

Beyond BMI and Hemoglobin Assessing Nutrition and Physical Development in Children from Low Income Communities in India

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Abstract

Background

Malnutrition and anemia continue to be major challenges for children growing up in disadvantaged environments. Globally, children from lower socioeconomic backgrounds face multiple health disadvantages, such as poor nutrition, reduced physical activity and increased vulnerability to illness. Malnutrition not only threatens immediate growth and wellbeing, but also strengthens the cycle of poverty by affecting school performance, raising healthcare costs, and limiting future productivity. In this study, we examined body mass index (BMI), hemoglobin (Hb) levels, and grip strength among children aged 5 - 14 years attending a street based Gurukul in Meerut, India.

Methodology

A community-based cross-sectional study was conducted among 84 children aged 5-14 years. A multi-stage sampling method was employed and physiological measurements like Hemoglobin, Melatonin and anthropometric measurements like BMI, Waist-Hip Ratio, and Grip Strength was taken and analyzed.

Results

The results showed that across all ages, grip strength was very low (0 - 1), pointing to inadequate muscle development. BMI values were consistently below normal reference ranges for both boys and girls, while Hb concentrations also fell below expected levels. Girls in particular showed lower Hb compared to boys, indicating a higher burden of anemia.

Conclusion

This study highlights the serious challenges facing child health in a disadvantaged community. Limited dietary variety, very low muscular strength, underweight status, and widespread anemia together reflect chronic undernutrition with significant implications for growth and development. While these patterns align with national and global data, our study also adds new insights, particularly through functional measures like grip strength. Addressing these issues requires coordinated efforts that combine nutritional support, investment in education, and poverty reduction. Without such efforts, cycles of malnutrition and disadvantage are likely to persist, affecting both individual potential and broader societal well-being.

Keywords: Hemoglobin (HB), Body Mass Index (BMI), Grip Strength, Melatonin, Waist Hip Ratio.

1. Introduction

Childhood malnutrition is not only a health issue but also a social challenge that affects millions of families worldwide. Recent global estimates suggest that 45 million children under the age of five suffer from undernutrition, while 149 million are stunted. These numbers represent more than statistics, they represent children whose growth, development, and future potential are compromised. Malnutrition in early life does not just result in smaller bodies; it undermines cognitive development, weakens immunity, and locks families into cycles of poverty and poor

health outcomes [1,2].

The burden of malnutrition is greatest in low- and middle-income countries, where families face daily struggles to secure nutritious food. Children from disadvantaged households are more likely to rely on inexpensive and less nutrient rich diets, which often fail to meet their developmental needs (Victoria et al., 2008). Socioeconomic status (SES), shaped by parental education, household income, and type of occupation, has long been recognized as a powerful determinant of children's health. Lower SES

is consistently linked to poor nutrition, anemia, and other adverse outcomes, and these differences can be seen as early as in childhood. In India, malnutrition remains one of the most urgent public health issues. The National Family Health Survey (NFHS-5, 2019-21) reports that more than one-third of children under five are stunted and nearly one-third are underweight, while two-third of children between 6 and 59 months are anemic. These figures highlight a dual burden of insufficient macronutrient intake and micronutrient deficiencies. Iron deficiency anemia in particular has been identified as a major contributor to childhood morbidity and impaired development. While measurements like body mass index (BMI) and hemoglobin (Hb) give us a quick view of a child's nutritional health, looking at how their body functions, such as muscle strength, tells us just as much about their wellbeing. Grip strength, a simple yet powerful measure of muscular development, has emerged as a reliable marker of overall health in both children and adults. Research shows that low grip strength in childhood is linked not only to poor nutrition but also to long term health risks, including chronic disease in later life. Together, BMI, Hb, and grip strength provide a multidimensional view of children's growth and wellbeing [3-8].

Children living in poverty often grow up facing multiple disadvantages simultaneously, poor diet, limited access to healthcare, reduced physical activity, and greater psychosocial stress. Studies have shown that children from lower SES families tend to report more psychosomatic symptoms, have a lower quality of life, and are more likely to experience critical life events compared to peers from higher SES backgrounds. These combined challenges do not just impact children's health today; they can influence their growth, development, and wellbeing well into their teenage years and adulthood. Even with plenty of data worldwide on child nutrition, we know little about children growing up in India's street based or informal schools, some of the most at risk and vulnerable populations. Understanding their nutrition is critical to developing meaningful and lasting interventions [9].

