Journal of Nutrition Explorations
Vol. 4, No. 4, November 2026, pp. 686~702
e-ISSN: 2987-761X
DOI: 10.36568/jone.v4i4.804
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Hemoglobin and Nutritional Status Changes in Adolescent Girls Following a Simulated Moringa–Mango Smoothie Intervention

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ARTICLE INFO

Article History:
Received September 25, 2026
Accepted November 4, 2026
Published online November 4, 2026

Keywords:
adolescent girls;
anemia;
hemoglobin;
mango;
moringa leaves

ABSTRACT

Anemia among adolescent girls requires nutritional approaches that consider local dietary needs and food availability. A moringa leaf–mango smoothie may serve as a supplementary food, although its clinical benefits require empirical evaluation. This study analyzed changes in hemoglobin levels and nutritional status using synthetic data from a modeled moringa leaf–mango smoothie intervention. A single-group pretest–posttest design was simulated based on the setting of SMKS Kesehatan Darussalam Lhokseumawe. Of 50 simulated participants, 45 adolescent girls aged 15–18 years with mild anemia met the per-protocol criteria of ≥80% adherence and complete paired measurements. The modeled intervention consisted of approximately 250 mL of smoothie daily for 14 days, with hemoglobin and anthropometric measurements simulated at baseline (day 0) and follow-up (day 15). Changes were analyzed using paired t-tests and 95% confidence intervals (CIs), while anthropometric analyses were considered exploratory. In the synthetic dataset, mean hemoglobin increased from 11.553 ± 0.300 to 12.098 ± 0.486 g/dL, with a mean increase of 0.544 g/dL (95% CI: 0.457–0.632; *p* < 0.001). Twenty-seven simulated participants (60.0%) achieved hemoglobin levels ≥12.0 g/dL. Mean body weight increased by 0.113 kg (*p* = 0.028), BMI by 0.047 kg/m² (*p* = 0.026), and BMI-for-age z-score by 0.0174 (*p* = 0.049). Despite statistical significance, these anthropometric changes were minimal and did not indicate meaningful nutritional improvement. The overall distribution of nutritional status categories remained unchanged between assessments. These synthetic-data findings illustrate modeled increases in hemoglobin levels and minimal anthropometric changes among participants meeting the per-protocol criteria. However, they do not provide evidence of clinical effectiveness or meaningful improvement in nutritional status. Controlled studies using real participant data, longer follow-up periods, and iron status assessments are needed to establish the clinical benefits and sustained nutritional outcomes of the proposed intervention.

INTRODUCTION

Anemia is characterized by a hemoglobin concentration below the normal threshold, resulting in a reduced capacity of the blood to transport oxygen to tissues [1,2]. Adolescent girls are particularly vulnerable because of rapid growth, increased iron requirements, menstrual blood loss, and changes in dietary habits. This vulnerability may be exacerbated by breakfast skipping, dietary restriction to maintain body shape, low consumption of animal-source protein, and inadequate fruit and vegetable intake. Anemia can cause fatigue, dizziness, reduced physical fitness, impaired concentration, and

poorer academic performance. If it persists into the reproductive years, anemia may also increase the risk of adverse health outcomes during pregnancy and childbirth [3,4].

Hemoglobin levels are associated with the availability of iron and other nutrients required for erythropoiesis [5], whereas nutritional status reflects the balance between nutrient intake and physiological requirements [6,7]. Moringa leaves (*Moringa oleifera*) contain iron, protein, folate, vitamins, and antioxidant compounds that may support red blood cell production. Mango (*Mangifera indica*) contains vitamin C, which can enhance non-heme iron absorption by reducing ferric iron to the more readily absorbed ferrous form [8,9]. Although the role of vitamin C in facilitating non-heme iron absorption is established, this mechanism does not demonstrate that the proposed smoothie provides sufficient bioavailable iron or produces a measurable hemoglobin response within 14 days. Its potential contribution depends on ingredient composition, preparation, dietary inhibitors, baseline iron status, and the underlying cause of anemia. The expected benefit of this particular formulation therefore remains a hypothesis rather than an established clinical effect. Combining moringa leaves and mango in a smoothie may also improve palatability and acceptability by modifying the distinctive taste and aroma of moringa leaves [10,11]. According to the study protocol, each serving contains 30 g of moringa leaves, 150 g of mango, 60 mL of water, and 10 mL of honey, yielding approximately 250 mL.

Anemia remains a widespread public health concern. The World Health Organization estimated that 30.7% of women aged 15–49 years worldwide had anemia in 2023, with menstruating adolescent girls among the most vulnerable groups [12]. In Indonesia, the 2018 Basic Health Research survey reported anemia prevalences of 26.8% among individuals aged 5–14 years and 32.0% among those aged 15–24 years [13]. The study protocol also cites research conducted in Banda Aceh that identified anemia in 30.9% of adolescent girls. SMKS Kesehatan Darussalam Lhokseumawe provides the contextual setting for the modeled protocol; however, the synthetic dataset does not establish anemia prevalence, dietary patterns, or intervention outcomes among students at this school.

The Indonesian government has implemented iron supplementation programs for adolescent girls; however, their success depends on distribution coverage and adherence. Some adolescents are reluctant to take supplements regularly because of their taste or odor, nausea, constipation, or concerns about adverse effects. These challenges indicate that program availability does not necessarily translate into consistent consumption. Locally available food-based interventions are therefore worth investigating as complementary strategies rather than substitutes for recommended anemia management. Moringa leaves and mango are relatively accessible and affordable in Aceh and can be prepared as a beverage that may appeal to adolescents. Nevertheless, the effectiveness of this formulation requires objective evaluation before it can be recommended for school-based programs. In an uncontrolled study, a rise in hemoglobin could also reflect regression to the mean, particularly when eligibility requires low baseline hemoglobin, as well as biological and measurement

variation, menstrual blood loss, dietary changes, supplement use, illness, or other unmeasured factors. A single-group comparison cannot separate these explanations from an intervention effect.

