

# Impact of a Nutrition Education Intervention on Knowledge, Healthy Eating Index, and Biochemical Profile in a Rural Community in Peru

Yessica Cusquisibán-Alcantara<sup>1,\*</sup>, Cesia Toledo-Garrido<sup>1,\*</sup>, Yaquelin E Calizaya-Milla<sup>1</sup>, Sandra P Carranza-Cubas<sup>2</sup>, Jacksaint Saintila<sup>2</sup>

<sup>1</sup>Research Group for Nutrition and Lifestyle, School of Human Nutrition, Universidad Peruana Unión, Lima, Perú; <sup>2</sup>School of Medicine, Faculty of Health Sciences, Universidad Señor de Sipán, Chiclayo, Perú

\*These authors contributed equally to this work

Correspondence: Yaquelin E Calizaya-Milla, Research Group for Nutrition and Lifestyle, School of Human Nutrition, Universidad Peruana Unión, Lima, Chosica, 15, Perú, Email yaquelincalizaya@upeu.edu.pe; Jacksaint Saintila, School of Medicine, Faculty of Health Sciences, Universidad Señor de Sipán, Carretera a Pimentel, Chiclayo, Lambayeque, 14001, Perú, Email jacksaintsaintila@gmail.com

**Background:** Non-communicable diseases in adults and anemia in children represent a major global public health problem, with multiple causes including poor dietary quality. However, nutrition education interventions can empower individuals to make appropriate dietary changes.

**Objective:** To evaluate the impact of a nutritional education intervention on nutrition knowledge (NK), healthy eating index (HEI), and biochemical profile in families in the community in Peru.

**Methods:** A pre-experimental study was conducted in the community of Sinchicuy, located on the banks of the Amazon River, Iquitos, Peru. Nutrition education was provided over a 16-week period to a total of 61 heads of household (23 children under 5 years of age and 23 older adults). Fasting glucose and hemoglobin (Hb) concentration analyses were also carried out before and after the intervention.

**Results:** After the intervention, a significant improvement in the NK score was observed, increasing by 90% ( $p < 0.001$ ). Additionally, the average HEI scores experienced a significant increase, rising by approximately 11.4% ( $p < 0.001$ ). In children under 5 years of age, the Hb level showed a significant increase of 5.1% ( $p = 0.017$ ). However, no statistically significant difference in glucose concentration was observed in older adults after the intervention.

**Conclusion:** The findings of this study indicated a positive impact on NK, HEI, and Hb in heads of households, older adults, and children under five in a rural community where there is limited access to basic services.

**Keywords:** nutrition education, nutritional knowledge, hemoglobin, glucose, children, rural communities

## Introduction

A balanced and nutritious diet is essential for the health and well-being of individuals, providing both essential macronutrients and micronutrients at every stage of life (infancy, toddler years, childhood, puberty, older adolescence, adulthood, middle age).<sup>1</sup> This adequate food helps maintain the body in optimal conditions and reduces the risk of non-communicable diseases, such as type 2 diabetes, anemia, obesity, among others.<sup>2</sup>

In fact, obesity is a disease that affects the health of children, with increased morbidity and mortality in adulthood, and its prevalence continues to increase at an exponential rate.<sup>3,4</sup> For example, according to the World Health Organization (WHO), 39% of individuals over 18 years of age are overweight, while 13% were obese.<sup>5</sup> In addition, it is estimated that 33.6% of children and adolescents are affected by overweight or obesity, and 8% of children under five years of age.<sup>4</sup> In Peru, obesity represents a serious public health problem. According to a recent UNICEF report, it is estimated that 8.6% of children under five years of age, as well as 38.4% of children and adolescents between 6 and 13 years of age, are overweight.<sup>3</sup> According to a report by the National

Institute of Health, 22.3% of the population over 15 years of age suffers from obesity,<sup>6</sup> these figures position Peru as one of the countries with the highest prevalence of obesity in the region. Regarding diabetes, at the national level, the prevalence of diabetes is 8.1% in the female population and 7.2% in males. There are approximately two new cases per 100 individuals per year.<sup>7</sup>

On the other hand, anemia is a serious public health problem that significantly affects different age groups, especially children under five years of age, women in their fertile period (due to blood loss during menstruation), pregnant women, and postpartum women.<sup>8</sup> In children, anemia impedes adequate psychomotor development, which in the long term may result in deficient performance in cognitive, social, and emotional areas.<sup>9</sup> In older adults, anemia can also lead to decreased physical and cognitive ability, which can affect their quality of life and independence.<sup>10</sup> In addition, anemia reduces physical capacity and productivity, thus generating a negative socioeconomic impact.<sup>4</sup> Worldwide, WHO estimates that anemia affects 20% of children aged 6 to 59 months, 37% of pregnant women, and 30% of women aged 15 to 49 years.<sup>11</sup> Similarly, it is estimated that more than 10% of older adults residing in rural communities are anemic;<sup>10,12</sup> which could result from nutritional deficiency, chronic kidney disease, chronic inflammation, or undetected blood loss due to gastrointestinal cancer, although in many individuals, the underlying cause remains unknown.<sup>10,12</sup> In the case of Peru, in 2021, figures from the National Institute of Statistics and Informatics revealed that almost 39% of children between 6 and 35 months suffered from anemia, with the rural area being the most affected, with a prevalence of almost 49%.<sup>13</sup>

Nutrition education interventions can help improve the health of children under 5 years of age and older adults by providing the necessary knowledge to heads of households to make informed decisions about foods rich in essential nutrients (iron, vitamin B12, folic acid, and vitamin C), their combination, preparation, and consumption;<sup>14</sup> which is essential for the prevention and management of anemia.<sup>15</sup> Furthermore, in relation to noncommunicable diseases, nutrition education can help to understand how to adapt the diet to prevent or manage them effectively.<sup>16</sup> For example, someone with diabetes needs to understand how different foods affect blood sugar levels.<sup>17</sup> Adequate nutritional knowledge acquired through nutrition education programs can empower heads of household to take control of their own and their family's health by helping them understand how their food choices affect health and well-being.<sup>15,18</sup>

Nutrition education programs have been reported to have a positive effect on the NK levels of heads of household adopting healthy eating habits. This was demonstrated by Castell et al,<sup>19</sup> who showed an improvement in knowledge about healthy eating after evaluating a group of 34 children (23 families). Similarly, one study evaluated the impact on knowledge, attitudes, and consumption of high-fat foods of a nutrition education intervention in women aged 19 to 65 years, suggesting that the intervention significantly improved women's knowledge and attitudes toward healthy eating, leading to a decrease in the intake of high-fat foods.<sup>20</sup> Likewise, another study evaluates the effects of an individualized nutrition education and support program on older adults living alone, focusing on their eating habits, knowledge, and nutritional status, finding that the program significantly improved eating habits and nutritional knowledge, which in turn had a positive impact on nutritional status.<sup>21</sup>

Additionally, nutrition education interventions can positively impact both hemoglobin levels and glucose concentration.<sup>14</sup> For example, Woźniak et al,<sup>15</sup> found that the nutritional intervention improved iron levels in a group of 203 children under five years of age. Furthermore, findings from a meta-review of systematic reviews suggested that specific nutrition interventions influence hemoglobin concentrations and anemia in children under five years of age.<sup>22</sup> In relation to glucose levels, a study that evaluated the impact of a lifestyle program that included nutritional aspects found that a significant decrease in glucose concentration.<sup>23</sup> Likewise, another study found that a randomized nutrition education intervention significantly improved hemoglobin A1c concentration.<sup>24</sup> In general, these studies underline the importance of nutrition education to promote healthy eating habits, which is essential in the prevention and management of noncommunicable diseases such as diabetes and anemia.

