobin in Peruvian Adolescents

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Background: Anemia and obesity are significant public health challenges among adolescents, often linked to inadequate nutritional knowledge, attitudes, and practices. Educational interventions targeting these factors may play a crucial role in improving adolescent health outcomes.

Objective: To determine the impact of a nutrition education program on the levels of knowledge, attitudes, and dietary practices, anthropometric parameters and hemoglobin in Peruvian adolescents.

Methods: A pre-experimental study was conducted among Peruvian adolescents between 12 and 18 years of age from an educational institution located in eastern Lima, Peru. Body mass index/age (BMI/age), waist circumference (WC), hemoglobin (Hb) levels, and a self-reported questionnaire were assessed. A nutrition education intervention was conducted for 16 weeks.

Results: After the implementation of the program, a significant improvement in knowledge scores (84.4%, $p < 0.001$), attitudes (59.1%, $p < 0.001$), and practices (47.7%, $p < 0.001$) scores was observed. BMI/age scores decreased by 3.1% ($p < 0.001$). Similarly, WC scores showed a significant decrease of 1.0% ($p < 0.001$). Hb levels increased significantly by 3.25% ($p < 0.001$) in women, but not in men.

Conclusion: This study showed that nutrition education programs could improve knowledge, attitudes, and dietary practices, BMI/age, WC, and Hb scores in Peruvian adolescents.

Keywords: nutrition education, adolescents, anemia, obesity, knowledge, attitudes, dietary practices, body mass index, waist circumference, hemoglobin

Introduction

Nutrition during adolescence plays a key role in healthy development and long-term well-being.[1] However, in numerous developing countries, including Peru, adolescents face considerable nutritional challenges that impede their health and development.[2] Malnutrition problems, including both undernutrition and obesity, are particularly prevalent and have serious implications for public health.[3] One of the main causes of malnutrition in adolescents is dietary practices that are deficient in critical micronutrients such as iron, iodine, and vitamin A, which can cause health problems such as anemia and stunted growth.[4] In Peru, approximately 20% of adolescents suffer from anemia, indicating a generalized iron deficiency or the presence of other factors that can negatively impact their school performance and future productivity.[5]

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On the other hand, 38.4% of Peruvian children and adolescents between the ages of 6 and 13 are overweight, increasing the risk of developing chronic diseases such as type 2 diabetes and cardiovascular disease at an earlier age.[6]

The high prevalence of anemia and obesity among adolescents can be attributed to a lack of nutritional knowledge and the adoption of suboptimal eating practices.[7] Although these health problems can be prevented, it is not uncommon for adolescents to engage in unhealthy eating habits and lack understanding of the causes of these health problems and the methods of prevention.[8] For example, a recent study focused on children and adolescents found that their knowledge of food and nutrition was generally low, suggesting an urgent need for educational interventions in this area.[9] In another study conducted in Iran with 300 high school students aged 13–16 years, it was determined that 23.3% of the students exhibited poor dietary practices and 25.7% demonstrated inadequate knowledge about anemia, including its symptoms and prevention methods.[10] These findings indicate the need to implement robust educational programs that can address these deficiencies and promote healthy eating habits among youth.

Nutrition education interventions have been shown to play a crucial role in improving knowledge, attitudes, and dietary practices, particularly among younger populations, such as adolescents.[2] In fact, through nutrition education, you can positively influence how adolescents understand and value the importance of healthy eating, which in turn can lead to lasting changes in their eating behaviours.[1] This was demonstrated by Raut et al[2] who reported an improvement in the levels of dietary knowledge and attitudes after the implementation of a nutrition education program in a group of 226 students aged 12 to 19 years. Similarly, an intervention conducted among 2709 school children aged 10 to 12 years found an improvement in nutrition knowledge.[11] In terms of diet practices, the effects of a school intervention reported an increase in breakfast consumption and a decrease in food purchases at school, but no changes in nutritional knowledge.[12] Overall, these findings suggest the effectiveness of nutrition education interventions in modifying adolescent eating behaviors.

In addition, nutritional intervention represents an effective strategy to improve several indicators of nutritional status in adolescents, including BMI/age, WC, among others.[3] Both are important nutritional indicators, as they are significant predictors of future health problems, particularly cardiometabolic diseases.[13] For example, a balanced diet and regular exercise can significantly reduce the risk of developing diseases such as type 2 diabetes and cardiovascular problems in adulthood.[14,15] This is due to the fact that a reduction in abdominal girth can be achieved through these lifestyle changes. Previous studies have shown that nutrition education interventions can positively impact adolescent BMI/age and WC.[14,15]

In this context, the implementation of a nutrition education program specifically designed for Peruvian adolescents is of great importance.[3] This study seeks to evaluate the impact of such a program not only on knowledge, attitudes, and eating practices, but also on critical anthropometric parameters such as BMI/age and WC, as well as Hb levels. These indicators are essential to understand the nutritional health status of adolescents and to identify areas that require ongoing intervention.[14,15] Therefore, the following hypothesis is proposed: The implementation of a nutrition education program significantly increases the level of knowledge, attitudes, and dietary practices and has a positive impact on BMI/age, WC, and Hb scores in adolescents.

Materials and Methods

Design, Type of Research, and Participants

The methodology used in the study was prospective and pre-experimental, since the data was collected over a 16-week period and obtained prior to the implementation of the educational program (see Figure 1); this allowed the establishment of a baseline against which results obtained after the intervention could be compared. The research was conducted in a school located in the Lurigancho-Chosica sector, one of the districts located east of Lima, Peru, and the sample was selected by nonprobabilistic sampling. A preliminary survey was applied to collect information on the levels of knowledge, attitudes, and dietary practices. Furthermore, Hb and WC levels were assessed, and weight, height and waist circumference were measured to subsequently determine BMI/age.