Previous studies have predominantly evaluated moringa in capsules, powders, extracts, teas, or fortified foods, whereas mango has generally been investigated separately as a source of vitamin C or as a dietary component [14]. Research has also focused more frequently on changes in hemoglobin levels than on concurrent changes in nutritional status. Differences in formulation, dose, intervention duration, participant characteristics, and comparison groups limit the direct applicability of existing findings to adolescent girls in Lhokseumawe. These empirical questions are distinct from the methodological question addressed here: how changes in hemoglobin and several anthropometric outcomes can be analyzed and interpreted within a synthetic dataset modeled on a short, uncontrolled smoothie protocol. The contribution of this study is an illustrative analysis that distinguishes statistical changes from clinical meaning and causal inference; it does not provide new empirical evidence of the smoothie's biological effects. Moreover, simulated results depend on how the data were generated and cannot independently validate the assumptions underlying the modeled responses.

The modeled protocol specifies one serving of moringa leaf–mango smoothie each morning after breakfast for 14 consecutive days, capillary hemoglobin assessment using a digital hemoglobinometer, and anthropometric assessment on days 0 and 15. It also specifies supervised consumption and a per-protocol adherence threshold of at least 80.0% of scheduled servings. These procedures describe the protocol underlying the simulation; no smoothie administration, biological measurement, or direct consumption monitoring was undertaken in this analysis. Hemoglobin was the primary analytical outcome, whereas body weight, BMI, BMI-for-age z-score, and nutritional-status categories were examined exploratorily. Their inclusion illustrates the interpretation of short-term anthropometric variation rather than an expectation of meaningful nutritional recovery within 14 days. Small differences in weight, BMI, or BMI-for-age z-score may reflect hydration, measurement variability, or ordinary short-term fluctuation, and changes in nutritional-status categories were not an expected outcome.

This study aims to describe paired changes in hemoglobin, body weight, BMI, BMI-for-age z-score, and the distribution of nutritional-status categories in synthetic data representing adolescent girls under a modeled moringa leaf–mango smoothie protocol. Its intended value is to inform analytical planning and cautious interpretation for future empirical research, rather than establish clinical effectiveness or support immediate implementation. The prespecified directional hypothesis for hemoglobin was a higher modeled follow-up concentration than at baseline, with the null hypothesis of no mean paired difference. Analyses of body weight, BMI, and BMI-for-age z-score were exploratory, without a prespecified directional hypothesis of improvement; nutritional-status categories were summarized descriptively without hypothesizing a favorable shift over 14 days. These

hypotheses concern the synthetic dataset and do not constitute tests of clinical benefit in actual participants.

METHODS

Study Design

This study employed a pre-experimental, single-group pretest–posttest design. Changes in hemoglobin levels and nutritional status were assessed by comparing measurements obtained before and after a moringa leaf–mango smoothie intervention administered for 14 consecutive days. Baseline measurements were obtained on day 0, and follow-up measurements were obtained on day 15. All participants received the same intervention, with no control group. The individual adolescent girl was the unit of both intervention and analysis.

The absence of a control group is a major methodological limitation because observed pre–post changes cannot be attributed specifically to the smoothie intervention. Alternative explanations include regression to the mean, particularly because participants were selected for low baseline hemoglobin, biological and measurement variation, menstrual blood loss, dietary changes, and other unmeasured factors. Accordingly, paired analyses were used to estimate within-participant changes rather than causal intervention effects. Statistical significance indicates evidence of a pre–post difference but does not establish that the smoothie caused the change or demonstrate its clinical effectiveness.

Study Setting and Period

The study was conducted at SMKS Kesehatan Darussalam Lhokseumawe, Aceh Province, Indonesia, from April to Juny, 2026. Study activities included preparation, participant screening, baseline assessment, intervention delivery, and follow-up assessment. Hemoglobin and anthropometric measurements were performed in a designated room provided by the school to ensure participant privacy and comfort. Baseline and follow-up assessments were conducted at approximately the same time of day. Assessment and smoothie administration dates were recorded to monitor adherence to the scheduled observation intervals.

Study Population and Sample

The target population comprised adolescent girls aged 15–18 years. The accessible population consisted of female students within this age range enrolled at SMKS Kesehatan Darussalam Lhokseumawe. Fifty participants were recruited in accordance with the target specified in the protocol. This target was not supported by a documented power-based sample size calculation. The final analytical sample comprised 45 participants who met the per-protocol criteria. The inclusion criteria were current enrollment at the school, age 15–18 years, nonpregnant status, a baseline hemoglobin concentration of 11.0–11.9 g/dL, willingness to participate, and provision of consent in accordance

with age-related requirements. Participants were also required to have no history of allergy to moringa leaves, mango, or honey. The exclusion criteria were a history of thalassemia or other blood disorders, kidney disease, chronic conditions affecting hemoglobin levels, acute illness that could interfere with participation, and regular use of iron supplements or medications affecting hemoglobin during the preceding month. Treatment required by prospective participants was not discontinued to enable study eligibility.