2. Methodology

2.1. Study Design

A community-based cross-sectional study was used to examine body mass index (BMI), hemoglobin (Hb) levels, and grip strength, melatonin level, waist-hip ratio among children aged 5 - 14 years attending a street based Gurukul in Meerut, India.

2.2. Study Setting

This study was organized in street gurukul in Meerut.

2.3. Study Population and Sample

In study 84 unprivileged children's including 44 males

and 40 females were recruited for this study from a Street Gurukul in Meerut.

2.4. Sampling Method

Street Gurukul in different area of Meerut were approached.

2.5. Data Collection

Each student name, age, gender, food type, wake up, sleep time were noted separately in a questionnaire. Firstly, we measure waist, hips and height with inch tapes in centimeters. Then we measure weight with weighing machine which calculate weight in kilograms and we use a hand dynamometer to measure grip strength. Then we extract blood from a vein by pricking the volunteer finger and then the sample put in the HemoCue Hb 301 and measure Hb value in blood. And then we tell the children's to collect the first urine after they wake up in morning and collect urine in mid of the flow. Next morning we collect the urine vials from the volunteers and put them in -20 till the ELISA is performed.

2.6. Data Analysis

MS Excel used to analyze the data. Statistical analysis was performed using the Prism (version 6).

2.7. Ethical Considerations

The study was approved by the Human Ethical Committee (HEC) at Chaudhary Charan Singh University, Meerut as per guidelines of Indian Council of Medical Research, India. Inclusion criteria were (1.) study in the Street Gurukul (2.) were aged between 5-14 years (3.) having any disease or disability. Students were not consented to enter the study if they were suffering from any disease in the past few months. A written informed consent was obtained from the Gurukul.

2.8. Data Analysis

Data collected from all the children's were presented in tabular form using Microsoft Excel. Prism (version 6) was used to calculate significance value and to make figures.

3. Results

In the study, 84 participant's data were recorded successfully from which 16 do not give all the information so they removed from the study. Respondents were grouped according to their gender (Male/Female), aged (6-14 years) and food type (vegetarian / non-vegetarian).

3.1. Anthropometric Measurements

like Body Mass Index (BMI), Waist-Hip Ratio, and Grip Strength.

3.1.1. Body Mass Index (BMI)

Figure 1 shows BMI value in different age groups in which highest BMI observe in aged 12 and lowest in 5 and so on with no significance value $p=0.0974$.

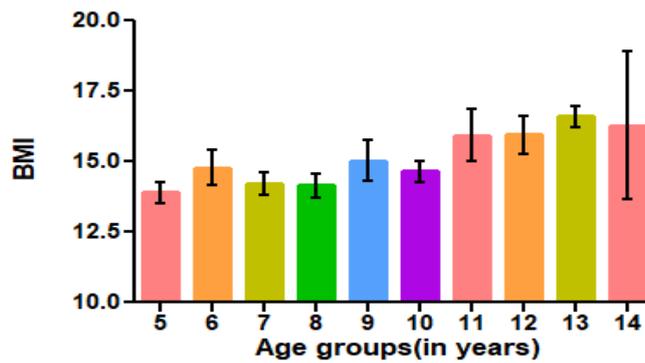


Figure 1: Value of BMI in Different Age Groups

3.1.2. Waist Hip Ratio

Figure15 shows Waist-Hip Ratio value in different age groups in which highest Waist-Hip ratio observe in aged 7 and lowest in 11.

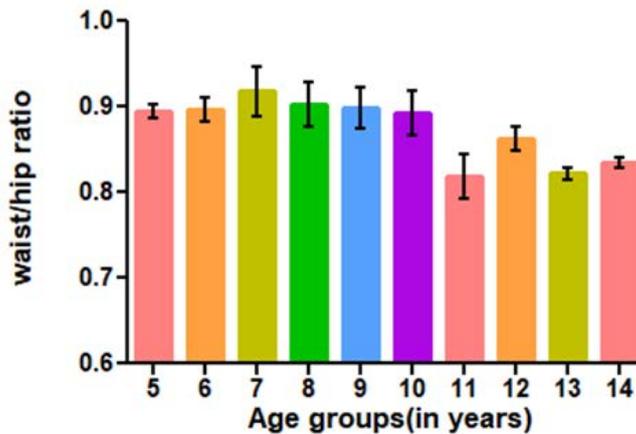


Figure 2: Value of Waist-Hip Ratio in Different Age Groups

3.1.3. Grip Strength

Figure13 shows grip strength in different age groups we observe least value that is zero in age group 5, 6 and 7 and

highest value that is 14.6 in age group 13 and so on with significance value $p < 0.0001$.