However, it is important to note that the effectiveness of nutritional interventions and the interpretation of their results are greatly influenced by the level of formal education in the target community, particularly in rural areas of Peru where access to formal education is limited. Indeed, formal education plays a fundamental role in awareness and understanding of nutrition and health topics, which is essential for the effectiveness of such programs.<sup>25</sup> Communities with limited access to education face additional challenges, including a lack of basic knowledge in nutrition and health, which can hinder the implementation of nutrition programs.<sup>26</sup> Therefore, it is vital to adapt interventions to the educational level of the community, using appropriate methods and language.<sup>27</sup> Furthermore, formal education enhances the ability to make healthy decisions, though less educated communities may require more time and specific strategies for significant changes in nutritional knowledge and practices.<sup>26,27</sup> Thus, formal education emerges as a key factor in understanding and improving nutrition in such communities.<sup>28</sup>

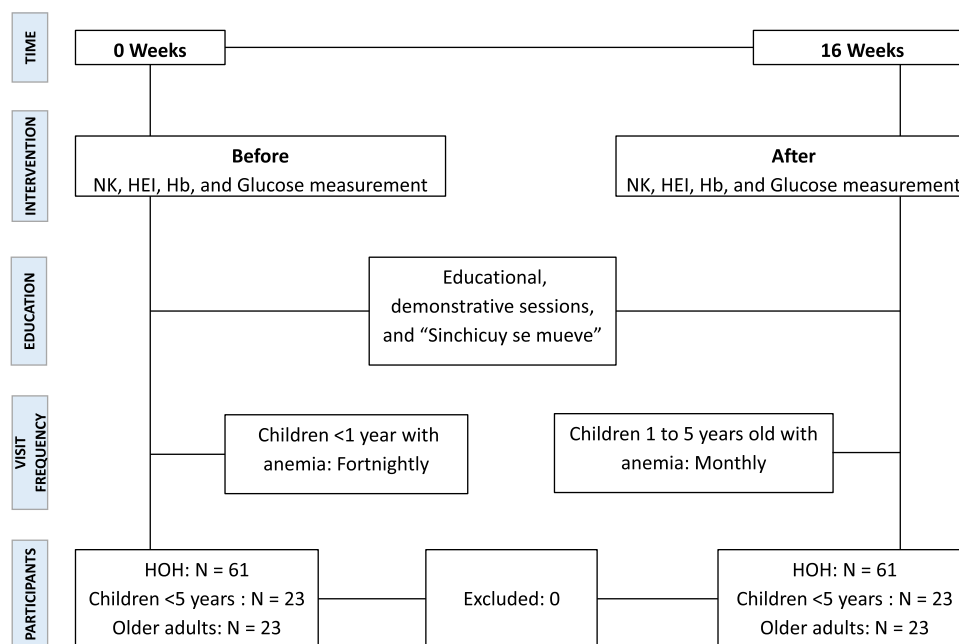
Nutrition education is widely applied to different population groups with the purpose of providing adequate information on nutrition and healthy diets and preventing certain diseases.<sup>16,17,29</sup> However, such interventions are rarely conducted in rural communities with vulnerable populations, such as children under 5 years of age and older adults, where education and basic services are limited. As a result, there is limited information available on the effect of nutritional programs on these groups. This represents a significant gap in our knowledge and highlights the need for more targeted research and programs in these areas. Additionally, in Peru, there are still gaps in access to nutrition education and health care for children and older adults residing in rural areas with limited resources.<sup>30</sup> Therefore, it is critical to develop and implement nutrition education programs in these vulnerable communities to better understand their specific needs and develop effective strategies to improve nutritional status and health and their quality of life. Therefore, the objective of the study was to evaluate the impact of the nutritional education intervention on NK, HEI, and biochemical profile in the families of the community of Sinchicuy. Additionally, we propose the following hypothesis: The implementation of a nutrition education intervention significantly increases the level of NK, improves HEI scores, and has a positive impact on Hb and glucose parameters.

## Materials and Methods

### Design, Type of Research, and Participants

The study employed a prospective, pre-experimental design, because participants were followed for 16 weeks and data were collected prior to the implementation of the educational intervention to have a baseline on which to compare outcomes after the intervention. The study protocol was reviewed and approved by the Research Ethics Committee of the Universidad Peruana Unión, with approval number 2022-CE-FCS-00042. Moreover, informed consent was obtained from all participants. In addition, considering that some participants were minors, a procedure was applied to ensure participation under parental consent. The study was conducted in accordance with the ethical criteria established in the 1975 Declaration of Helsinki and its subsequent amendments.

The study was conducted in the community of Sinchicuy, located near the Amazon River, in the Indiana district, province of Maynas, department of Loreto, Iquitos, Peru. All participants who met the selection criteria and were willing to participate were included in the study. The total sample size was N = 107 (61 heads of household aged 20 to 59, 23 older adults, and 23 children under five years of age) (Figure 1). This sample was obtained by non-probabilistic convenience sampling. In this case, families from the Sinchicuy community that had a family record and were part of the Salud Total project were included. The study was



**Figure 1** Design of nutritional education intervention on nutritional knowledge, healthy eating index, and biochemical profile.

**Abbreviations:** NK, Nutritional Knowledge; HEI, Healthy Eating Index; Hb, haemoglobin; HOH, Heads of household.

conducted from September 1 to December 15, 2022. Salud Total is a health project that seeks to combat anemia and family violence in the community of Sinchicuy and has as partners Universidad Peruana Unión, Adventist Medical Network, Centura Health, Dirección Regional de Salud (Loreto, Peru) and Municipality of Indiana.

## Application of Data Collection Instruments

Validated instruments were used that included a) a nutritional knowledge test, b) the healthy eating index, c) and a sociodemographic and biochemical data recording form (See [supplementary Material S1](#)). The application of the instrument was conducted in person, through home visits, in two stages: before and after the educational intervention. Both tests were administered to heads of household, while for hemoglobin concentration, children under 5 years of age and older adults were considered, the latter also having their glucose concentration evaluated.