Eligibility was based on hemoglobin concentration rather than confirmation of iron deficiency. Ferritin, transferrin saturation, inflammatory markers, hepcidin, and other iron-status biomarkers were not measured. Therefore, participants were classified as having mild anemia, without establishing its underlying cause, and should not be described as having confirmed iron-deficiency anemia. These exclusions did not rule out all alternative causes of anemia. Consequently, any observed increase in hemoglobin cannot be interpreted as evidence of improved iron status or attributed specifically to increased iron availability from the smoothie.

Sampling and Group Assignment

Participants were selected through purposive sampling based on the inclusion and exclusion criteria. Recruitment involved coordination with school personnel, provision of study information, eligibility screening, and obtaining consent to participate. Participation was voluntary and did not affect academic assessment or access to healthcare. All 50 participants received the intervention in a single group without randomization. The recruitment target was specified in the protocol without a documented power-based calculation; therefore, the sample was considered exploratory, and adequate statistical power to detect clinically meaningful changes cannot be assumed. Each participant's baseline measurement served as the paired reference for her follow-up measurement.

The per-protocol analysis included participants with complete baseline and follow-up measurements who consumed at least 80% of the total scheduled smoothie volume. Forty-five participants met these analytical criteria. Three participants did not meet the adherence threshold, and two did not attend the follow-up assessment; these participants were excluded from the analysis of outcome changes. Thus, five of the 50 participants (10.0%) were excluded from the outcome analysis. Purposive sampling limits representativeness, while restriction to adherent participants with complete follow-up introduces potential selection and attrition bias. If excluded participants differed in their characteristics or responses, the estimated changes could overestimate or underestimate those among all intervention recipients. Accordingly, the findings apply to the analyzed participants and should not be generalized to all recruited participants or the wider adolescent population. All intervention recipients remained included in safety reporting for their available observation periods.

Intervention

Participants received one serving of moringa leaf–mango smoothie, with a final volume of approximately 250 mL, each morning after breakfast for 14 consecutive days. Each serving contained 30 g of fresh moringa leaves, 150 g of ripe mango flesh, 60 mL of boiled drinking water, and 10 mL of honey. Ingredient weights referred to edible portions. The formulation was standardized across servings, and no ice was added. The iron, vitamin C, energy, protein, carbohydrate, and fat content per serving was not quantified by laboratory analysis or a documented food-composition calculation. Ingredient quantities therefore describe the formulation but do not establish the nutrient dose delivered. In particular, iron bioavailability and vitamin C retention after preparation were not assessed, limiting interpretation of the proposed nutritional mechanism. Moringa leaves were separated from their stems, sorted, and washed with potable water. Mangoes were washed, peeled, and pitted before weighing. All ingredients were blended until homogeneous using clean equipment. Smoothies were prepared and consumed on the same day, with attention to hand hygiene and the cleanliness of ingredients, equipment, and serving containers.

Consumption was documented using daily monitoring forms recording the volumes provided and consumed, missed servings, and reasons for incomplete consumption. On school days, consumption was monitored directly by the researcher or a supervising teacher. On nonschool days, monitoring relied on parent or guardian reports. Records distinguished direct observations from caregiver-reported information. Adherence was calculated as the total volume consumed divided by the total volume scheduled during the intervention, multiplied by 100%. Participants were classified as adherent if they consumed at least 80% of the scheduled volume. Missed servings were not compensated for by providing double servings. The smoothie was provided as a supplementary food and did not replace main meals or necessary anemia treatment.

Outcomes and Study Variables

The primary outcome was the change in hemoglobin concentration, expressed in g/dL and calculated by subtracting the day 0 value from the day 15 value. Positive values indicated an increase in hemoglobin. An additional outcome was the proportion of participants with hemoglobin concentrations ≥12.0 g/dL at follow-up. Hemoglobin measurements were not used to establish a diagnosis of iron deficiency anemia because iron status biomarkers were not assessed. Secondary outcomes comprised changes in body weight, body mass index (BMI), and BMI-for-age z-score and were analyzed as exploratory outcomes. BMI was calculated as weight in kilograms divided by height in meters squared. BMI-for-age z-scores were determined using age at the date of assessment and sex according to the WHO growth reference for individuals aged 5–19 years.

Nutritional status was classified as severe thinness for z-scores <−3, thinness for z-scores ≥−3 to <−2, normal weight for z-scores ≥−2 to ≤+1, overweight for z-scores >+1 to ≤+2, and obesity for z-scores >+2. Changes in BMI were interpreted in relation to baseline nutritional status; an increase in

BMI was therefore not automatically considered an improvement in nutritional status. Monitored variables included age, menstrual history, dietary intake, medication or supplement use, health status, consumption adherence, and adverse events. Dietary intake excluding the smoothie was recorded separately from the study intervention.

Measurement Instruments

Hemoglobin was measured using a digital hemoglobinometer with capillary blood samples. Blood was collected by trained personnel using sterile, single-use lancets in accordance with the device instructions. Equipment and consumables were checked before use. The same device was used for baseline and follow-up measurements. The fingertip was cleaned with alcohol and allowed to dry before puncture. Blood was collected without excessive squeezing. Blood-drop handling and loading of the testing medium followed the device instructions. Reading errors prompted repeat testing according to the measurement procedure and were documented on the assessment form.

Body weight was measured using a digital scale, and height was measured using a wall-mounted height measure (microtoise). Participants wore light clothing and removed footwear and carried items before measurement. Each anthropometric measurement was performed twice. Discrepancies exceeding 0.2 kg for weight or 0.5 cm for height prompted a third measurement, and the mean of the two closest measurements was used. Additional instruments included participant characteristics forms, health and menstrual history forms, 24-hour dietary recall forms, smoothie consumption monitoring forms, and adverse event forms.