The study included all secondary school adolescents of both sexes enrolled in the educational institution. However, participants were excluded if they did not respond completely to the questionnaire, had more than 50% non-attendance to

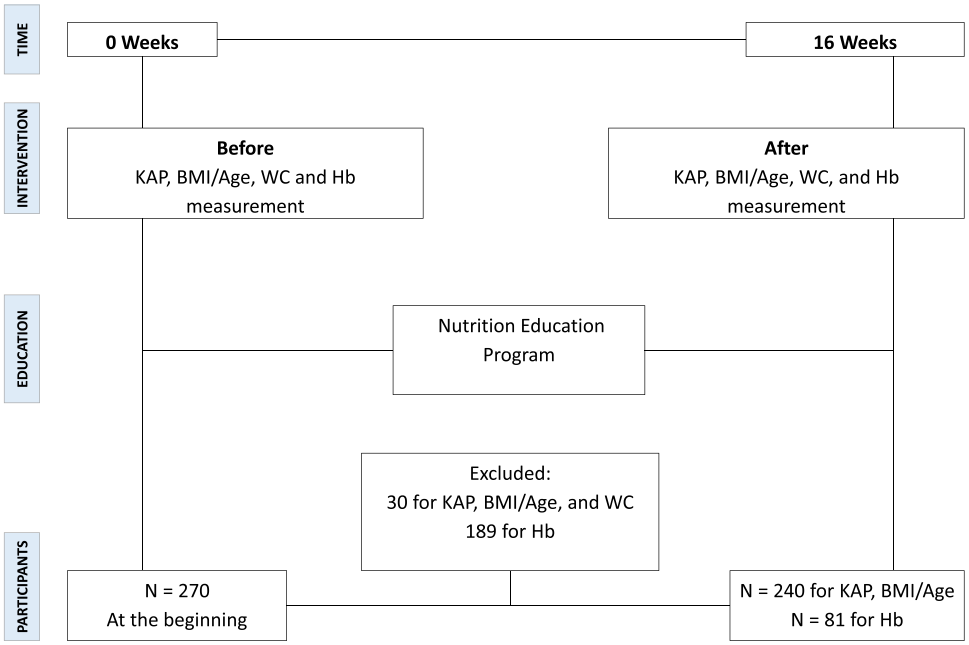

Figure 1 Design of a nutrition education program for adolescents.
Abbreviations: KAP, Knowledge, attitudes, and practices; BMI/Age, Body mass index/age; WC, waist circumference; Hb, hemoglobin.

the program, did not provide informed consent, were pregnant or lactating, or had been diagnosed with chronic diseases or conditions known to affect hemoglobin levels, such as chronic kidney disease, autoimmune disorders, or other medical conditions that could confound the outcomes of the intervention. The sample size was calculated using G*Power software version 3.1.9.7, based on an estimated long-term effect size (d = 0.8), with a statistical power of 0.93 and a type I error (α) of 0.05. For this estimation, a minimum of 26 participants per group (52 participants in total) was required. To account for variability and to explore potential effects with a lower to medium effect size (d = 0.4), the required sample size increased to 76 participants (N = 76). To ensure the robustness of the study and to address potential dropout rates commonly observed in longitudinal studies, we initially recruited 270 adolescents. At the end of the program, 30 participants did not attend the evaluation of the questionnaire and anthropometric measurements, resulting in 240 participants who completed these assessments. For hemoglobin (Hb) measurements, additional consent was required due to the invasive nature of the procedure. Consequently, only 81 individuals participated in this aspect of the study. The study began on 5 September 2023 and ended on 22 December 2023 (see Figure 1).

Ethical Considerations

The Ethics Committee of the Faculty of Health Sciences of the Universidad Peruana Unión approved the study (Reference Number: 2024-CEB-FCS - UPeU-N°014). Before the measurement, instruments and data collection were applied, informed consent was obtained from the parents or legal guardians of the participants. In addition, the ethical principles dictated by the Declaration of Helsinki of 1975 and its subsequent updates were taken into account.

Implementation and Development of the Nutrition Education Program

The nutritional education intervention program included educational and demonstration sessions, which were conducted through the use of didactic material during visits to the educational institution. The educational sessions addressed five key topics, as detailed in Table 1. The educational sessions addressed five key topics: (1) anemia: causes, effects, and prevention during adolescence; (2) guidelines for healthy eating in adolescents; (3) the use of warning octagons on products high in critical nutrients such as sugar, sodium, and saturated and trans fats; (4) the importance of consuming water and being physically active on a regular basis; (5) the importance of including fruits and vegetables in the daily diet. However, the demonstration sessions were conducted according to the guidelines established by the Peruvian

Table 1 Topics of Educational Sessions

Sessions	Topics	Contents
1	Anemia, causes, consequences, and prevention in adolescence	- Definition of anemia - Cause and consequences - Iron-rich foods - Iron supplementation
2	Healthy eating in adolescence	- Nutritional pyramid - Food groups: Energetic, regulators, and builders - Healthy plate and nutritional recommendations
3	Warning octagons for foods high in critical nutrients (sugar, sodium, saturated, and trans fats)	- Definition of octagons - Types and consequences - Example of products with octagons - Healthy options
4	Importance of water consumption and regular physical activity.	- Benefits of water and exercise. - Recommended amount of water. - Types of exercise and recommended time
5	Importance of fruit and vegetable consumption	- Benefits of fruit and vegetable consumption - Recommended amount - Consequences of low consumption

Ministry of Health (MINSA) and utilized the ARDE methodology, which encompasses the following elements: animation, reflection, demonstration and evaluation. Each demonstration session was held for 20 minutes, followed by a 10-minute session to clarify any remaining doubts and answer any remaining questions from the participants.

