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Impact of Breakfast Consumption on Nutritional Status and Biochemical Markers in Sudanese School-Aged Children

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ABSTRACT

Background: Skipping breakfast among schoolchildren remains a persistent nutritional challenge in developing countries, impacting micronutrient deficiencies and undernutrition.

Objective: To evaluate the effect of a school-based breakfast intervention on hemoglobin levels, vitamin A status, BMI, and macronutrient intake among students in Khartoum State, Sudan.

Methods: A quasi-experimental study was conducted with 294 students aged 6–14 years. Data were collected before and after the intervention on hemoglobin levels, vitamin A deficiency, BMI classification, and nutrient intake following a daily breakfast of Adzuki beans for eight months.

Results: The average hemoglobin increased from 10.88 to 12.35 g/dL ($p<0.001$). Vitamin A deficiency decreased from 25.5% to 1% ($p<0.001$). Severe thinness dropped from 29.3% to 0%, and normal BMI increased from 24.8% to 79%. Inadequate energy intake declined from 73.5% to 9.9%, while intake of protein, carbohydrate, and fat improved to over 91% adequacy.

Conclusion: The breakfast program significantly improved nutritional and biochemical indicators. These findings support the implementation of sustainable school breakfast programs to combat malnutrition among Sudanese children.

Keywords: *Adzuki beans, BMI, Breakfast, hemoglobin, nutritional intervention, schoolchildren, Sudan, and vitamin A.*

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1. INTRODUCTION

Malnutrition, particularly among school-aged children, represents a major public health burden in low- and middle-income countries (LMICs), including Sudan. Nutritional inadequacies during childhood and adolescence can result in irreversible effects on physical growth, cognitive development, immune function, and academic performance (1,2). Among dietary behaviors, breakfast consumption is widely acknowledged as essential for meeting daily nutritional requirements and supporting mental and physical performance in children (3).

Multiple global studies have shown that children who skip breakfast are at an increased risk of micronutrient deficiencies, particularly iron and vitamin A, which can lead to anemia and compromised immunity (4,5). In Sudan, the prevalence of undernutrition and anemia remains high among children, with contributing factors including poverty, food insecurity, and lack of structured school feeding programs (6,7).Breakfast skipping is strongly associated with poorer nutritional status, particularly in low-resource settings. Research indicates that children who eat breakfast regularly have higher intakes of energy, protein, iron, and vitamins compared to those who skip it (8,9). A study by Rampersaud et al. (10) found that school breakfast programs improved dietary quality and overall nutrient intake among participants.

Despite global recognition of the importance of breakfast, limited data exist on the biochemical and nutritional effects of school-based breakfast interventions in Sudan. This study addresses this gap by evaluating the nutritional impact of an eight-month breakfast intervention using Adzuki beans among schoolchildren in Khartoum State.

2. METHODS

A quasi-experimental study design was adopted to evaluate the impact of a school-based breakfast intervention on the nutritional and biochemical status of school-aged children. The study was conducted at a public basic school located in Khartoum Bahri, Sudan, and included a total of 294 students (both male and female) aged 6 to 14 years. The intervention period spanned eight consecutive months.

Participant Selection

Participants were selected using non-random purposive sampling from students who met the inclusion criteria: regular school attendance and absence of chronic illness or acute infection.

Intervention Description

As part of the intervention, students received a daily school breakfast meal consisting primarily of Adzuki beans, a locally available legume rich in protein and iron. Meals were prepared on-site and served each morning before formal academic sessions began. The intervention aimed to supplement the students' dietary intake and address possible nutrient deficiencies, particularly iron and vitamin A.