Study Procedures

Study preparation included checking ethics documentation and school authorization, preparing ingredients and measurement instruments, and standardizing procedures among study personnel. Prospective participants and their parents or guardians received information about the study objectives, procedures, risks, anticipated benefits, data confidentiality, and the right to withdraw. Study-specific assessments were performed after the required consent had been obtained.

On day 0, eligibility was assessed, participant characteristics were recorded, and menstrual history, medication or supplement use, and 24-hour dietary intake were documented. Hemoglobin and anthropometric measurements were also obtained. The smoothie was administered from day 1 through day 14, accompanied by monitoring of consumption, health status, and reported symptoms. Hemoglobin measurements, anthropometric assessments, and dietary recalls were repeated on day 15 using the same procedures.

Participants were asked to maintain their usual dietary and daily activity patterns without restricting access to nutritious foods or necessary treatment. Absences, scheduling changes, illnesses, and newly initiated treatments were documented during follow-up. Safety monitoring included all 50 intervention recipients, including those who did not meet the outcome analysis criteria.

Reported symptoms were recorded from the first consumption until the end of each participant's available observation period. For participants lost to follow-up, safety records included the date of last contact and limitations in information available thereafter.

Measures to Address Bias

Measures to reduce selection bias included consistent application of eligibility criteria and documentation of participant recruitment and flow. Measurement bias was addressed through standardized procedures, equipment checks, use of the same devices, and assessments conducted under comparable conditions. The study was open-label, with neither participants nor outcome assessors blinded. Menstrual history was recorded at baseline and follow-up. Assessments were scheduled outside menstruation and at least three days after menstrual bleeding had ceased. Menstruation during the intervention and deviations from the assessment schedule were documented. This information informed interpretation because assessments conducted outside menstruation do not eliminate the influence of menstrual blood loss on hemoglobin levels.

Dietary intake was assessed using 24-hour recalls at baseline and follow-up. Medication or supplement use, illness, and adherence were monitored throughout the intervention. This monitoring helped identify factors that could influence outcome changes but did not substitute for control of confounding through study design or statistical analysis. The number of participants excluded from the analysis and the reasons for exclusion were reported to clarify the potential for selection bias associated with the per-protocol analysis. Interpretation also considered regression to the mean, natural changes over time, and behavioral changes associated with monitoring, none of which could be distinguished from the intervention effect in the absence of a control group.

Ethical Considerations

Ethical approval was documented in the clearance issued by the Research Ethics Committee of the Faculty of Medicine, Universitas Sebelas Maret, under approval number 97/UN27.06.11/KEP/EC/2026. Consent to participate was obtained in accordance with age-related requirements after the study had been explained. Participation was voluntary, and participants could withdraw without consequences for academic assessment or access to healthcare. Participant privacy was maintained during assessments, and data confidentiality was addressed during the consent process.

Statistical Analysis

Per-protocol analyses included 45 participants with complete paired measurements and ≥80% adherence. No data imputation or sensitivity analyses were performed. Data were checked for completeness and plausibility. Categorical variables were summarized as frequencies and percentages, and continuous variables as means ± standard deviations. The distribution of within-participant differences was assessed using the Shapiro–Wilk test and graphical inspection. Changes

in hemoglobin and anthropometric outcomes were analyzed using paired t-tests and reported as mean changes with 95% confidence intervals (CIs). Paired tests were used because baseline and follow-up measurements were obtained from the same participants. Hemoglobin was the primary analytical outcome, whereas body weight, BMI, and BMI-for-age z-score were examined as related exploratory outcomes rather than independent confirmatory endpoints. The hemoglobin effect size was calculated using Cohen's \(d_z\). The proportion achieving hemoglobin ≥12.0 g/dL was reported with an exact binomial 95% CI. Nutritional status categories, dietary intake, and adherence were summarized descriptively.

Anthropometric analyses were exploratory, without adjustment for multiple testing. This strategy was intended to describe the magnitude and direction of short-term changes and generate hypotheses for future studies. Nevertheless, testing multiple outcomes increases the probability of type I error, and their correlation does not eliminate this concern. Anthropometric p-values were therefore treated as nominal and interpreted cautiously, particularly when close to 0.05. The corresponding 95% CIs were outcome-specific and did not provide simultaneous coverage across outcomes. Interpretation emphasized absolute changes, their uncertainty, and clinical relevance rather than whether individual p-values crossed the significance threshold. These analyses were not considered confirmatory evidence of improved nutritional status. All tests were two-sided, with significance set at $p < 0.05$. Findings were interpreted as within-group changes rather than causal effects.