Data Collection Instruments and Variables

Knowledge, Attitudes, and Practices Questionnaire

The questionnaire on knowledge, attitudes, and dietary practices of adolescents was used, which is structured in three sections and consists of 56 items (15 on knowledge, 20 on attitudes, and 21 on practices). The "knowledge" variable was evaluated by assigning a score based on the following criteria: 0 to 7 points indicated "low knowledge" and 8 to 12 points indicated "high knowledge". Each answer was scored as either correct (1 point) or incorrect (0 points). The "attitude" variable was operationalized using a scale of 0 to 33 points for "unfavorable attitude" and 34 points or more for "favorable attitude". Each item was rated on a polynomial scale (Strongly agree = 3, agree = 2, disagree = 1, strongly disagree = 0). Regarding the variable "practices", the scores were categorized as follows: 0 to 33 points were considered to reflect "inadequate practices", while 34 points or more were considered to reflect "adequate practices". This categorization was based on a Likert-type scale where "Always" = 3, "Almost Always" = 2, "Sometimes" = 1, and "Never" = 0. The reliability of the questionnaire was evaluated using the Kuder-Richardson analysis for knowledge and Cronbach's alpha for attitudes and practices, with values above 0.7 obtained for both. These values are within the acceptable range of 0.75 to 0.90.[1]

Sociodemographic Characteristics Registration Form

The initial section of the questionnaire encompassed six items, including age, sex, geographical origin (coast, highlands, and jungle), and academic year (1st grade, 2nd grade, 3rd grade, 4th grade, and 5th grade).

BMI/Age

The weight and length of the subject were measured using a calibrated SECA 700 mechanical column scale with a capacity of 220 kg and a measuring range of 60 to 200 cm (SECA®, Hamburg, Germany). These anthropometric data were taken following the guidelines of the "Technical Guide for the Anthropometric Nutritional Assessment of Adolescents" of MINSA.[16] Subsequently, the BMI/age was calculated, and the parameters established by the WHO

and MINSA were classified.[16,17] The results were interpreted as follows: a standard deviation below −2 indicated underweight; between −2 and +1, normal weight; between +1 and +2, overweight; and above +2, obesity.[17]

WC

Waist circumferences (WC) were measured using a tape measure (SECA®, Hamburg, Germany). The tape was placed horizontally around the subject's abdomen in order to prevent any compression of the abdomen during the measurement process.[18] This indicator enables the early identification of abdominal obesity in adolescents.[19] This measurement is particularly important because it allows one to foresee possible metabolic risks.[18]

Hemoglobin Test

The hemoglobin concentration was quantified according to the technical document entitled "Therapeutic and preventive management of anemia in children, adolescents, pregnant women, and postpartum women" (15). A hemoglobinometer (HemoCue HB 201) with microwells and disposable retractable lancets was used for the analysis. A single drop of blood was required for the hemoglobinometer reading, which was then allowed to incubate for one minute before the hemoglobin result was displayed. In adolescents aged 12 to 14 years, the normal hemoglobin range is the same for both sexes (≥12 g/dL). However, for individuals aged 15 years and older, the threshold increases to ≥13 g/dL for males, while remaining at ≥12 g/dL for females.[20]

All data collection was conducted by qualified professionals to ensure accuracy and consistency. Anthropometric measurements, including weight, height, and waist circumference, as well as the administration of the KAP questionnaires, were carried out by a certified nutritionist with experience in adolescent health assessments. Hemoglobin testing was performed by a licensed laboratory technician using standardized procedures and validated equipment to ensure reliable results.

Statistical Analysis

The normality of the sample distribution was determined by means of the Kolmogorov–Smirnov test. To describe sociodemographic variables, measures such as mean (M) and standard deviation (SD), as well as absolute and percentage frequencies, were used. Skewness and kurtosis coefficients were used to explore the distribution of the variables. Knowledge, attitudes and eating practices, Hb, BMI/age, and WC scores before and after the education program through the Wilcoxon nonparametric statistical test. Data were processed and analyzed using statistical packages through free software R version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria; http://www.R-project.org) and SPSS version 27 (SPSS Inc., Chicago, IL, USA). A p-value (p-value) of less than 0.05 was considered statistically significant.

Results

Table 2 presents a description of the sociodemographic characteristics of the program participants. It indicates that there is a higher proportion of women (54.6%) compared to men (45.4%), with a mean age of 14.41 ± 1.52 years (age range: 12 to 18 years). Similarly, regarding origin, the coastal region was the most prevalent (84.6%), and with respect to the academic year, a total of 240 students were evaluated from the first to the fifth year of secondary school.

Table 3 illustrates the outcomes of the nutrition education program, which resulted in a statistically significant improvement in dietary knowledge scores (from 6.18 ± 0.87 to 11.40 ± 1.85, $p < 0.001$). Furthermore, there was a notable increase in the Attitudes and Dietary Practices scores, which increased by 17.1 points (from 29.24 ± 3.18 to 46.53 ± 6.37, $p < 0.001$) and 15.2 points (from 30.60 ± 2.49 to 45.22 ± 6.29, $p < 0.001$), respectively, after the intervention compared to the baseline scores.

The results presented in Figures 2–4 demonstrate the impact of the nutrition education intervention on the levels of knowledge, attitudes, and dietary practices among adolescents. Variations, but not significant, were observed in median knowledge (from 5 to 12, $p > 0.05$), attitudes (from 30 to 47, $p > 0.05$), and practices (from 31 to 45, $p > 0.05$).

Additionally, the mean, standard deviation, distribution, difference in non-parametric measures and effect size of adolescent BMI/age and WC are described (Table 3). A significant reduction in BMI/age scores (from 22.05 ± 3.7 to 21.36 ± 2.93, $p < 0.001$) was evidenced after the execution of the program. In relation to WC, the scores showed

Table 2 Sociodemographic Characteristics and Anthropometric Values Before and After the Nutritional Education Program

	%
Age (M±SD)	14.41 ±1.52
Sex	n (%)
Female	131 (54.6)
Male	109 (45.4)
Origin	
Coast	203 (84.6)
Highlands	16 (6.7)
Jungle	21 (8.8)
School year	
1st degree	54 (22.5)
2nd degree	64 (26.7)
3rd degree	57 (23.8)
4th degree	37 (15.4)
5th degree	28 (11.7)

Abbreviations: M, Mean; SD, Standard Deviation.