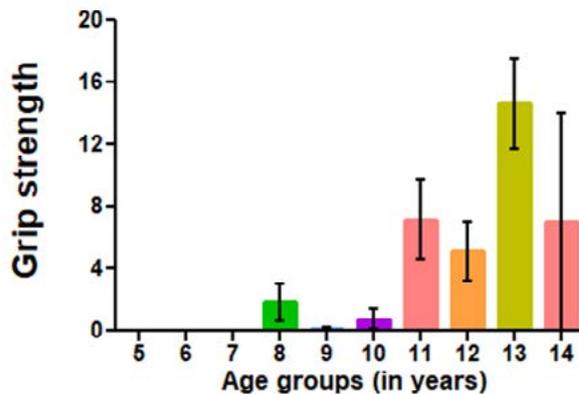


Figure 3: Value of Grip Strength in Different Age Groups

3.2. Physiological Measurements

3.2.1. Hemoglobin

Figure 3(a.) is showing comparison between Hb value in

male and female participants which shows that male has more Hb in their blood than females with significance value $p < 0.0001$.

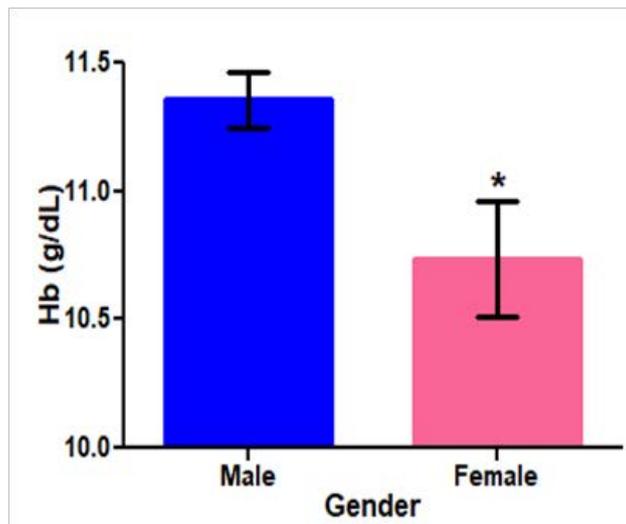


Figure 3 A: A Comparison Between Male and Female HB Levels

Figure 3(b.) show comparison between Hb value in vegetarian and non-vegetarian in which it is clear that non-vegetarian has more Hb level in their blood than vegetarian but it has no significance value $p=0.8520$.

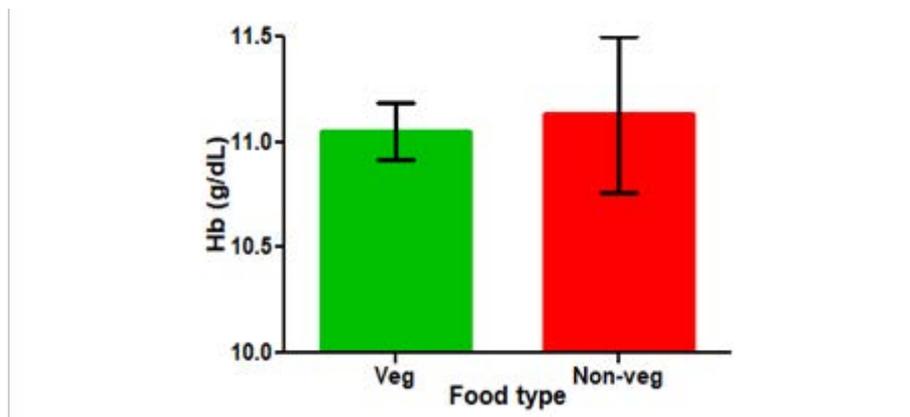


Figure 3 B: Comparison Between HB Levels in Vegetarian and Non-Vegetarian

Figure 3 © shows that in males aged 8 has highest Hb and females of aged 14 has lowest value of Hb level in blood and so on with no significance value $p=0.3254$ and it also shows than more children's are anemic.