## Sociodemographic and Biochemical Data Record Form

The sociodemographic record form included the personal data of each head of household, such as age, sex, marital status, level of education, and hemoglobin and glucose concentration. They were also asked if they attended “Sinchicuy se mueve” (Sinchicuy moves), a program that is part of the Total Health Project. To this question they had to answer “Yes” or “No”.

## Nutritional Knowledge Test

To determine NK, the healthy eating knowledge test validated in the Peruvian population was applied.<sup>31</sup> The instrument consists of two parts; in the first part the general data of the participants are recorded, and in the second part there are questions about knowledge of healthy eating, with a total of sixteen questions and each correct answer has a value of 2 points. Knowledge was classified as “low”, “medium”, and “high” with scores of less than 17, 17–25, and more than 25, respectively. This allows us to assess the level of nutritional knowledge of the participants about healthy eating before and after the intervention.<sup>31</sup> To evaluate its reliability, the Kuder-Richardson coefficient was calculated, obtaining a value of 80.7%, which is an acceptable score for its application.

## Healthy Eating Index

To measure the dietary index, the Healthy Eating Index for the Spanish Population (IASE) was used,<sup>32</sup> whose elaboration was based on the methodology of the North American Healthy Eating Index (HEI).<sup>33</sup> The instrument is composed considering 10 food components: Cereals and derivatives, Vegetables, Fruits, Milk and derivatives, Meats, Legumes, Cold cuts and sausages, Sweets, Soft drinks with sugar, and Variety of diet. For each component, a score ranging from 0 to 10 is assigned according to the established criteria, where 10 indicates full compliance with the recommendations proposed by the Sociedad Española de Nutrición Comunitaria. The sum of the scores for all food groups gives a maximum value of 100 and allows the diet to be classified into three categories: “healthy” if the score is greater than 80; “needs changes” if the score is between 50 and 80; and “unhealthy” if the score is less than 50. In the current study, the Content Validity Index was 0.85.

## Biochemical Profile

### Hemoglobin (Hb)

The analysis of Hb concentration was performed in children under five years of age and older adults in the community. For this purpose, a Konsung Portable Hemoglobin Analyzer, model H7–3, hemoglobin microwells type HB-01, Roche ACCU-CHEK SAFE-T-PRO PLUS lancets and a biosafety kit (cotton, alcohol, hazardous waste bag, and gloves) were used. The evaluation was conducted at two points in time, before and after the nutritional education intervention. In the case of children under five years of age, those whose parents gave their permission were included and those who could not be located after having tried to visit them on three different occasions were excluded. Children who were diagnosed with anemia in the initial analysis received iron supplementation and were followed up: biweekly for children under 1 year old and monthly for children under 5 years old. For this purpose, an anemia follow-up form adapted by the Universidad Peruana Unión was used, following the recommendations of the Peruvian Ministry of Health.<sup>4</sup> For older

adults, anemia testing was performed on those who voluntarily participated and were mentally lucid. Those who were not present after three home visit attempts were not included in the study.

The cut-off points considered to assess the measured hemoglobin were taken from the Technical Document: National Plan for the Reduction and Control of Maternal and Child Anemia and Chronic Childhood Malnutrition in Peru: 2017–2021. Considering the following values: for children under five years of age, normal Hb  $\geq 11.0$  g/dL; mild anemia 10.0 g/dL - 10.9 g/dL; moderate anemia 7.0 g/dL - 9.9 g/dL; severe anemia  $<7.0$  g/dL. For older adults (females) Normal Hb  $\geq 12.0$  g/dL; mild anemia 11.0 g/dL - 11.9 g/dL; moderate anemia 8.0 g/dL - 10.9 g/dL; severe anemia  $<8.0$  g/dL. For older adults (males), normal Hb  $\geq 13.0$  g/dL; mild anemia 11.0 g/dL - 12.9 g/dL; moderate anemia 8.0 g/dL - 10.9 g/dL; severe anemia  $<8.0$  g/dL.<sup>4</sup>

## Glucose

To measure glucose levels, an Accu Chek digital glucometer was used, along with Accu Chek glucometer test strips, lancet, cotton, alcohol, and gloves. The glucose value measured was postprandial, considering as a normal a value lower than 200 mg/dl, considering as reference the criteria of the Clinical Practice Guidelines for the Diagnosis, Treatment, and Control of type 2 diabetes mellitus.<sup>34</sup> Glucose was measured in adults over 60 years of age who voluntarily participated and were mentally lucid at the time of testing. Those who were not present after three attempts to visit were excluded.

## Nutritional Education Intervention Procedure

The nutritional education intervention included educational sessions, demonstrations, and a physical activity program called Sinchicuy moves and was conducted using educational material during home visits. As for the educational sessions, four aspects were considered (Table 1): (1) Food Safety at Home, (2) Critical nutrients and healthy eating, (3) Anemia and supplementation, and (4) Foods harmful to health and physical exercise (See [supplementary material S2](#)). With respect to the demonstration sessions, they were developed according to the specifications of the Peruvian Ministry of Health, but considering the food and nutritional recommendations, emphasizing local foods from the community. The ARDE methodology (animation, reflection, demonstration, and evaluation) was used for implementation. These sessions were aimed at all members of the community, specifically heads of household and mothers of children under 5 years of age. The educational sessions were conducted by dietitians. During the 16 weeks of intervention, the intervention team remained in the community, as it is located quite far from urban areas.

## Statistical Analysis

Before proceeding with the analyses, the normality of the sample distribution was verified using the Kolmogorov–Smirnov test. For the descriptive analysis of variables such as age, sex, marital status, level of education, and regular

**Table 1** Topics of Educational Sessions Conducted in the Nutritional Intervention

Sessions	Topics	Contents
1	Food Safety at Home	- Definition of hygiene and disinfection - Cross contamination - 5 keys of food safety
2	Critical nutrients and healthy eating	- Nutritional pyramid - Food groups: Energetic, regulators, and builders - Healthy plate and nutritional recommendations
3	Anemia and supplementation	- Definition of anemia - Causes and consequences - Iron-rich foods - Supplementation
4	Foods harmful to health and physical exercise	- Non-communicable diseases - Unhealthy foods - Importance of physical exercise.

attendance at “Sinchicuy moves”, measures such as mean (M) and standard deviation (SD) were used, as well as absolute and percentage frequencies. In addition, to analyze the distribution of the variables, the skewness and kurtosis coefficients were used. To determine the differences in NK, HEI scores, as well as glucose and Hb concentration before and after the implementation of the nutrition education program, the Wilcoxon nonparametric statistical test was used. The data were processed and analyzed using statistical packages using the free software R 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria; <http://www.R-project.org>) and SPSS, version 27 (SPSS Inc., Chicago, IL, USA). P-values less than 0.05 were considered statistically significant.