RESULTS

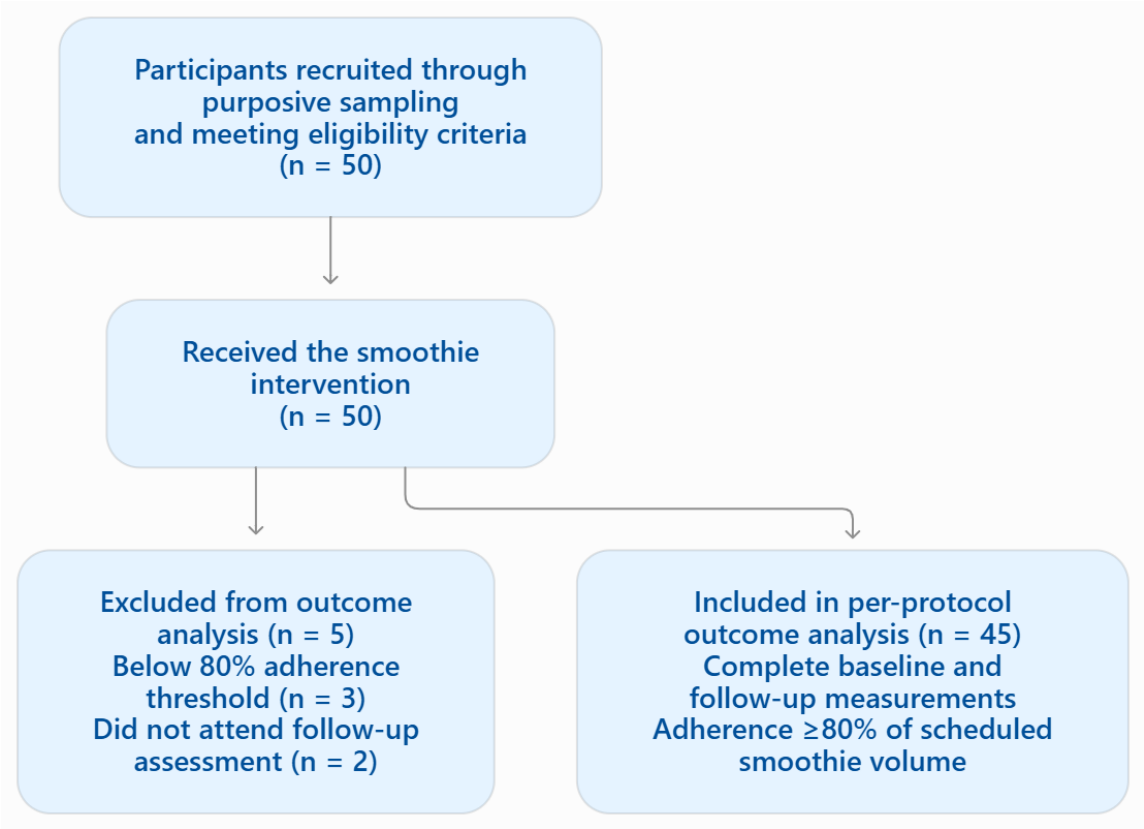


Figure 1. Participant flow through recruitment, intervention, follow-up, and per-protocol analysis

Adherence was defined as consumption of at least 80% of the total scheduled smoothie volume. All 50 intervention recipients were included in safety reporting for their available observation periods.

Table 1. Baseline characteristics of participants included in the per-protocol analysis

Characteristic	Value
Age in completed years, mean ± SD	16.33 ± 1.00
Age group, n (%)	
15 years	11 (24.4)
16 years	14 (31.1)
17 years	14 (31.1)
18 years	6 (13.3)
Height, cm, mean ± SD	155.33 ± 3.34
Body weight, kg, mean ± SD	47.50 ± 10.02
BMI, kg/m², mean ± SD	19.68 ± 4.11
BMI-for-age z-score, mean ± SD	−0.67 ± 1.38
Hemoglobin, g/dL, mean ± SD	11.55 ± 0.30
Hemoglobin range, g/dL	11.1–11.9
Mild anemia, n (%)	45 (100.0)

The mean participant age was 16.33 ± 1.00 years. Participants aged 16 and 17 years constituted the largest age groups, each comprising 14 participants (31.1%). At baseline, mean body

weight was 47.50 ± 10.02 kg, and mean BMI was 19.68 ± 4.11 kg/m². All participants had mild anemia, with a mean hemoglobin concentration of 11.55 ± 0.30 g/dL and a range of 11.1–11.9 g/dL.

Table 2. Adherence and assessment procedures among participants included in the per-protocol analysis

Component	Value
Met the adherence threshold of ≥80%, n (%)	45 (100.0)
Adherence, mean ± SD, %	90.97 ± 5.81
Adherence range, %	82.06–99.27
Had complete baseline and follow-up measurements, n (%)	45 (100.0)
Completed the follow-up assessment on day 15, n (%)	45 (100.0)
Underwent both assessments outside menstruation and ≥3 days after menstrual bleeding had ceased, n (%)	45 (100.0)
Were assessed using the same hemoglobinometer at both time points, n (%)	45 (100.0)
Used iron supplements or anemia treatment during follow-up, n (%)	0 (0.0)

Baseline and follow-up hemoglobin measurements were obtained using the same device for all participants included in the analysis. Both assessments were conducted outside menstruation and at least three days after menstrual bleeding had ceased. No use of iron supplements or anemia treatment was recorded during follow-up among these 45 participants. These procedures do not exclude the potential influence of menstrual blood loss during the intervention or other concurrent factors on hemoglobin changes.

The aggregate distribution of nutritional-status categories was identical at baseline and follow-up; however, identical marginal counts do not establish that every participant remained in the same category. Individual transitions between categories could have occurred in opposite directions. A participant-level baseline-by-follow-up cross-tabulation was not included in the reported analysis; therefore, the numbers remaining in the same category, moving to a lower category, or moving to a higher category cannot be determined from the aggregate results. The findings should consequently be described as an unchanged aggregate distribution rather than an absence of individual categorical changes.

Dietary intake excluding the smoothie was recorded at baseline and follow-up. Mean energy intake was 1730.91 ± 226.17 and 1740.58 ± 267.73 kcal/day, respectively. Corresponding mean intakes were 52.00 ± 9.34 and 52.62 ± 10.38 g/day for protein, 10.47 ± 1.82 and 10.51 ± 2.12 mg/day for iron, and 46.75 ± 13.58 and 48.65 ± 14.95 mg/day for vitamin C. The differences between follow-up and baseline group means were +9.67 kcal/day for energy, +0.62 g/day for protein, +0.04 mg/day for iron, and +1.90 mg/day for vitamin C. Dietary intake data were summarized descriptively, without statistical testing of differences. Although these group-level differences were small, they do not establish stable intake within individuals or exclude dietary changes as a contributor to the hemoglobin increase. Moreover, assessments at two time points do not capture dietary variation throughout the 14-day intervention. The contribution of dietary changes to hemoglobin changes therefore remains uncertain.