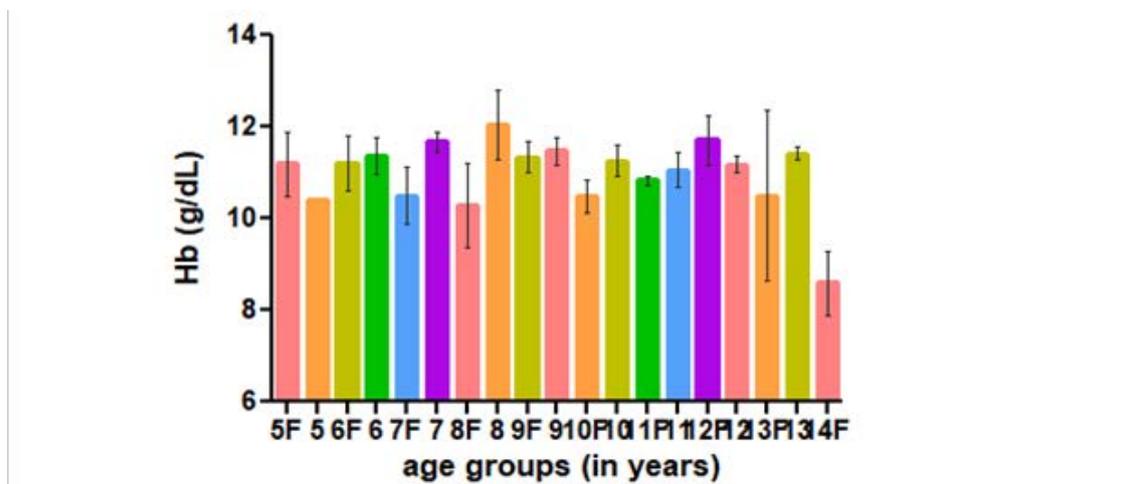


Figure 3 C: Different Level of HB In Different Age in Males and Females

Figure 3 (d) shows females are more anaemic than males and son on with significance value $p<0.0001$.

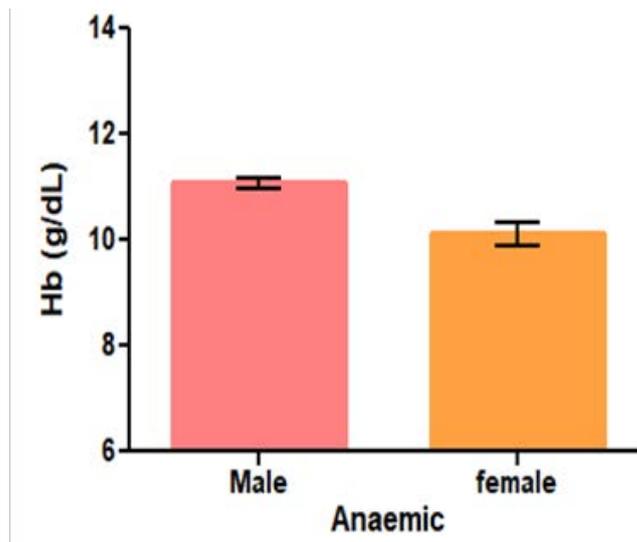


Figure: 3D: Comparison Between HB Level in Male and Female

3.2.2. Melatonin

Figure 4(a) shows difference between Melatonin level in male and female with no significance value $p=0.1370$.

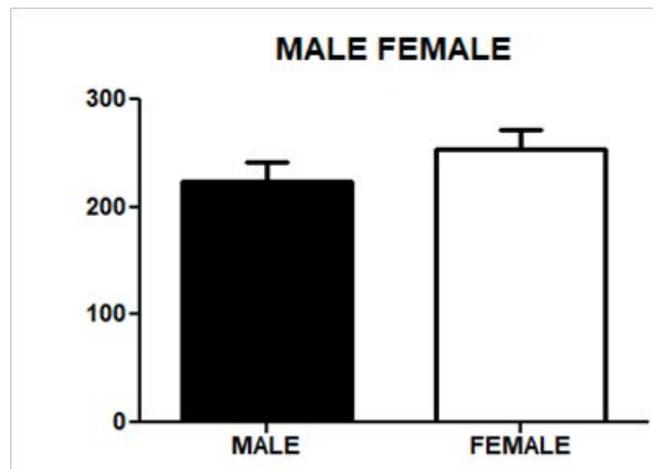


Figure 4A: Comparison Between Level Of Melatonin Level In Male And Female

Figure 4(b) shows Melatonin level in all age groups in which highest value of melatonin found in children’s with age group 5 and lowest value in age 14 and so on with no significance difference with value $p= 0.2181$.