## Results

Table 2 shows the results of the sociodemographic data of the head of household of the families and older adults in Sinchicuy. The mean age was  $45.84 \pm 17.29$  years,  $71.00 \pm 6.05$  years, and  $3.1 \pm 1.09$  years for heads of household, older adults, and children under five years of age, respectively. Approximately 82% of heads of household were female, while older adults were predominantly male (52.2%). More than half (65.2%) of the children under five years of age were female. More than 80% of heads of household were married; in contrast, 69.6% of older adults were single. Most heads of household (55.7%) and older adults (65.2%) had incomplete education. More than half (52.5%) of the heads of household did not participate in the “Sinchicuy moves” program regularly.

Table 3 shows the results of the NK test and the HEI before and after the nutritional education intervention. It was found that the NK score improved significantly after the application of the program (from  $14.66 \pm 3.73$  to  $27.88 \pm 2.71$ ,  $p < 0.001$ ). Similarly, a significant increase in mean HEI scores was observed after the program compared to the initial mean (from  $66.19 \pm 8.71$  to  $73.76 \pm 6.01$ ,  $p < 0.001$ ).

Figures 2 and 3 show the effect of the nutritional intervention program on NK and HEI, respectively. In relation to the program application time (before and after), significant variations are observed in the median NK (16 vs 28,  $p < 0.001$ ) and HEI (67 vs 74,  $p < 0.001$ ).

**Table 2** Sociodemographic Characteristics, KN, and HEI Before and After the Program

Variables	Head of Household	Older Adult	Children < 5 Years Old
Age (M $\pm$ SD)	45.84 $\pm$ 17.29	71.00 $\pm$ 6.05	3.1 $\pm$ 1.09
	n (%)	n (%)	n (%)
<b>Sex</b>			
Female	50 (82)	11 (47.8)	15 (65.2)
Male	11 (18)	12 (52.2)	8 (34.8)
<b>Marital status</b>			
Single	12 (19.7)	16 (69.6)	
Living in couple	49 (80.3)	7 (30.4)	
<b>Level of education</b>			
Incomplete studies	34 (55.7)	15 (65.2)	
Complete studies	27 (44.3)	8 (34.8)	
<b>Regular attendance at “Sinchicuy moves”.</b>			
Yes	29 (47.5)		
No	32 (52.5)		

**Note:** Estudios primarios y secundarios completos; estudios primarios y secundarios incompletos.

**Abbreviations:** M, media; SD, desviación estándar; NK, Nutritional Knowledge; HEI, Healthy Eating Index.

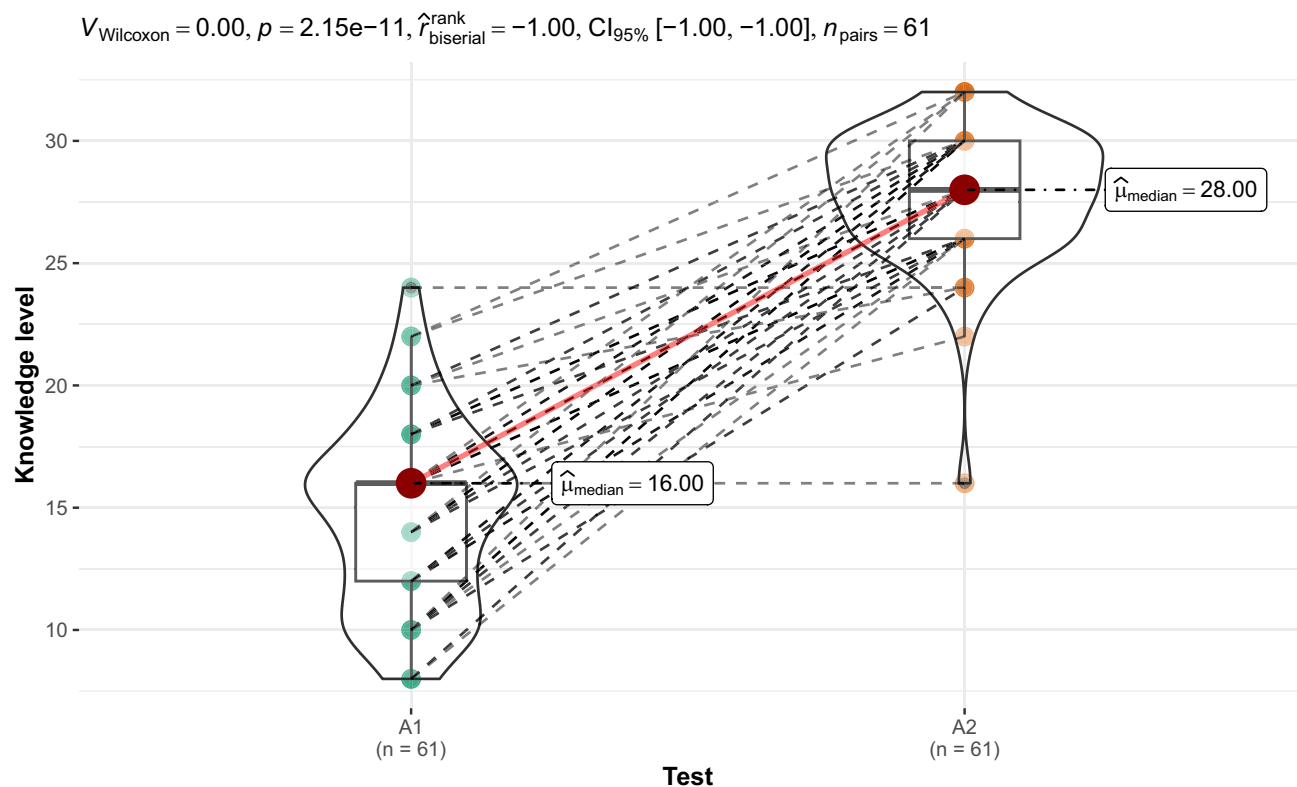
**Table 3** Mean, Standard Deviation, Distribution, Difference of Nonparametric Measures, and Effect Size of NK and HEI of the Head of Household Before and After the Nutritional Education Intervention

Variables	M	SD	SE	S	K	MD	p	Wilcoxon	P	E. Size*
<b><sup>a</sup>NK</b>										
Before	14.66	3.73	0.47	0.16	-0.58	-13.18	< 0.001	3694	< 0.001	4.03
After	27.88	2.71	0.34	-1.38	4.06	-				
<b><sup>b</sup>HEI</b>										
Before	66.19	8.71	1.11	-0.19	0.53	-7.57	< 0.001	804.5	< 0.001	0.97
After	73.76	6.01	0.77	-0.40	0.13	-				

**Notes:** <sup>a</sup>NK, Nutritional knowledge, <sup>b</sup>HEI, Healthy Eating Index. \*For the Wilcoxon test, the effect size is given by the paired rank biserial correlation and through the Hodges-Lehmann estimator.