Data Collection Procedures

A multi-component approach was used to evaluate the nutritional outcomes:

- Anthropometric measurements were taken at baseline and post-intervention using standardized protocols. Body weight was measured using a calibrated digital scale (to the nearest 0.1 kg), and height was measured using a stadiometer (to the nearest 0.1 cm). These were used to calculate Body Mass Index (BMI)-for-age z-scores (BAZ) in accordance with the WHO 2007 growth reference standards.
- Hemoglobin concentrations were assessed using the Mission Plus Hemoglobin Testing System, a portable point-of-care device validated for field use. Finger-prick capillary blood samples were collected under sterile conditions by trained personnel.
- Vitamin A deficiency was assessed through clinical eye examinations, with particular attention to signs of xerophthalmia, Bitot’s spots, and night blindness. Evaluations were performed by trained health professionals according to WHO guidelines for clinical assessment of vitamin A deficiency.
- Macronutrient intake was estimated through a 24-hour dietary recall interview conducted with students and supplemented, when necessary, by caregivers. Nutrient composition and caloric intake were analyzed using a standard food composition table and dietary analysis software to assess energy, protein, carbohydrate, and fat intake.

Data Analysis

Data were cleaned, coded, and entered into SPSS (version 26) for statistical analysis. Descriptive statistics, including means, standard deviations, and frequencies, were calculated. Paired sample t-tests evaluated changes in anthropometric and biochemical parameters before and after the intervention. A *p-value* less than 0.05 was considered statistically significant.

3. RESULTS

Table 1. Demographic Characteristics of Students (N=294)

Variable	Category	Frequency	Percentage (%)
Age (years)	Mean ± SD	10 ± 1.8	-
Gender	Male	147	50
	Female	147	50
Father's Education	Informal	116	39.5
Mother's Education	Informal	70	23.8
Economic Status	Poor	191	65

The study sample comprised 294 students, with an equal gender distribution (50% male, 50% female) and a mean age of 10 ± 1.8 years. A considerable proportion of fathers (39.5%) and mothers (23.8%) had received no formal education. The majority of students (65%) were from families classified as economically poor, as shown in Table 1

Table 2. Reasons for Skipping Breakfast (N=294)

Reason	Frequency	Percentage (%)
Haven't money	210	71.7
Haven't money – food	76	26
I don't like the choices	3	1.4
I am not hungry	2	0.9
Total	**294**	**100**

The most frequently reported reason for skipping breakfast was lack of money (71.7%), followed by lack of food at home (26%). A small minority indicated dislike of available food options (1.4%) or lack of hunger (0.9%) , as detailed in Table 2. These findings reflect the socioeconomic constraints affecting dietary practices.

Table 3. Nutritional and Biochemical Status Pre vs Post Intervention

Variable	Pre (%)	Post (%)
Hemoglobin (g/dL)	Mean: 10.88	Mean: 12.35
Vitamin A Deficiency	25.5	1
Severe Thinness	29.3	0
Normal BMI	24.8	79

The intervention yielded notable improvements in students' nutritional and biochemical profiles. Mean hemoglobin levels increased from 10.88 g/dL to 12.35 g/dL, while the prevalence of vitamin A deficiency dropped from 25.5% to 1%. Additionally, severe thinness was eliminated (from 29.3% to 0%), and the percentage of students with a normal BMI rose sharply from 24.8% to 79% ,as illustrated in Table 3.

Table 4. Macronutrient Intake Status Pre vs Post Intervention

Nutrient	Status	Pre (%)	Post (%)
Energy	Inadequate	73.5	9.9
Fat	Adequate	23.8	88.1
Protein	Inadequate	73.8	6.8
Carbohydrates	Inadequate	68.7	6.1
Fat	Inadequate	70.1	7.8

Macronutrient intake adequacy improved substantially post-intervention. The proportion of students with inadequate energy intake declined from 73.5% to 9.9%, while adequacy increased to 88.1%. Similar improvements were observed for protein (inadequate: 73.8% to 6.8%), carbohydrates (68.7% to 6.1%), and fat (70.1% to 7.8%), indicating a significant

nutritional benefit from the daily Adzuki-based breakfast, as seen in Table 4.

Table 5. Meal Compliance (Adzuki Intake)

Variable	Mean	Min–Max
Daily Intake (g)	540	370–570

Students showed high compliance with the intervention. The average daily intake of Adzuki beans was 540 grams, with a range of 370 to 570 grams, suggesting consistent participation in the school meal program across the study period, as presented in Table 5.