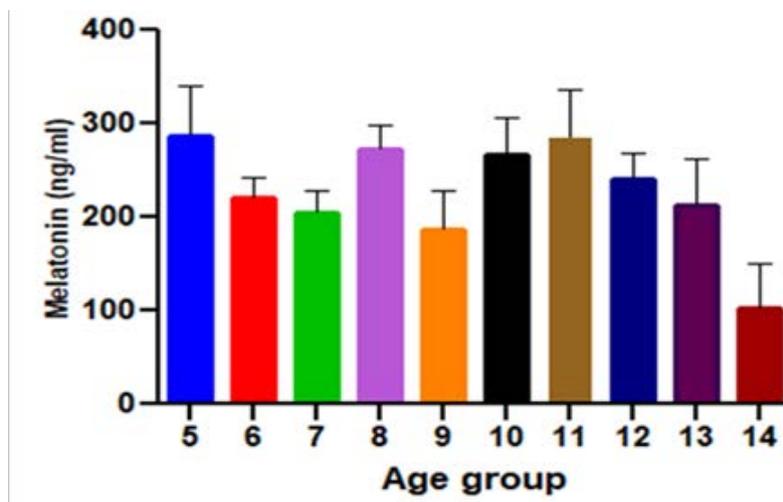


Figure 4B: Compare Difference in Level of Melatonin in Male and Females

Figure 4© shows Agewise melatonin level in male and females which shows female has highest level of melatonin at age 10 and males in age 11 and lowest value of melatonin at age 14 in both.. and it clearly shown that female melatonin level is higher than males.

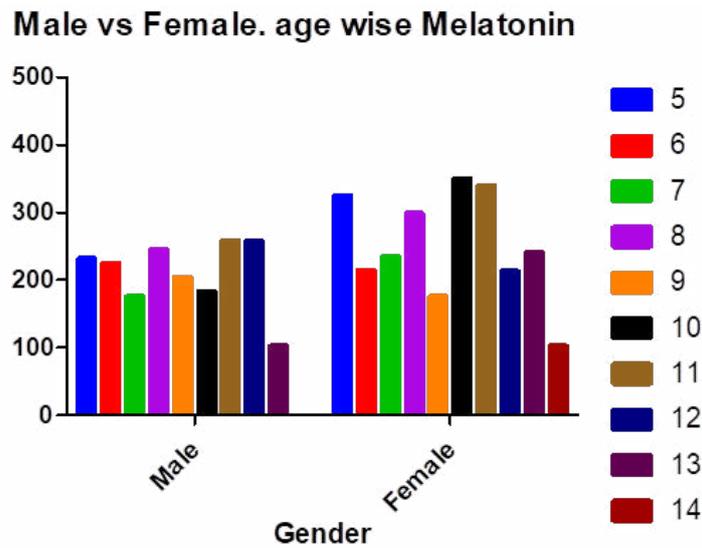


Figure 4C: Comparison Of Different Level Of Melatonin In Different Age Groups Of Male And Female

Figure 4(d) shows the relationship between melatonin and BMI so it shows that BMI value 15 is common with most melatonin level ranges between 100-400 lies at this BMI and so on with is no significance difference with value of $p=0.8167$.

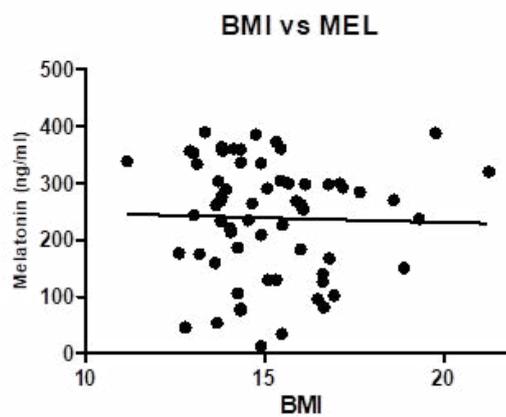


Figure 4D: Relationship Between Melatonin and BMI

Figure 4(e) shows relationship between Hb and Melatonin so it shows that mostly Hb ranges between 10-12 g/dL with most melatonin level ranges between 100-400 and so on with no significance difference with value of $p=0.9866$.