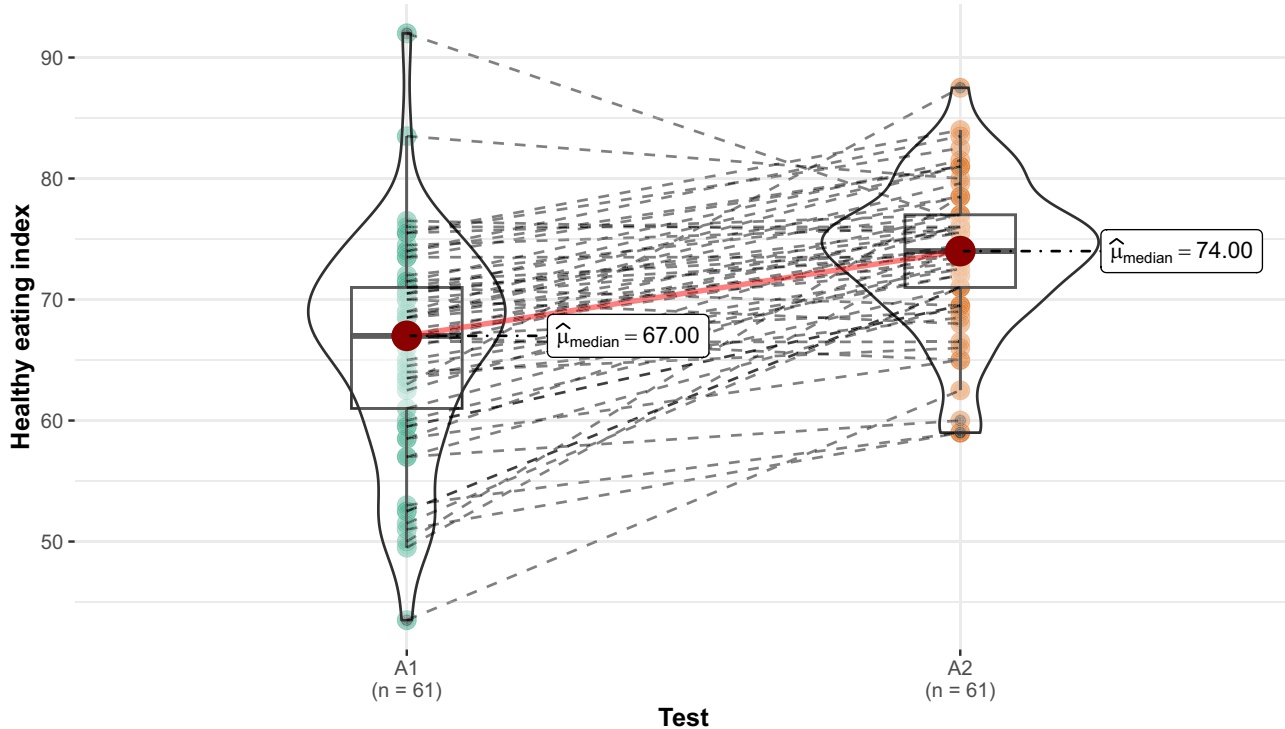
**Abbreviations:** E. Size, effect size; K, kurtosis coefficient; M, mean; MD, mean difference; P, probability of error; S, coefficient of skewness; SD, standard deviation; SE, standard error of the mean.

Table 4 describes the biochemical results of children under 5 years of age and older adults before and after the application of the nutritional intervention program. The mean hemoglobin level scores in children under 5 years of age increased after the intervention program compared to the initial mean (from  $10.46 \pm 0.94$  to  $10.99 \pm 1.22$ ,  $p = 0.017$ ). Similarly, Figure 4 shows statistically significant changes in the median hemoglobin level before (10.60) and after (11.20) the intervention,  $p = 0.04$ . On the other hand, the mean hemoglobin of adults went from  $12.41 \pm 1.2$  to  $12.8 \pm 0.92$ , before and after intervention, with no statistically significant difference ( $p > 0.05$ ). As for glucose concentration, a decrease was observed after application of the program (from  $121.2 \pm 18.69$  to  $113.6 \pm 27.16$ ), however, no statistically significant



**Figure 2** Level of NK before and after the intervention program.  
**Note:** A1, pre-test; A2, post-test.

$$V_{\text{Wilcoxon}} = 79.00, p = 1.85e-09, \hat{r}_{\text{biserial}}^{\text{rank}} = -0.91, \text{CI}_{95\%} [-0.95, -0.84], n_{\text{pairs}} = 61$$



**Figure 3** HEI before and after the nutrition education intervention program.  
**Note:** A1, pre-test; A2, post-test.

difference was found ( $p > 0.05$ ). Similar information can be evidenced in Figures 5 and 6 regarding the median Hb and glucose level, respectively, in older adults.

### Discussion

Nutrition education programs are a fundamental pillar for promoting NK, improving health and well-being; it is also essential for guiding informed dietary decisions at the household level regarding diet quality.<sup>23,35,36</sup> However, in many

**Table 4** Mean, Standard Deviation, Distribution, Nonparametric Measures Difference, and Effect Size of Glucose and Hb Level in Children and Older Adults

	M	SD	SE	S	K	MD	p	Wilcoxon	P	E. Size*
Children < 5 years old										
Hemoglobin 1 <sup>a</sup>	10.46	0.94	0.19	0.51	1.26	-0.52	0.48	156.5	0.017	0.47
Hemoglobin 2 <sup>b</sup>	10.99	1.22	0.25	-1.01	0.37	-				
<b>Older adult</b>										
Hemoglobin 1 <sup>a</sup>	12.41	1.2	0.25	-0.68	-0.25	-0.38	0.18	231	0.468	0.35
Hemoglobin 2 <sup>b</sup>	12.8	0.92	0.19	0.56	0.35	-				
Glucose 1 <sup>a</sup>	121.2	18.69	3.89	0.4	-1.03	7.60	0.3	291.5	0.560	0.32
Glucose 2 <sup>b</sup>	113.6	27.16	5.66	-2.13	6.13					

**Note:** <sup>a</sup>Measurement 1 (before the intervention); <sup>b</sup>Measurement 2 (after the intervention). \*For the Wilcoxon test, the effect size is given by the paired rank biserial correlation and through the Hodges-Lehmann estimator.