Table 3. Changes in hemoglobin and anthropometric measures among participants included in the per-protocol analysis

Variable	Baseline, mean ± SD	Follow-up, mean ± SD	Mean change (95% CI)	t (df = 44)	p
Hemoglobin, g/dL	11.553 ± 0.300	12.098 ± 0.486	0.544 (0.457–0.632)	12.509	<0.001
Body weight, kg	47.496 ± 10.017	47.609 ± 9.954	0.113 (0.013–0.213)	2.280	0.028
BMI, kg/m²	19.679 ± 4.114	19.726 ± 4.090	0.047 (0.006–0.088)	2.302	0.026
BMI-for-age z-score	−0.667 ± 1.375	−0.650 ± 1.364	0.0174 (0.0001–0.0348)	2.023	0.049

Mean hemoglobin increased from 11.553 ± 0.300 g/dL at baseline to 12.098 ± 0.486 g/dL at follow-up. The mean increase was 0.544 g/dL (95% CI: 0.457–0.632; t = 12.509; p < 0.001). The standardized effect size for the paired change, Cohen's dzd_z, was 1.865. This effect size describes the within-group change rather than a difference relative to a control group.

Mean body weight increased by 0.113 kg (95% CI: 0.013–0.213; p = 0.028), while mean BMI increased by 0.047 kg/m² (95% CI: 0.006–0.088; p = 0.026). The BMI-for-age z-score increased by 0.0174 (95% CI: 0.0001–0.0348; p = 0.049). Although all three anthropometric changes had p-values below 0.05, their magnitudes were very small. The mean weight increase corresponded to approximately 113 g over 14 days, accompanied by minimal changes in BMI and BMI-for-age z-score. These findings do not demonstrate clinically or nutritionally meaningful improvement, particularly because the aggregate distribution of nutritional-status categories remained unchanged. Anthropometric findings were considered exploratory, with no adjustment for multiple testing. Accordingly, the nominal statistical significance should not be interpreted as evidence of nutritional recovery.

Table 4. Distribution of hemoglobin and nutritional status categories before and after the intervention

Variable and category	Baseline, n (%)	Follow-up, n (%)
Hemoglobin		
<12.0 g/dL	45 (100.0)	18 (40.0)
≥12.0 g/dL	0 (0.0)	27 (60.0)
Nutritional status based on BMI-for-age		
Severe thinness	0 (0.0)	0 (0.0)
Thinness	9 (20.0)	9 (20.0)
Normal weight	30 (66.7)	30 (66.7)
Overweight	4 (8.9)	4 (8.9)
Obesity	2 (4.4)	2 (4.4)

The aggregate distribution of nutritional status categories was identical at baseline and follow-up. Most participants were classified as having normal weight (n = 30; 66.7%), followed by thinness (n = 9; 20.0%), overweight (n = 4; 8.9%), and obesity (n = 2; 4.4%). No participants were classified as having severe thinness at either assessment. Identical category counts were not interpreted as evidence that no individual-level category transitions had occurred.

DISCUSSION

This study showed an increase in hemoglobin levels among participants who met the per-protocol criteria, whereas anthropometric changes were very small. Among the 45 participants analyzed, mean hemoglobin increased by 0.544 g/dL (95% CI: 0.457–0.632; $p < 0.001$), and 27 participants (60.0%) achieved hemoglobin concentrations ≥12.0 g/dL at follow-up. Reaching this threshold indicates that these participants no longer met the study's hemoglobin-based criterion for anemia at that assessment. However, it does not establish correction of iron deficiency, replenishment of iron stores, or resolution of the underlying cause of anemia. Sustained improvement was also not assessed beyond day. Meanwhile, increases in body weight, BMI, and BMI-for-age z-score were not accompanied by changes in the aggregate distribution of nutritional status categories. These findings illustrate differing patterns of hematological and anthropometric change during the observation period. The hemoglobin effect size of 1.865 represents the magnitude of the change relative to the variability of within-participant differences, rather than superiority over a control group. Thus, the analysis fulfilled its objective of describing changes in both outcome domains, but it did not establish the clinical effectiveness of the smoothie.

The direction of the hemoglobin change was consistent with several previous studies, although the intervention contexts differed. Tirtawati et al. [15] reported an increase in hemoglobin among adolescent girls from 10.71 to 11.03 g/dL after 15 days of moringa tea consumption and to 11.63 g/dL after 30 days. The initial increase of 0.32 g/dL was smaller than the change observed in the present analysis; however, this difference does not demonstrate the superiority of the smoothie. Li et al. [16] reported hemoglobin increases of 2.00 g/dL with oral iron plus vitamin C and 1.84 g/dL with oral iron alone after two weeks, with both regimens meeting the study's equivalence criteria. Meanwhile, Tahit et al. [17] showed that the effect of vitamin C on iron absorption from a complete diet was smaller than that observed in single-meal studies. Together, these studies provide context for interpreting the potential contributions of moringa and vitamin C without assuming that their combination necessarily confers additional benefits. They do not verify the nutrient delivery, absorption, or mechanism of action of the formulation used in this study.