Table 3 Mean, Standard Deviation, Distribution, Nonparametric Measures Difference and Effect Size of Knowledge, Attitudes and Dietary Practices, BMI and WC in Adolescents

	M	SD	SE	S	K	MD	Wilcoxon	P	E. Size*
KAP									
Knowledge 1	6.18	0.87	0.05	−0.84	0.29	5.22	13.411	< 0.001	5.500
Knowledge 2	11.40	1.85	0.12	−0.36	−0.60				
Attitudes 1	29.24	3.18	0.20	−0.83	0.23	17.29	13.230	< 0.001	17.500
Attitudes 2	46.53	6.37	0.41	−1.12	8.88				
Practices 1	30.60	2.49	0.16	−1.02	0.58	14.62	13.214	< 0.001	14.500
Practices 2	45.22	6.29	0.40	−0.26	13.68				
BMI and WC									< 0.001
BMI Pre	22.05	3.7	0.24	0.94	1.95	0.69	−8.432	< 0.001	−0.600
BMI Post	21.36	2.93	0.18	1.03	2.79				
WC Pre	72.27	8.49	0.54	0.96	2.51	0.71	−5.907	< 0.001	−0.650
WC Post	71.56	7.59	0.49	1.02	3.27				
Hb									
General									
Hb 1	13.01	1.61	0.17	0.42	−1.18	0.32	5.167	< 0.001	0.350
Hb 2	13.34	1.32	0.14	0.26	−1.22				
Female									
Hb 1	12.63	1.33	0.16	0.57	−0.87	0.40	5.759	< 0.001	0.450
Hb 2	13.04	1.15	0.14	0.43	−0.84				
Male									
Hb 1	14.44	1.82	0.44	−1.05	−0.45	−0.01	−0.190	0.849	−0.050
Hb 2	14.44	1.39	0.33	1.08	−0.32				

Notes: *For the Wilcoxon test, the effect size is given by the paired rank biserial correlation and through the Hodges-Lehmann estimator.
Abbreviations: BMI, Body Mass Index; WC, Waist circumferences; Hb 1, The baseline hemoglobin level (pre-intervention); Hb 2, The hemoglobin level measured after the intervention (post-intervention); E. Size, effect size; K, kurtosis coefficient; M, mean; MD, mean difference; P, probability of error; S, coefficient of skewness; SD, standard deviation; SE, standard error of the mean.

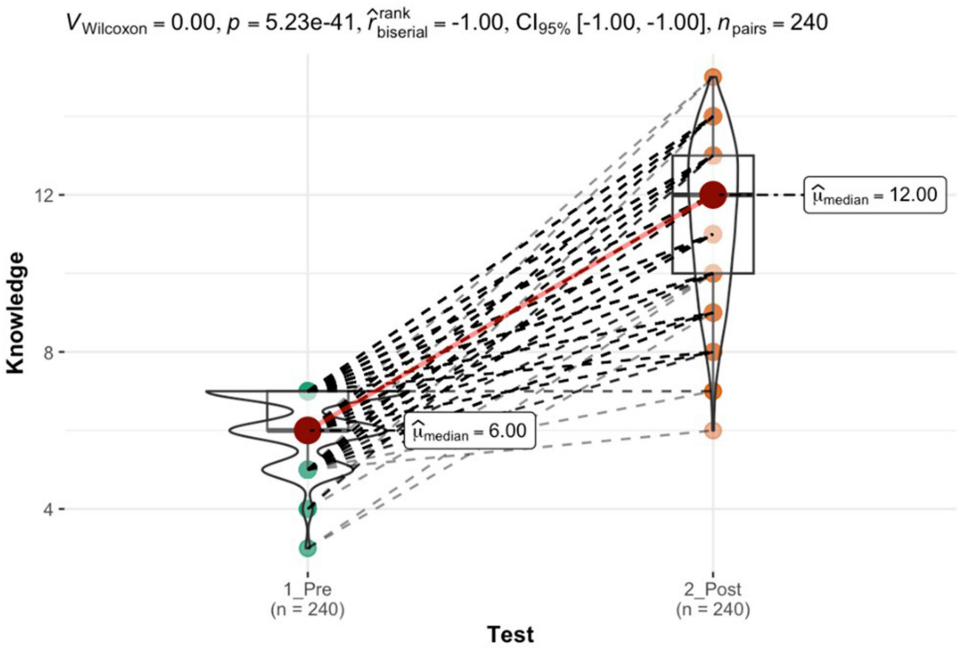

Figure 2 Knowledge before and after the nutrition education program.