**Abbreviations:** 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.



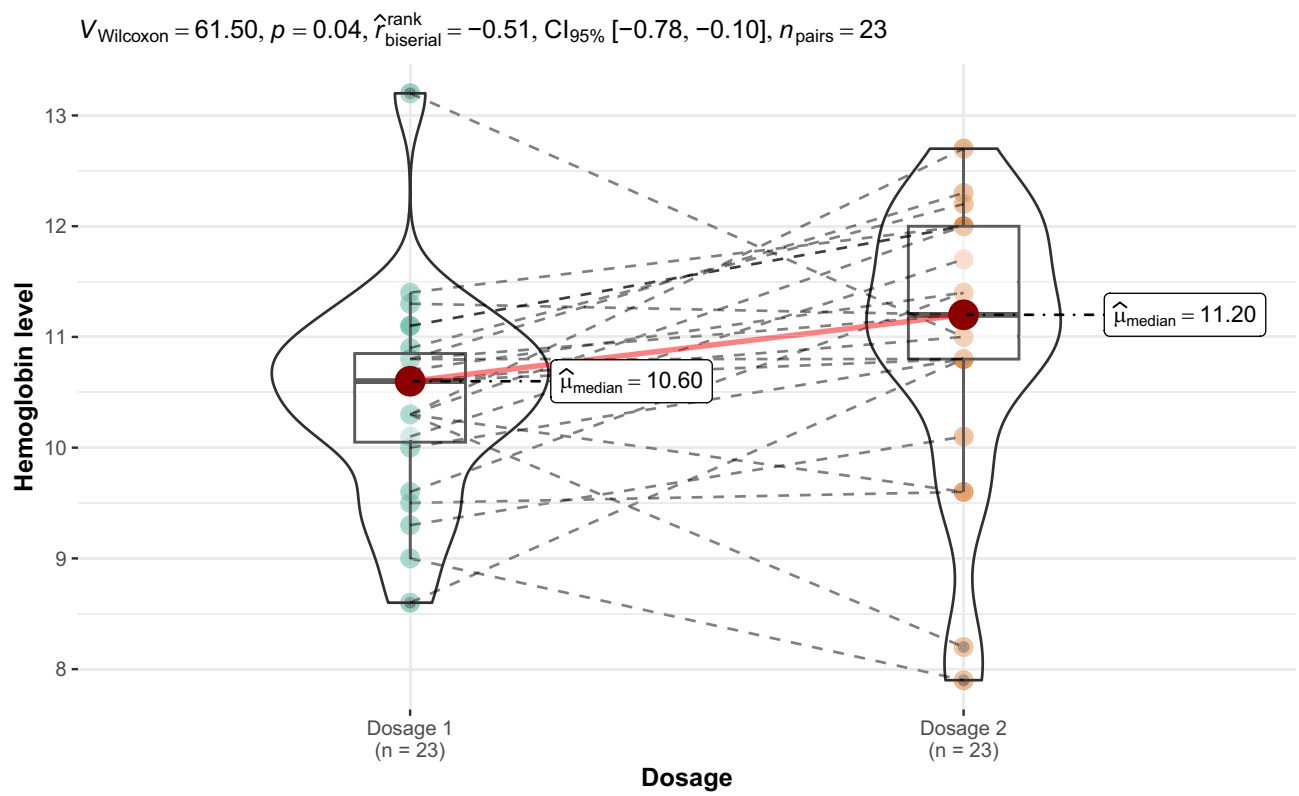


Figure 4 Hb level of children under 5 years of age before and after the intervention program.

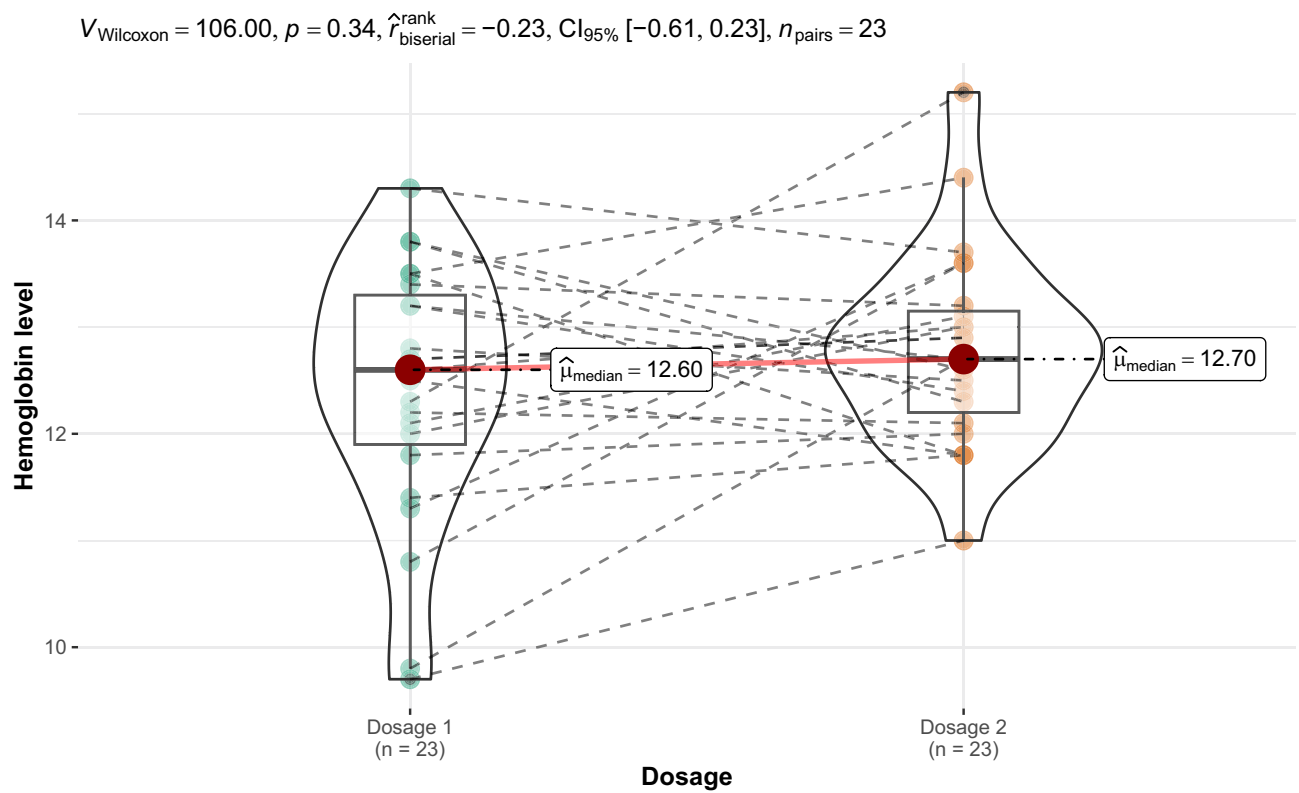
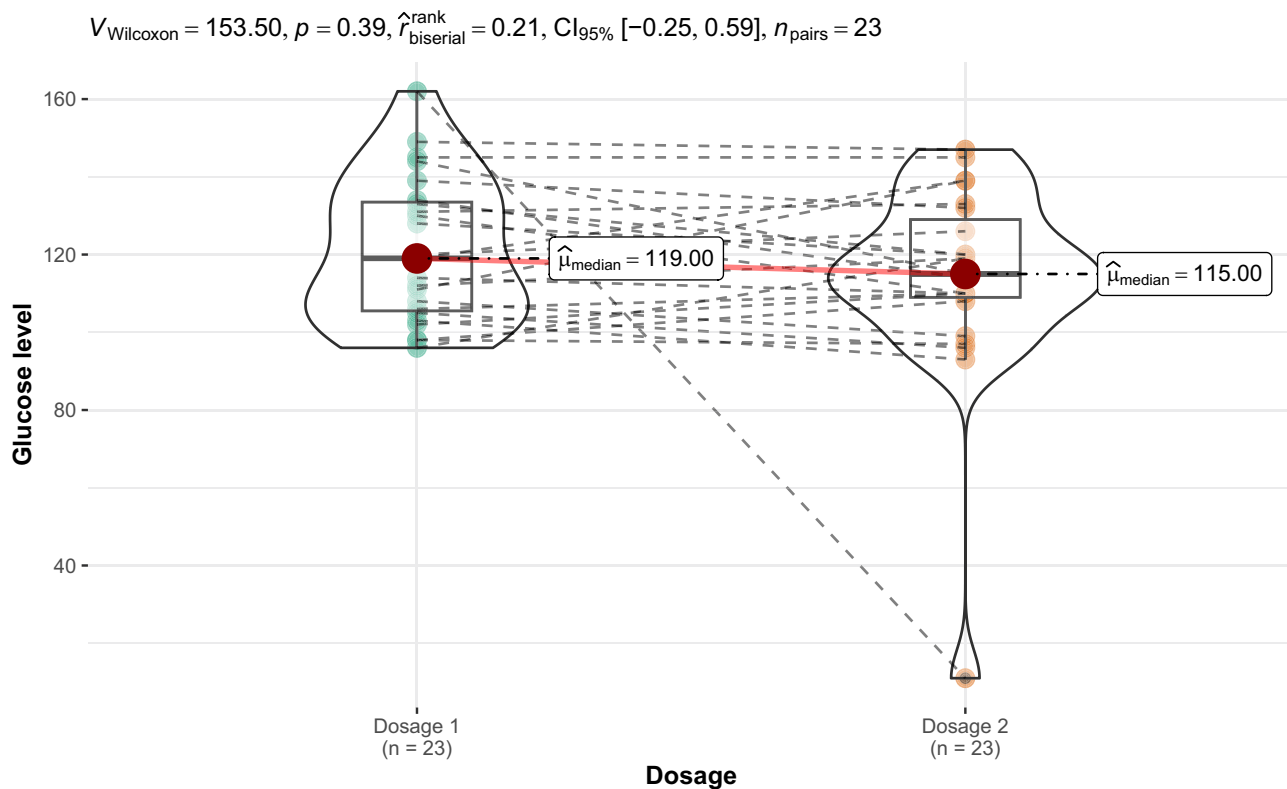