Similarities with the study by Tirtawati et al. [15] include the adolescent female population, the use of moringa, and the single-group pretest–posttest design. Differences include formulation, ingredient quantity, consumption frequency, and intervention duration. Their study used a moringa infusion twice daily for 30 days, whereas the intervention modeled in the present analysis consisted of fresh moringa leaves combined with mango once daily for 14 days. Differences in processing and composition mean that ingredient quantities cannot be treated as equivalent doses of bioavailable iron. The study by Li et al. [16] involved randomization, a comparison group, and iron therapy in adults with iron deficiency

anemia, resulting in different clinical characteristics and greater inferential strength. Cook and Reddy assessed iron absorption directly rather than changes in hemoglobin or anthropometric measures. Consequently, differences in populations, baseline iron status, formulations, and outcomes limit comparisons of the magnitude of change across studies as a measure of relative effectiveness.

Iron availability and hemoglobin synthesis provide a plausible biological context rather than a demonstrated explanation for the observed changes [18]. Vitamin C may help maintain non-heme iron in a more readily absorbable form, although its effect depends on the overall composition of the diet, as described by Cook and Reddy [19]. Silitonga et al. [20] demonstrated that hepcidin regulates iron availability through its interaction with ferroportin. However, neither enhanced iron absorption nor changes in this regulatory pathway were demonstrated in the present study. Ferritin, transferrin saturation, hepcidin, and inflammatory markers were not measured, and the smoothie's nutrient content was not quantified. Consequently, the hemoglobin increase cannot be attributed specifically to improved iron availability, vitamin C activity, or another nutrient-mediated mechanism. These remain hypotheses requiring direct investigation [21].

Adherence and participant characteristics also warrant consideration when interpreting the findings. Mean adherence of 90.97% indicated high smoothie consumption within the analytical sample, but this value was influenced by restricting the analysis to participants with adherence of at least 80%. Accordingly, adherence in this group does not represent that of all intervention recipients. The value describes only the 45 adherent participants with complete paired measurements and cannot be interpreted as the overall adherence rate among the 50 participants who received the intervention. Excluding participants with lower adherence or missing follow-up may also bias estimates of outcome changes. The smoothie formulation may facilitate moringa consumption, but palatability was not assessed and therefore cannot be established as an explanation for adherence [22]. At follow-up, 40.0% of participants still had hemoglobin concentrations below the threshold. Differences in anemia etiology, iron stores, blood loss, and intervention adequacy are possible explanations that were not tested [23]. Furthermore, increases of 0.113 kg in body weight and 0.047 kg/m² in BMI were too small to demonstrate meaningful nutritional improvement. The weight difference corresponds to approximately 113 g over 14 days, and the BMI-for-age z-score increased by only 0.0174. Variations in hydration, gastrointestinal contents, and measurement may also contribute to these small changes. Without evidence of changes in body composition or sustained growth, these findings should not be interpreted as restoration of body tissue or nutritional recovery.

Associations among hemoglobin, nutritional status, dietary intake, and adherence were not examined using correlation analyses. The findings therefore do not demonstrate that participants with larger increases in BMI also experienced larger increases in hemoglobin, or that adherence was statistically associated with hemoglobin change. Biologically, these outcomes may share some

determinants, but BMI is not an indicator of iron stores. Impaired iron availability can occur in individuals with either normal or elevated BMI. Although the inflammation–hepcidin pathway offers a possible explanation for differences between hematological and anthropometric outcomes, this pathway was not assessed in the participants [24]. Thus, increased hemoglobin alongside an unchanged aggregate distribution of BMI-for-age categories does not represent a contradiction between outcomes [25]. Moreover, identical aggregate distributions do not establish the absence of individual-level category transitions without examination of paired categorical data.

The implications of this study for school health services are limited to hypothesis generation and the development of further studies integrating anemia screening, dietary monitoring, and nutritional assessment. These empirical findings describe changes in an actual intervention cohort, but the uncontrolled design does not justify recommending the smoothie as an established treatment or as a substitute for indicated therapy. Limitations include the uncontrolled design, purposive sampling, a single setting, short follow-up, and restriction of the analysis to adherent participants. Selection based on low baseline hemoglobin also leaves open the possibility of regression to the mean. Standardizing equipment and assessment timing may reduce some measurement variability but does not eliminate the influence of blood loss during follow-up or other confounding factors. Two dietary recalls do not capture overall intake throughout the intervention, while the absence of ferritin and inflammatory markers limits interpretation of anemia etiology. Descriptive dietary comparisons also cannot exclude changes in background intake as an explanation for hemoglobin changes. Anthropometric findings require caution because the analyses were exploratory and were not adjusted for multiple testing. A safety summary covering all intervention recipients was not available in the reported results; consequently, intervention safety, including long-term safety, could not be determined.

CONCLUSION

The analysis showed increased hemoglobin levels among participants who met the adherence criteria following the 14-day moringa leaf–mango smoothie intervention. Although changes in body weight, BMI, and BMI-for-age z-score were statistically significant, their magnitudes were very small and did not demonstrate meaningful nutritional improvement. The aggregate distribution of nutritional status categories remained unchanged. These findings do not establish clinical effectiveness or causality and are insufficient to support routine implementation in healthcare practice.

Further research should include a comparison group and a longer follow-up period. Assessments of iron status, inflammatory markers, repeated dietary intake, and the smoothie's nutrient content are needed to clarify the mechanisms underlying hemoglobin changes. Analyses encompassing all participants, as appropriate to the study design, and comprehensive safety

monitoring should be planned from the outset. The smoothie should not be positioned as a substitute for necessary anemia assessment and treatment.