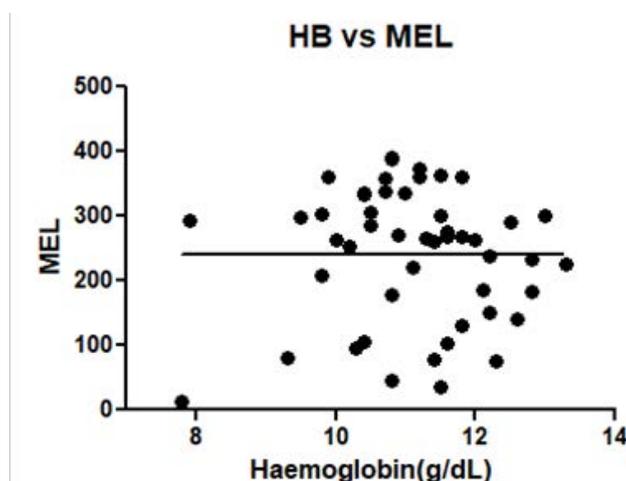


Figure 4E: Relationship Between HB And Melatonin

4. Discussion

Malnutrition remains one of the most pressing challenges in child health, particularly in populations living with socioeconomic disadvantage. The data presented here, drawn from children aged 5-14 years enrolled in an informal educational setting, highlight concerning patterns of poor nutritional health, low hemoglobin concentrations, and suboptimal BMI values. While these results are context specific, they strongly echo global evidence on the links between poverty, malnutrition, and developmental risk. In this discussion, we place our results within the existing scientific evidence, drawing comparisons with earlier studies, and reflecting on their broader implications for health, education, and policy [10].

4.1. Nutritional Vulnerabilities and Dietary Patterns

One of the most noticeable findings in our study was that most children ate very limited types of animal protein, mostly chicken legs and wings, foods that are cheaper and easier to find in local markets. While this makes them technically non-vegetarian, their diet lacks the variety and nutritional balance typical of a healthy omnivorous diet. Previous research in India has shown that families with lower incomes often focus on foods that fill the stomach but are low in nutrients (Meenakshi, 2016). This dietary pattern contributes to both undernutrition and micronutrient deficiencies, which we also observed in our study [11].

The link between socioeconomic status (SES) and diet quality is not unique to India. Studies from Europe and North America show that children from lower SES families tend to eat fewer fruits, vegetables, and protein rich foods, and more processed, calorie dense options (Hanson & Chen, 2007). Our findings reflect these global trends, highlighting how limited resources shape diets, while also pointing to local cultural and economic factors that influence what children eat [12].

4.2. Grip Strength and Muscular Fitness

Another important aspect of child health we looked at was grip strength, which was extremely low, ranging from 0 to 1 in nearly all children. Low grip strength is a well known sign of poor muscle fitness and has been linked to poorer overall health and a higher risk of metabolic problems later in life (Artero et al., 2014). In large European studies, adolescents with weak muscles also showed higher levels of inflammation and an increased risk of future cardiovascular issues. Ortega et al. (2008) similarly highlighted that muscular fitness in childhood is a key predictor of metabolic health in adulthood. The widespread weakness we observed likely reflects both undernutrition and limited opportunities for physical activity. Informal schools often lack playgrounds or sports facilities, and children from disadvantaged backgrounds are frequently involved in household chores or informal work instead of structured play. This combination may explain the very low grip strength, which could affect their long term physical capacity, productivity, and ability to stay healthy [13,14].

4.3. BMI And Hemoglobin: Comparing With Standards

When we compared BMI values in our group against WHO

child growth standards, many children were below the expected range for their age. For instance, boys aged 11-15 had average BMIs around 16.0, lower than the healthy range of 16.5-23.4. Hemoglobin levels were also consistently low across all groups, with girls showing particularly concerning values. These results reflect patterns seen in the National Family Health Survey (NFHS-5, 2019-21), which reported high rates of anemia among Indian children and adolescents, especially girls. The gender gap in hemoglobin aligns with previous evidence. Studies across South Asia show that adolescent girls are more vulnerable to iron deficiency anemia, due to both biological factors, like menstrual blood loss, and social factors, such as lower priority in household food distribution. Our findings reinforce the urgent need for targeted measures, including iron supplementation, fortified foods, and gender sensitive nutrition programs. Interestingly, the link between BMI and hemoglobin has been explored in other studies. While undernutrition often accompanies anemia, some research suggests that overweight or obesity can also raise anemia risk through inflammation related iron issues. In our cohort, however, low BMI and anemia appeared together, pointing to classic undernutrition rather than more complex metabolic mechanisms [15-18].