Figure 5 Hb level of older adults before and after the intervention program.



**Figure 6** Glucose level of older adults before and after the intervention program.

rural communities, especially those with limited access to education and basic services, the lack of nutrition education can contribute to the adoption of unhealthy dietary habits and nutritional deficiencies and, in the long term, to noncommunicable diseases.<sup>20,24,37</sup> Despite ongoing efforts to improve the nutrition of individuals in rural communities, in the Peruvian context, there are still significant gaps in NK and in the understanding and application of nutritional principles in daily life.<sup>37</sup> In this context, the current study embarks on the essential task of determining whether nutrition-based educational interventions can serve as effective tools to address these gaps and improve nutritional and health status and well-being in the community studied. The following are the main findings: (a) The NK score improved significantly after the application of the program, (b) a significant increase in mean HEI scores was observed after the program compared to the baseline mean, (c) Hb level in children under 5 years of age increased significantly after the program, and (c) however, there was no statistically significant difference in glucose and Hb concentration in older adults.

Adequate NK is essential for any individual; however, it becomes especially important for those living in rural communities with limited access to education and basic services.<sup>38</sup> In resource-constrained communities, NK becomes an essential tool, as it can enable families to select and prepare food appropriately to get the maximum nutritional value from what is available.<sup>39</sup> In fact, the acquisition of NK is a fundamental tool for individual and community empowerment in disease prevention and management.<sup>23,35</sup> In our study, it was evident that the NK score improved significantly after the application of the program. These findings are consistent with the results of a study conducted on mothers and adolescent girls in a Nicaraguan community where it was found that participants' nutritional knowledge scores improved significantly after participating in the nutritional intervention program.<sup>40</sup> Similarly, in two rural communities in southwestern Nigeria, the impact of a nutrition education program significantly improved knowledge and attitudes regarding key feeding recommendations for infants and young children.<sup>41</sup> These findings reinforce the idea that, through well-structured nutrition education programs adapted to local needs and realities, it is possible to improve the level of knowledge of individuals living in rural communities.<sup>39</sup> This improvement, in turn, has the potential to positively influence the dietary

decisions of heads of household and, therefore, their health status and that of family members, particularly the most vulnerable in the household, such as young children and older adults.<sup>15</sup> In fact, several studies suggest that good knowledge of maternal/caregiver nutrition protects young children from events leading to acute and chronic malnutrition.<sup>41–44</sup> Therefore, such interventions are consolidated as a valuable investment for the well-being and sustainable development of rural communities, especially in the health and nutrition of young children, who represent the future of these communities.

The HEI is considered an effective tool for assessing the quality of an individual's or community's diet.<sup>32,33</sup> Its purpose is to measure the extent to which a diet aligns with standardized dietary recommendations.<sup>45</sup> A diet with a high HEI score indicates a dietary pattern that closely follows the recommendations, while a low score suggests the opposite.<sup>46</sup> Diets that adhere to high quality standards, such as those indicated by a high HEI, tend to be rich in essential nutrients and low in components potentially detrimental to health.<sup>45,46</sup> Thus, it has been observed that these high-quality diets are associated with a lower risk of developing non-communicable diseases, such as heart disease, type 2 diabetes, obesity, and certain types of cancer.<sup>47</sup> In the current study, a significant increase in mean HEI scores was observed after nutritional intervention compared to the baseline mean. Findings from previous studies of nutrition education-based interventions showed positive effects on the quality of participants' diets.<sup>48,49</sup> Precisely, the results of an investigation using the Healthy Eating Index for HemoDialysis patients (HEI-HD) demonstrated that providing nutrition education based on the HEI-HD to patients and nurses had a beneficial impact on optimizing diet quality.<sup>49</sup> On the other hand, another intervention study showed that nutrition education significantly reduced the amount of red meat, processed meats, sugars, and desserts, while increasing the amount of cereals and whole grains, vegetables, milk, and fermented milk beverages served in schools.<sup>48</sup> The literature shows that linking nutrition education with NK can have a positive impact on eating habits, which is necessary to improve dietary quality and health outcomes at all stages of the life cycle in rural communities.<sup>50–52</sup> Therefore, it seems that investing in studies that evaluate the impact of nutrition education on NK and diet quality emerges as a progressive strategy, considering that conditions linked to inadequate diets continue to rise globally.