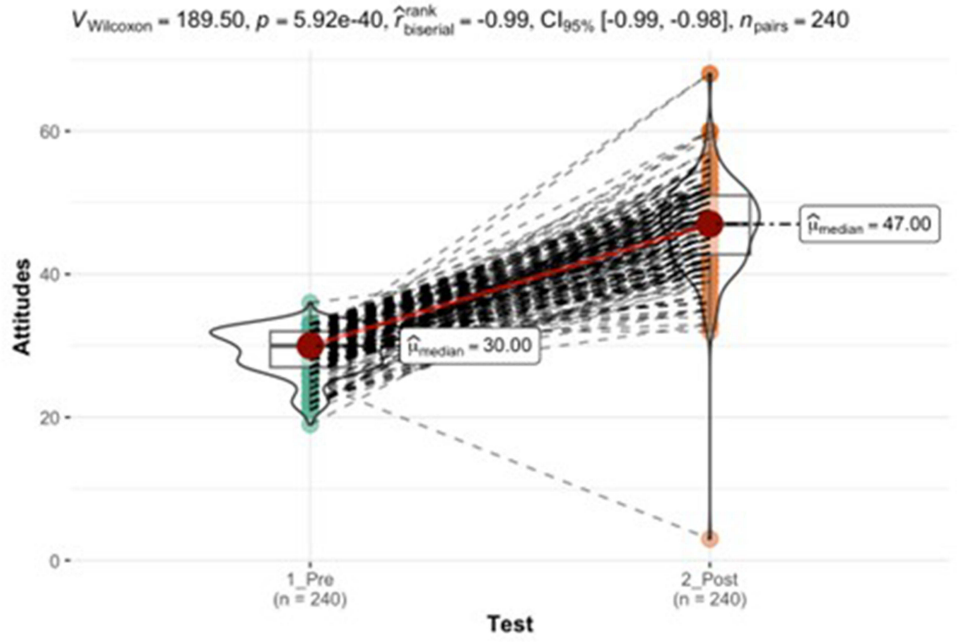

Figure 3 Attitudes before and after the nutrition education program.

a statistically significant decrease (from 72.27 ± 8.49 to 71.56 ± 7.59, $p < 0.001$). Additionally, Figures 5 and 6 illustrate variations in median BMI and age, respectively, before and after the intervention. However, these variations were not statistically significant ($p > 0.05$). The same was observed for median WC (71.50 vs 71, $p > 0.05$).

A significant difference in Hb levels was observed in the general population (Table 3) between the pre- and post-intervention measurements, with a mean increase of 0.322, $p < 0.001$, and a moderate effect size (0.35). A significant difference was also observed in women, with a mean increase of 0.409 ($p < 0.001$), indicating a moderate to large effect

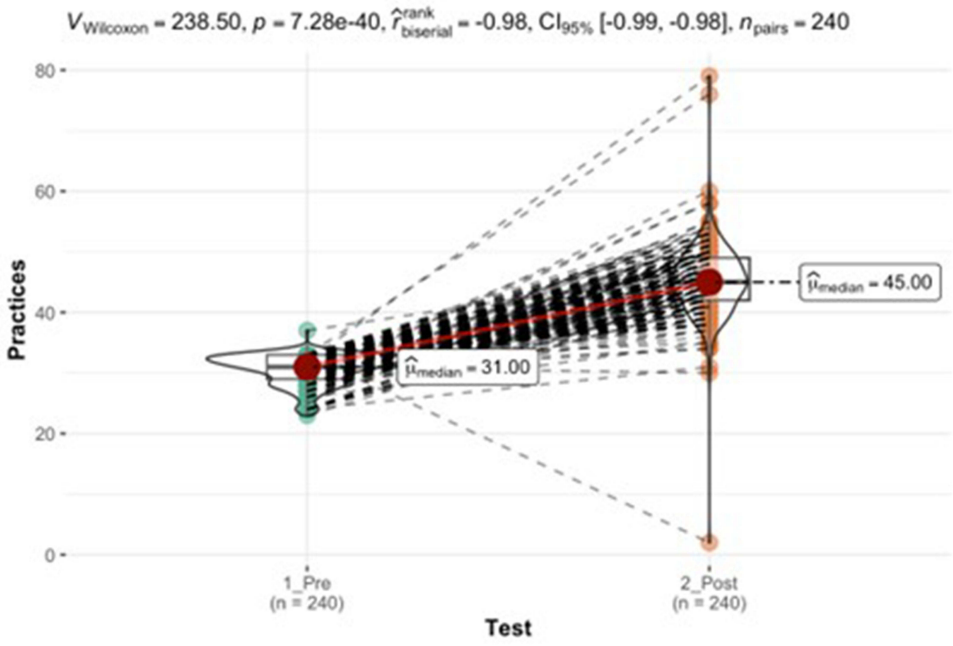

Figure 4 Practices before and after the nutrition education program.

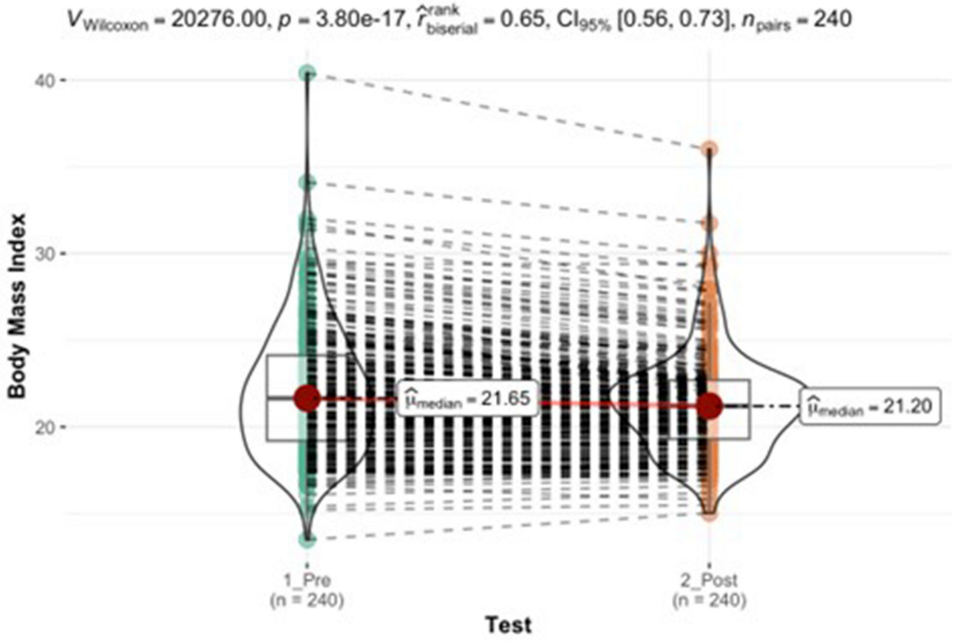

Figure 5 BMI/age before and after the nutrition education program.

size (0.45). No significant differences were observed in the males. Figure 7 shows that there is no significant difference in the median hemoglobin concentration before and after the intervention.