4.4. The Role of Socioeconomic Status

The impact of socioeconomic status on child health was clear throughout our study. Poor diet, low muscle strength, and anemia are not isolated problems, they reflect broader social and economic realities. Numerous studies show that children from low SES families experience poorer health overall, with higher rates of malnutrition, lower levels of physical activity, and more psychosomatic complaints. Findings from the LIFE Child Study in Germany further highlight how SES shapes a range of child health outcomes, including BMI, lipid levels, and hemoglobin. While the influence of SES sometimes lessens during adolescence as peers and schools become more important, in settings of extreme poverty or informal schooling, these protective effects are weaker, leaving children continuously at risk. Poverty does more than increase the risk of malnutrition, it fuels a vicious cycle of poor health, limited learning, and lower future productivity, which in turn reinforces poverty. The children in our cohort, attending informal schools, exemplify this cycle, poor nutrition impairs both health and learning, while restricted educational opportunities limit their chances of socioeconomic mobility [19-22].

4.5. Global Context: Comparing Local Findings with International Data

Globally, around 45 million children experience acute malnutrition each year while our study focused on a small and specific group, the patterns we observed reflect this wider global burden, especially in low- and middle-income countries (LMICs). The high rates of anemia and low BMI in our participants mirror findings from Sub Saharan Africa and South Asia, where food insecurity and limited healthcare access combine to threaten child health. The very low grip strength we observed adds an important new perspective. Most global reports focus on traditional measures like BMI, stunting, or wasting, but fewer examine muscular fitness in

resource limited settings. Our results suggest that including functional health indicators such as grip strength could offer deeper insights into the long-term developmental risks of malnutrition, complementing standard anthropometric assessments [23,24].

4.6. Biological Mechanisms and Developmental Implications

From a biological perspective, malnutrition in childhood and adolescence disrupts key periods of growth and brain development. Chronic undernutrition not only reduces lean body mass but also limits cognitive potential, affecting school performance and future earning capacity. Anemia worsens these effects by lowering oxygen delivery to tissues, further restricting both mental and physical performance. The very low grip strength we observed may reflect weaknesses in muscle mass as well as neuromuscular development, showing that malnutrition affects multiple biological systems. Without intervention, these deficits are likely to continue into adulthood, perpetuating cycles of disadvantage across generations [25].

4.7. Implications for Policy and Intervention

The findings of this study highlight the urgent need for action on multiple fronts. On the nutritional side, school based mid-day meal programs and fortified food initiatives have shown promise in addressing both calorie gaps and micronutrient deficiencies. At the community level, awareness campaigns aimed at parents and caregivers can help improve dietary habits even within limited resources. At the policy level, investment in formal education, social protection programs, and poverty reduction remains essential. In addition, including functional measures like grip strength in routine child health checks could give policymakers a fuller understanding of children's well-being. These measures can reveal deficits that BMI or hemoglobin alone might miss, guiding more comprehensive and effective interventions [26].

4.8. Strengths and Limitations

A key strength of our study is its focus on a highly vulnerable and often overlooked population, children in informal educational settings. These children are frequently excluded from large national surveys, yet they represent some of the most disadvantaged groups in society. By documenting their health, our study provides valuable evidence that can help guide targeted interventions. At the same time, there are important limitations to note. The cross-sectional design prevents us from drawing causal conclusions, and the relatively small sample size limits how broadly the findings can be applied. Additionally, dietary intake was based on self-report rather than measured with validated tools. In future research, we plan to study larger, longitudinal cohorts with detailed dietary, biochemical, and developmental assessments to build a more complete picture of child health [27,28].

5. Conclusion

In summary, this study highlights the serious challenges facing child health in a disadvantaged community. Limited

dietary variety, very low muscular strength, underweight status, and widespread anemia together reflect chronic undernutrition with significant implications for growth and development. While these patterns align with national and global data, our study also adds new insights, particularly through functional measures like grip strength. Addressing these issues requires coordinated efforts that combine nutritional support, investment in education, and poverty reduction. Without such efforts, cycles of malnutrition and disadvantage are likely to persist, affecting both individual potential and broader societal well-being [28].

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