BIBLIOGRAPHY

1. Tesfaye A, Tamiru D, Belachew T. Effect of nutrition counseling on nutritional status and gestational weight gain of pregnant adolescents in West Arsi, Central Ethiopia: a cluster randomized controlled trial. Sci Rep. 2024;14(1):5070.
2. Tesfaye A, Wondimagegne YA, Tamiru D, Belachew T. Exploring dietary perception, beliefs and practices among pregnant adolescents, their husbands and healthcare providers in West Arsi, Central Ethiopia: a phenomenological study. BMJ Open. 2023;13(12):e077488.
3. Tampy ST. The associations between anemia, stunting, low birthweight, and cognitive ability in indonesian children: an analysis from indonesian family life survey. J Matern Child Heal. 2020;5(4):402–12.
4. Smith C, Teng F, Branch E, Chu S, Joseph KS. Maternal and perinatal morbidity and mortality associated with anemia in pregnancy. Obstet Gynecol. 2019;134(6):1234.
5. Ganz T, Nemeth E. Hepcidin and iron homeostasis. Biochim Biophys Acta. 2012 Sep;1823(9):1434–43.
6. Camaschella C. Iron-deficiency anemia. N Engl J Med. 2015;372(19):1832–43.
7. Screening, diagnosis, evaluation, and staging of obesity in adults: standards of care in overweight and obesity—2026. Diabetes Obes Cardiometabolic CARE. 2026;1(4):536–71.
8. Weiss G, Goodnough LT. Anemia of chronic disease. N Engl J Med. 2005;352(10):1011–23.
9. Pasricha SR, Tye-Din J, Muckenthaler MU, Swinkels DW. Iron deficiency. Lancet (London, England). 2021 Jan;397(10270):233–48.
10. Stohs SJ, Hartman MJ. Review of the safety and efficacy of Moringa oleifera. Phyther Res. 2015;29(6):796–804.
11. Saini RK, Sivanesan I, Keum YS. Phytochemicals of Moringa oleifera: a review of their nutritional, therapeutic and industrial significance. 3 Biotech. 2016;6(2):203.
12. World Health Organization. Guideline on haemoglobin cutoffs to define anaemia in individuals and populations [Internet]. 5 March 2024. Available from: https://www.who.int/publications/i/item/9789240088542?utm_source=chatgpt.com
13. Kementerian Kesehatan Indonesia. Peraturan Menteri Kesehatan Nomor 2 Tahun 2020 tentang Standar Antropometri Anak [Internet]. 08 Jan 2020. Available from: https://jdih.kemkes.go.id/documents/peraturan-menteri-kesehatan-nomor-2-tahun-2020?utm_source=chatgpt.com
14. Kandinata Y, Jayani NIE, Budipramana K, Herawati F. Moringa oleifera L. Sebagai Suplemen

Untuk Anemia Defisiensi Besi: Systematic Review. JPSCR J Pharm Sci Clin Res. 2023;8(2):165–78.

15. Tirtawati GA, Kusmiyati K, Purwandari A, Donsu A, Korompis M, Wahyuni W, et al. Moringa oleifera Teabags Increase Hemoglobin in Adolescent Females. Open Access Maced J Med Sci [Internet]. 2021;9(A):393–6. Available from: https://oamjms.eu/index.php/mjms/article/view/6270
16. Li N, Zhao G, Wu W, Zhang M, Liu W, Chen Q, et al. The Efficacy and Safety of Vitamin C for Iron Supplementation in Adult Patients With Iron Deficiency Anemia: A Randomized Clinical Trial. JAMA Netw Open [Internet]. 2020;3(11):e2023644. Available from: https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2772395
17. Tahir E, Ayotte P, Little M, Bélanger RE, Lucas M, Mergler D, et al. Anemia, iron status, and associated protective and risk factors among children and adolescents aged 3 to 19 years old from four First Nations communities in Quebec. Can J Public Heal. 2020;111(5):682–93.
18. Skolmowska D, Głąbska D. Effectiveness of dietary intervention with iron and vitamin C administered separately in improving iron status in young women. Int J Environ Res Public Health. 2022;19(19):11877.
19. Cook JD, Reddy MB. Effect of ascorbic acid intake on nonheme-iron absorption from a complete diet. Am J Clin Nutr [Internet]. 2001;73(1):93–8. Available from: https://pubmed.ncbi.nlm.nih.gov/11124756/
20. Silitonga HTH, Salim LA, Nurmala I, Wartiningsih M. Compliance of iron supplementation and determinants among adolescent girls: A systematic review. Iran J Public Health. 2023;52(1):37.
21. Bhattacharya A, Tiwari P, Sahu PK, Kumar S. A review of the phytochemical and pharmacological characteristics of Moringa oleifera. J Pharm Bioallied Sci. 2018;10(4):181.
22. Deng J, Ramelli L, Li PY, Eshaghpour A, Li A, Schuenemann G, et al. Efficacy of vitamin C with Fe supplementation in patients with iron deficiency anemia: a systematic review and meta-analysis. Blood Vessel Thromb Hemost. 2024;1(4):100023.
23. Silitonga HTH, Salim LA, Nurmala I. A systematic review of iron supplementation's effects on adolescent girls. J Gizi Indones (The Indones J Nutr. 2024;12(2):60–9.
24. Sun B, Tan B, Zhang P, Zhu L, Wei H, Huang T, et al. Iron deficiency anemia: a critical review on iron absorption, supplementation and its influence on gut microbiota. Food Funct. 2024;15(3):1144–57.
25. Handiso YH, Belachew T, Abuye C, Workicho A, Baye K. A community-based randomized controlled trial providing weekly iron-folic acid supplementation increased serum-ferritin,-folate and hemoglobin concentration of adolescent girls in southern Ethiopia. Sci Rep. 2021;11(1):9646.