Discussion

Malnutrition and diet-related health issues are becoming increasingly prevalent among adolescents, particularly in developing countries such as Peru.[5,6] Adolescence is a critical stage of growth and development, during which

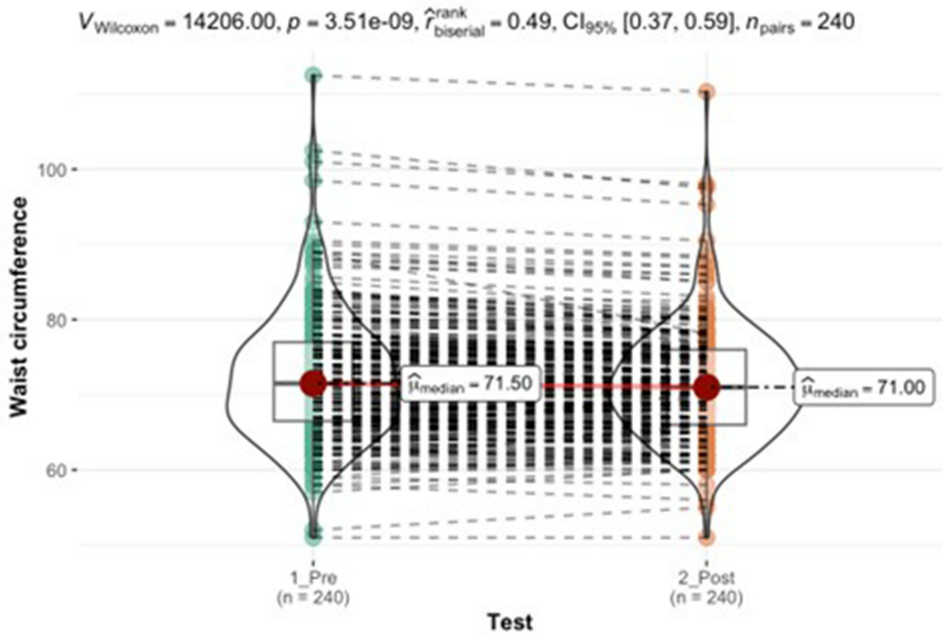

Figure 6 WC before and after the nutrition education program.

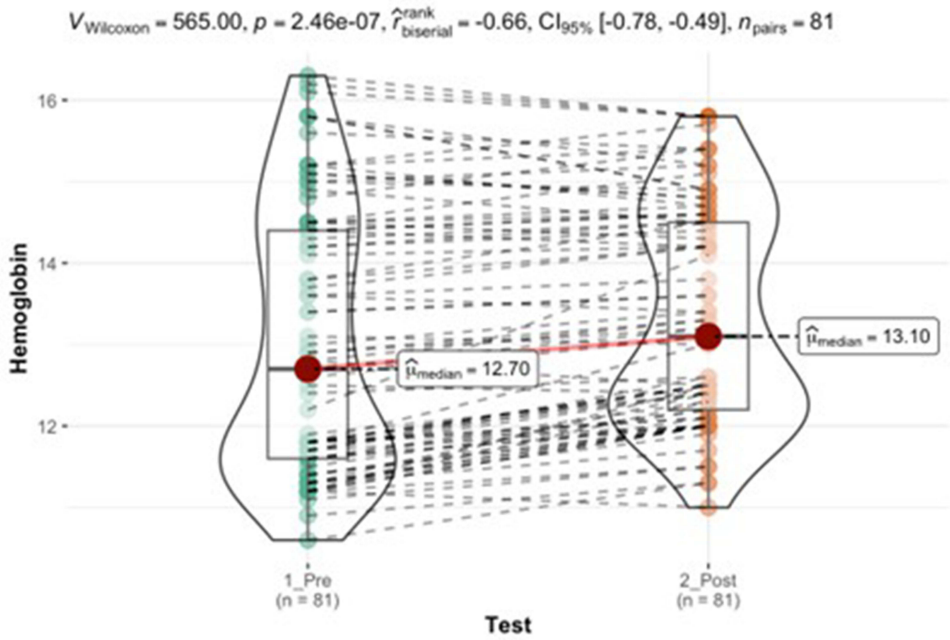

Figure 7 Hb before and after the nutrition education program.

adolescents' nutritional needs are especially important.[21] However, a considerable proportion of adolescents exhibit a lack of knowledge of nutrition, which can lead to maladaptive eating practices and, in turn, lead to adverse health outcomes such as malnutrition or obesity.[7–9] In response to this problem, nutrition education programs have been implemented as a strategy to improve knowledge, attitudes, and practices among youth.[2] These programs not only seek to provide information, but also to promote healthy habits and improve health parameters, such as anthropometric indices and hemoglobin levels, which are key indicators of nutritional status and general health.

In this context, the present study evaluated the impact of a nutrition education program in Peruvian adolescents. The study examined changes in the adolescents' knowledge, attitudes, and dietary practices, as well as in their anthropometric parameters and hemoglobin levels. The primary findings were as follows: (a) A significant improvement was observed in knowledge, attitudes, and practices scores was observed; (b) BMI scores decreased significantly after program implementation; (c) Similar results were evident for adolescent WC; (d) In women, but not in men, a significant increase in Hb levels was observed.