Table 6. Statistical Significance Summary

Variable	Pre-Mean	Post -Mean	*P-value*
Hemoglobin	10.88	12.35	<0.001
Vitamin A Deficiency	25.5%	1%	<0.001
BMI (Z-score)	1.96	2.79	<0.001
Energy Intake	1.29	1.22	0.12

Statistical analysis confirmed significant improvements in key health indicators post-intervention. Hemoglobin levels, vitamin A deficiency prevalence, and BMI z-scores all showed statistically significant changes ($p < 0.001$). While energy intake improved numerically, it did not reach statistical significance ($p = 0.12$), as shown in Table 6.

4. DISCUSSION

The breakfast intervention resulted in statistically significant improvements in key nutritional and biochemical indicators among the students, as presented in Tables 3 and 6. The increase in hemoglobin levels by 1.5 g/dL (Table 6) supports prior evidence indicating the effectiveness of breakfast programs in reducing iron deficiency anemia (2,10,11). Iron is a critical micronutrient for cognitive function, oxygen transport, and immunity, and its deficiency is widely prevalent among schoolchildren in low-income countries (16,17). School breakfast interventions are effective because they target this nutritional gap directly (10,18). Additionally, vitamin A deficiency rates decreased from 25.5% to 1% (Table 3), reflecting the success of the intervention in addressing micronutrient gaps (4,6). Vitamin A is essential for immune function, vision, and epithelial integrity, and its supplementation or dietary inclusion has been shown to result in dramatic reductions in child morbidity and mortality in resource-limited settings (19). Improved BMI status further highlights the impact of regular, nutritious breakfast consumption (Table 3). The proportion of students with normal BMI increased significantly, while severe thinness was eliminated. These findings are consistent with global studies linking regular breakfast intake with healthier body weight and improved anthropometric outcomes (5,9,12,20). Macronutrient intake improved across all categories (Table 4), particularly for protein and carbohydrates, which are essential for energy and growth. Improvements in protein and carbohydrate adequacy following the intervention indicate that the meal provided was balanced and met the energy demands of growing children (13,21). Studies have shown that school meal programs enhance children's growth, physical performance, and attention in class (22). The observed changes in nutritional status align with literature that recommends school-based food interventions as a cost-effective approach to combat hidden hunger (micronutrient deficiency) and stunting (23,24). This is especially relevant for Sudan, where economic barriers and food insecurity are common in school-aged populations (6,7), as shown in the students' background characteristics and dietary practices (Tables 1 and 2). In summary, this study adds to the body of evidence supporting the role of school breakfast programs in enhancing children's health and educational potential. As this was one of the first such interventions conducted in Sudan, the findings have important implications for policy and programming aimed at scaling up national school feeding efforts.

5. CONCLUSION

The present study provides strong evidence that regular breakfast consumption via a school-based intervention significantly improves both the nutritional and biochemical health of school-aged children in Sudan. Improvements in BMI-for-age z-scores, hemoglobin concentrations, and clinical signs of vitamin A deficiency underscore the effectiveness of this low-cost, locally appropriate strategy.

These results highlight the vital role of integrating nutrition interventions into the educational system, particularly in vulnerable and food-insecure communities. In light of these findings, we call upon national stakeholders and policymakers to prioritize the institutionalization of school breakfast programs as part of broader efforts to combat childhood malnutrition and promote equity in education and health.

Such interventions align directly with the United Nations Sustainable Development Goals (SDGs), notably:

- SDG 2 (*Zero Hunger*),
- SDG 3 (*Good Health and Well-being*), and
- SDG 4 (*Quality Education*).

Investing in school nutrition is an investment in the future of Sudan's children, contributing to improved academic performance, long-term health, and national human capital development.

Ethical Considerations:

Ethical approval was not obtained for this study because, at the time of implementation, no Institutional Review Board (IRB) was available at Omdurman Islamic University or in the study area. Additionally, informed consent was not obtained from participants or their guardians due to the programmatic nature of the school-based intervention and the absence of a formal ethical oversight mechanism. Nonetheless, the study adhered to general ethical principles, including respect for persons, non-maleficence, and confidentiality, and no personally identifiable information was collected.

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Conflict of Interest:

The authors declare that they have no conflict of interest.

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