Iron plays a fundamental role in the overall development of a child throughout the various stages of growth.<sup>30</sup> This micronutrient is vital to produce red blood cells, muscle cells, DNA replication, as well as for proper brain development and strengthening of the immune system.<sup>29</sup> However, in children, iron deficiency is one of the most prevalent micronutrient deficiencies and one of the main causes of anemia.<sup>15</sup> In the current study, it was found that the Hb level in children under 5 years of age was significantly increased after the implementation of the nutrition education program. These findings could be due in part to the fact that an improvement in NK levels and a better HEI were observed, which translates into better diet quality, which is particularly relevant considering that, during the first 1000 days of a child's life, both nutrient overload and nutrient insufficiency can have long-lasting repercussions on developing tissues and can reshape their metabolism.<sup>15</sup> Several studies have shown a positive impact of nutrition education interventions on iron levels in young children.<sup>30,38</sup> For example, an intervention study that provided nutrition education to parents of a group of children under 5 years of age reported an improvement in the children's iron status.<sup>15</sup> Also, similar findings are found in studies conducted in pregnant women [28] and adolescent girls where it is observed that the iron level and Hb level increased significantly after nutritional intervention.<sup>40,53</sup> Similarly, these findings are contemplated in specific nutritional interventions to prevent and control anemia, finding that, in children under 5 years of age, iron fortification of milk or cereals, multiple micronutrient powder, home fortification of complementary foods, and complementary feeding increased Hb levels and reduced the risk of anemia.<sup>54</sup> It is important to note that, in the current study, children identified with anemia at the first evaluation were given iron supplementation. In addition, constant monitoring was carried out: every two weeks for infants under one year old and once a month for those under five years old. In fact, research conducted in children aged 6 to 35 months in three Andean areas in Peru showed that iron supplementation significantly decreased the prevalence of anemia. In addition, it was observed that those children with mild and moderate anemia at the beginning of the study improved at the end of the intervention.<sup>30</sup> Iron supplementation can be an effective strategy in the fight against anemia in children under five years of age. Given the relevance of nutrition education in relation to children's health, it is important from a public health perspective to increase awareness in rural communities in this regard. Before and after the implementation of the nutritional education program, an evaluation of the blood glucose

concentration of the older adults was carried out. The results showed a 6% decrease in glucose levels after the intervention. This indicates that the intervention had an apparent positive effect on glucose values in these individuals. One possible justification is that our intervention focused on improving aspects such as diet quality and physical exercise, which, in turn, could favor these results. However, when detailed statistical analyses were performed to determine the statistical significance of this change, it was found that the difference was not statistically significant enough to be attributed with certainty to the intervention. Although a positive trend is not evident, the decrease in glucose concentration is an indication that the intervention could have potential benefits on the metabolic health of the participants. In fact, a similar study that delivered healthy eating and physical activity topics over 18 weeks found a statistically significant reduction in glucose concentration after a telehealth intervention.<sup>23</sup> Furthermore, a study conducted in diabetic patients during the COVID-19 pandemic identified that glycosylated hemoglobin values were significantly lower after education compared to baseline values of education.<sup>55</sup> Blood glucose is an important marker of health status, and elevated levels of this marker can be a precursor to conditions such as type 2 diabetes, heart disease, among other complications.<sup>56</sup> Although the observed decrease was not statistically significant in this study, any reduction in glucose levels can be considered a step in the right direction in terms of prevention in older adults.

## Limitations

This study had several limitations. One of the main limitations is the absence of a control group, which could have provided a more solid basis for comparing the results obtained with the nutritional education intervention. Without a control group, it is more challenging to determine whether the changes observed in the community are directly due to the intervention or whether they can be attributed to other external or coincidental factors. Additionally, the lack of a control group may limit the study's ability to establish causal relationships between the intervention and the observed outcomes. In future studies, it would be beneficial to incorporate an experimental design that includes a control group to strengthen the validity of the findings. Another relevant limitation of the study is that the sample was homogeneous, consisting only of heads of households, children under five years of age, and older adults from a particular rural community in a specific region of Peru. This may affect the generalizability of the results. Given the homogeneity of the sample, the findings may not be representative of other rural communities and regions in Peru or other countries. Different communities may have different eating habits, cultures, and access to nutrition education and basic services, and these factors may influence the effectiveness of the intervention. However, it could be argued that focusing on a specific rural community allowed us to have a deep and detailed understanding of the dynamics and needs of that community. On the other hand, it is important to mention that the biochemical analysis focused only on Hb as a biomarker to detect anemia, without including additional tests that would evaluate in more detail the iron status in the body, such as ferritin measurement. This situation could affect the complete understanding of iron nutritional status, as ferritin is an important indicator of iron stores in the body. Finally, the absence of a longitudinal design prevents us from understanding the durability and persistence of the benefits obtained because of the intervention. It is possible that, without continuous reinforcement and long-term monitoring, the acquired knowledge and behaviors may fade over time. Despite this aspect, the fact that the study proved to be effective after 16 weeks of intervention is a positive indicator. To ensure the sustainability of these changes, it is recommended to consider additional phases of reinforcement and follow-up, or even to consider the implementation of a permanent nutrition education program in the community.

## Implications for Public Health and Future Perspectives

This study highlights the importance and impact of nutrition education interventions in rural communities with limited access to formal education and basic health and nutrition services. By evidencing an increase in the level of NK after the intervention, the suggestion that nutrition education can be a useful tool to improve the health and well-being of individuals living in a rural community is reinforced. In addition, by observing improvements in the rate of healthy eating, the study suggests that such interventions can directly influence the quality of a population's diet. As is well known, a balanced and healthy diet is essential to prevent several non-communicable diseases, which could potentially reduce the burden of disease in these communities, thereby reducing health care costs and improving the quality of life of their inhabitants. On the other hand, although the intervention did not show a statistically significant change in glucose

concentration in older adults, the study underscores the need for longer-term or more intensive interventions to observe more significant changes in other health markers. This can serve as a basis for future research or interventions in low-resource rural communities. Finally, the intervention, by focusing on the nutritional education of heads of household and its impact on the health of children and older adults, highlights the importance of addressing health and nutrition from a family and community approach, which can have broader public health implications for the community.

## Conclusion

This pre-experimental prospective study reveals the positive impact that a nutritional education intervention can have in the rural community of Sinchicuy, Peru. Throughout the intervention, a notable increase in the level of NK of the participants and an improvement in the HEI was observed, reflecting a better diet quality of the heads of household. In addition, statistically significant improvements in the Hb levels of children under five years of age were evidenced. These findings are particularly significant considering that an adequate and balanced diet is essential to prevent numerous non-communicable diseases, including anemia, and to ensure healthy development, especially in children. On the other hand, despite not finding a statistically significant difference in glucose concentration in older adults after the intervention, the trend toward a decrease in glucose levels is a favorable direction. These results suggest that investing in nutrition education, especially in rural communities with limited access to basic resources, can be a valuable strategy to improve the NK of heads of household, promote public health, and prevent diet-related diseases in both children and older adults.

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## Disclosure

Yessica Cusquisibán-Alcantara and Cesia Toledo-Garrido are co-first authors for this study. The authors declare that they have no potential conflicts of interest for this work.

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