Knowledge, Attitudes, and Dietary Practices

The current study revealed a notable enhancement in nutritional knowledge scores among adolescents before and after the implementation of a nutrition education program. The results demonstrate that the intervention was effective in enhancing the nutritional knowledge of the participants, which represents a crucial initial step in fostering constructive alterations in their dietary patterns. The observed improvement in nutritional knowledge is consistent with previous studies that have demonstrated the efficacy of nutrition education programs in significantly improving knowledge and understanding of fundamental nutritional concepts among adolescents and children.[22,23] For example, findings from a study by Kamalaja et al[24] revealed that nutrition education in adolescent females improved nutritional knowledge in regard to healthy eating. A similar study reported that adolescents who participated in nutrition education programs in Nepal exhibited significant improvements in their nutritional knowledge.[2] Likewise, en Nicaragua, Moore et al[25] found that a nutritional intervention program had a positive impact on the nutritional knowledge of a group of adolescent women. Greater knowledge can enable adolescents to make more informed decisions about their eating habits, thereby promoting a healthy lifestyle that can extend into adulthood.[26]

However, it is crucial to recognize that while improved nutritional awareness is undoubtedly a crucial factor, it does not always result in immediate behavioral changes.[7] Nutrition education should be integrated into a comprehensive strategy that encompasses ongoing support, a nurturing environment, and family and community involvement.[1] The efficacy and longevity of these programs can be enhanced by their integration with other public health initiatives and adaptation to the specific needs of the target population.[2]

On the other hand, the findings of the current study demonstrated that the eating attitudes of the participants exhibited a notable improvement after the implementation of the nutritional intervention. The results indicate that the intervention led to an increase in knowledge about nutrition, which subsequently influenced adolescents' perceptions and beliefs about the importance of healthy eating in a positive way. This finding is consistent with the results of another study that demonstrated that educational programs can significantly enhance adolescents' attitudes toward healthy eating.[24] Furthermore, a study by Raut et al[2] demonstrated that nutrition education programs in secondary schools were associated with more positive attitudes toward healthy eating and greater intention to follow dietary recommendations. A positive attitude toward healthy eating is an essential first step in the process of promoting healthy and sustainable long-term eating habits.[27] Indeed, a positive attitude toward healthy eating may serve as a motivating factor for adolescents to adopt and maintain beneficial diet practices, which could potentially reduce the risk of chronic diseases related to diet in the future.

However, it is fundamental to acknowledge that while the observed change in attitudes is a promising indicator, the true challenge lies in translating these attitudes into tangible actions.[28] Nutrition education programs should be designed to inform and change attitudes, as well as to provide the skills and support necessary for adolescents to implement and maintain changes in their eating habits.[9] It is evident that active parental participation, integration with school and community policies, and access to healthy foods are important factors in ensuring that improvements in attitudes translate into improvements in eating behavior.[27]

Another notable finding is that a notable improvement was observed in adolescents' scores on the assessment of eating practices. This outcome demonstrates that the nutrition education program not only affected adolescents' understanding and attitudes toward food, but also resulted in tangible changes in their daily dietary patterns. Furthermore, previous studies have shown that nutrition education programs can increase the frequency of fruit and vegetable consumption among adolescents.[29,30] A similar study found that nutrition education in secondary schools led to increased adherence to recommended dietary guidelines and a reduction in the consumption of unhealthy foods.[31] It is important to

note that alterations in dietary practices serve as a clear indicator of the successful implementation of the knowledge and attitudes acquired through the nutrition education program.[27] This indicates that adolescents are not only aware of the importance of a nutritious diet, but are also implementing this awareness in their daily routines. However, to ensure the sustainability of these changes, it is essential that educational programs are continuous and complemented by the support of families, schools, and communities.[32]

BMI/Age

Excess body weight represents a significant public health problem among Peruvian adolescents.[6] The nutritional intervention has been shown to be an effective and sustainable strategy to improve various indicators of nutritional status in children and adolescents. The present study demonstrated a significant decrease in BMI scores following the implementation of the nutrition education program. This finding is consistent with that reported by other studies, such as In-Iw et al,[33] which observed a significant reduction in BMI in high school students after the implementation of school nutrition programs. Similarly, Annan et al[14] demonstrated that nutrition-focused educational interventions resulted in a reduction in BMI/age in adolescents. These findings are corroborated by a systematic review and meta-analysis indicating that school-based health education interventions have the potential to reduce adolescent BMI.[34]

The impact of the interventions on nutritional status was evaluated using the age-adjusted BMI z-score. This index is used to monitor the growth of school-aged children and adolescents, allowing an accurate assessment of their physical development relative to reference standards.[35] Furthermore, a reduction in BMI is a positive indicator, particularly during adolescence. High BMI is a key predictor of noncommunicable diseases such as type 2 diabetes, hypertension, and cardiovascular disease. Furthermore, it has been shown to improve general well-being and self-esteem of adolescents.[36] Consequently, the implementation of effective nutrition education interventions during this stage of development is of paramount importance in order to foster the establishment of healthy habits and to prevent the onset of long-term health problems.

WC

In adolescents, WC represents an important anthropometric indicator used to assess body fat distribution and the associated risk of developing metabolic diseases.[37] This parameter is of particular relevance, as higher abdominal fat accumulation is associated with an increased risk of chronic diseases, including type 2 diabetes, hypertension, and cardiovascular disease.[38] The measurement of WC is a simple and effective tool that, together with other indicators such as BMI, provides a more complete picture of the nutritional and health status of adolescents.[19,38,39] The results of our study indicate that the waist circumference of adolescents decreased after the implementation of a nutritional intervention program. This observation suggests that the program may have a positive impact on the reduction of abdominal fat. This result reinforces the importance of implementing healthy eating education programs that contribute to better overall health and disease prevention.

Similarly, a study conducted in Indian adolescents revealed a notable decline in waist circumference among the evaluated subjects. The authors posit that educational initiatives within the school environment can effectively promote healthy dietary habits and prevent the accumulation of abdominal fat, which is a risk factor for various metabolic diseases.[40] Additionally, a separate study that concentrated on the elements of nutrition and lifestyle interventions in a cohort of adolescents between the ages of 15 and 17 reported a reduction in the mean waist circumference of the participants.[15] The results of the BMI and WC analysis indicate that the nutrition education program has led to beneficial changes in the anthropometric profiles of the participants. This underscores the importance of implementing and maintaining nutrition-focused educational interventions to improve the overall well-being of adolescents.

Hemoglobin

In Peru, anemia is a major public health concern among adolescents.[5,41] This public health problem has a detrimental impact on the physical and cognitive development of young people, which in turn affects their academic performance and overall well-being.[42] Anemia in adolescents is frequently associated with nutritional deficiencies, particularly iron

deficiencies. These deficiencies may be compounded by inadequate diets, a lack of access to nutritious foods, and inadequate nutritional education.[43] In the current study, a significant increase in hemoglobin levels was observed in females, but not in males. This finding indicates that the nutrition education program had a different impact according to gender, with a more pronounced effect on hemoglobin levels in adolescent girls. The observed improvement in hemoglobin levels in women can be attributed to a number of factors, including greater adherence to the intervention program or a more positive response to the promoted dietary changes. Given that adolescents are more susceptible to iron deficiency anemia due to menstruation, the observed increase in hemoglobin levels suggests an increased intake of essential nutrients, such as iron, which is crucial for the prevention of anemia.[44]

Our findings are consistent with those of previous studies that indicate that nutritional interventions may have disparate effects on men and women.[7] For example, a study by Moore et al in 182 adolescent women in Nicaragua demonstrated that a nutritional intervention program resulted in a more pronounced improvement in hemoglobin levels.[25] The significant increase in hemoglobin levels observed in women in this study serves to illustrate the efficacy of the nutrition education program in improving the nutritional status of adolescent girls. A similar result was observed in a study conducted by Khani et al[45] conducted in 160 female students (mean age 13.85 + 1.72 years), demonstrating that educational intervention has a positive effect on improving iron deficiency anemia preventive behaviours in this population. It is important to note that the absence of change in men indicates the need for further investigation into the underlying causes of this discrepancy and the development of interventions that ensure equitable benefits for all groups. The findings underscore the importance of adopting a personalized approach in nutrition programs to address the distinctive needs of each demographic and improve the general well-being of the adolescent population.

Limitations and Future Perspectives

Despite the significant and positive changes observed in the knowledge, attitudes, and dietary practices of the participants, this study is subject to certain limitations that should be considered when interpreting the findings. These include the use of a single measurement of BMI/age, WC, and hemoglobin levels. First, it should be noted that the study was conducted in a specific region of Peru, which may limit the generalizability of the results to other regions or populations in the country. The geographic, cultural, and socioeconomic diversity of Peru may influence the effectiveness of nutritional interventions. Therefore, it is recommended that this study be replicated in different contexts to validate the findings.[46]

Second, although hemoglobin levels were evaluated, ferritin levels, which are a more specific marker of iron stores in the body, were not measured. Furthermore, other potential influences on hemoglobin levels, such as the menstrual cycle in adolescent girls, were not taken into account.[44] Additionally, the study did not differentiate between nutritional and non-nutritional causes of anemia, such as inherited conditions (eg, thalassemia or sickle cell anemia), as no specific diagnostic tests were performed to identify these types. Future research should incorporate such assessments to provide a more comprehensive understanding of anemia in this population. Third, the questionnaire utilized to assess knowledge, attitudes, and practices was self-reported, which may have introduced social desirability or recall bias. It is possible that participants may have provided responses that they considered socially acceptable or that they may not have accurately recalled their eating habits. The use of complementary methods, such as structured interviews or direct observation, could help to reduce the impact of this bias.

Fourth, the absence of a control group in the study design represents a significant limitation. The absence of a control group makes it difficult to attribute the observed changes exclusively to the nutritional intervention, as other uncontrolled external factors could have influenced the results. Future studies should include a control group to strengthen the internal validity of the findings.

Finally, the relatively short duration of the study (four months) and the absence of a longitudinal design limit the ability to evaluate the long-term sustainability of the favorable outcomes achieved through the intervention. Although significant improvements in BMI/age, WC, and hemoglobin levels were observed within this timeframe, it is unclear whether these changes can be maintained over time without additional reinforcement. A longer follow-up period would allow for a more comprehensive assessment of the persistence of these effects and could help identify the need for adjustments or continued support to ensure sustained effectiveness.

Practical Implications for Public Health

The findings of this study have several implications for public health practice. Firstly, the considerable improvement in knowledge, attitudes and practices among adolescents serves to illustrate the efficacy of nutrition education as a means to promote the adoption of healthy dietary habits. These changes in KAP are important, as greater knowledge and a positive attitude towards healthy eating can lead to healthy food choices throughout life. On the contrary, the notable decrease in BMI/age and WC scores after the intervention indicates that nutrition education may be a viable approach to addressing obesity and reducing abdominal fat accumulation in adolescents. This is particularly relevant, as these factors are directly associated with a reduced risk of metabolic and cardiovascular disease in the future. Finally, the significant increase in Hb levels in women highlights the effectiveness of the program in addressing specific deficiencies in nutrients, such as iron, that are common among adolescent girls due to menstruation. These findings underscore the need to incorporate gender-specific considerations into the design and implementation of public health programs. The divergence in response to the intervention between men and women indicates that nutritional strategies should be adapted to optimize their efficacy in different demographic groups. It is recommended that public health policies include specific components to address the unique nutritional needs of men and women, with the goal of ensuring that both groups benefit fully from interventions.

Conclusions

Obesity and anemia represent a significant public health concern among adolescents. Consequently, it is imperative to improve knowledge, attitudes, and eating practices to effectively address these issues. This study demonstrated that a nutrition education program can have a significant impact on improving knowledge, attitudes, and diet practices, as well as reducing adolescent BMI/age and WC, and increasing hemoglobin levels in women. The results indicate that the implementation of nutrition education programs in schools can be an effective approach to improving nutritional status and preventing long-term health problems such as anemia, obesity, type 2 diabetes, and cardiovascular diseases.

Data Sharing Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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