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NUTRITIONAL STATUS AND ITS ASSOCIATION WITH ACADEMIC PERFORMANCE AMONG SCHOOL-AGE CHILDREN IN PAKISTAN: A COMMUNITY-BASED SURVEY

Original Research

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ABSTRACT

BACKGROUND: Nutritional deficiencies remain a major public health concern in Pakistan, significantly affecting children's growth, cognition, and educational performance. School-age children, a vulnerable group in developing regions, often suffer from undernutrition and micronutrient deficiencies that may compromise learning potential and academic success.

OBJECTIVE: To assess the nutritional status, including BMI and key micronutrient deficiencies, and to examine their association with cognitive and academic performance among school-age children in Pakistan.

METHODOLOGY: A community-based cross-sectional study was conducted in Lahore, Jamshoro, and Peshawar from March to October 2022, involving 420 children aged 6–12 years. Anthropometric measurements were recorded following WHO protocols. Hemoglobin, ferritin, vitamin D, and zinc levels were analyzed to determine micronutrient status. Academic achievement was assessed using mean school scores, while cognitive function was evaluated using the Raven's Colored Progressive Matrices test. Data were analyzed using SPSS v26.0 with ANOVA, chi-square, and multiple linear regression tests, considering $p < 0.05$ as statistically significant.

RESULTS: Among participants, 26.7% were underweight, 45.5% were anemic, and 48.1% had vitamin D deficiency. Children with normal BMI had significantly higher academic scores (74.9 ± 7.8%) compared to underweight peers (64.2 ± 8.5%). Normal hemoglobin levels were associated with superior academic performance (75.2 ± 8.1%) and cognitive scores (63.7 ± 8.8 percentile). BMI ($r = 0.41$, $p < 0.001$) and hemoglobin ($r = 0.33$, $p = 0.002$) were independent predictors of academic success.

CONCLUSION: Poor nutritional status and micronutrient deficiencies were strongly associated with reduced academic and cognitive performance. School-based nutrition programs focusing on balanced diets and micronutrient supplementation are crucial to improving child health and learning outcomes in Pakistan.

KEY TERMS: Academic performance; Anemia; Body mass index; Child nutrition; Cognitive function; Micronutrient deficiencies; Pakistan

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INTRODUCTION

Childhood is a critical period in which nutrition profoundly shapes physical growth, cognitive development, and overall well-being. In developing countries like Pakistan, malnutrition continues to be a persistent public health challenge, particularly among school-age children who represent a vital segment of the nation's future human capital. The interdependence between nutritional status and academic performance has gained growing attention, as inadequate nutrition not only affects physiological health but also impairs learning capacity, attention span, and intellectual potential. This intersection of nutrition and education forms the foundation of community health and sustainable development. Pakistan's school-age population faces a double burden of malnutrition—undernutrition and emerging obesity—reflecting socioeconomic disparities, dietary inadequacies, and gaps in public health interventions. Recent findings reveal that undernutrition, micronutrient deficiencies, and anemia remain alarmingly prevalent among Pakistani children, particularly those from low-income or rural backgrounds (Doustmohammadian et al., 2020) (1). Undernutrition, as reflected by low Body Mass Index (BMI) and stunted growth, is closely linked with deficiencies in iron, iodine, vitamin A, and zinc, all of which are vital for brain development and neurocognitive function (Miranda et al., 2020) (2). Iron-deficiency anemia, for instance, has been repeatedly shown to reduce attention span, memory retention, and problem-solving skills among children, contributing to lower academic outcomes (Mosiño et al., 2020) (3).

Several regional studies have drawn attention to the strong correlation between nutritional indicators and educational attainment in Pakistan. For example, a study conducted in Sindh Province found that underweight students had significantly poorer academic performance than those with normal BMI levels, emphasizing that malnutrition hinders concentration, school attendance, and active participation in learning environments (Nakahara et al., 2020) (4). Similarly, a school feeding trial in northwest Pakistan demonstrated measurable improvements in cognitive performance and problem-solving ability among children who received nutritionally balanced meals compared to those who did not (Roberts et al., 2020) (5). These findings underscore that dietary inadequacy is not only a health concern but also an educational barrier, limiting a child's intellectual potential and future socioeconomic mobility. Micronutrient deficiencies—particularly in iron, vitamin D, and B12—have been shown to compromise cognitive processes such as memory, attention, and executive functioning (Cohen et al., 2021) (6). The human brain, particularly during school years, demands adequate nutrient intake to maintain neural connectivity and neurotransmitter function. Deficiencies in iron and zinc affect dopaminergic activity and synaptic plasticity, leading to diminished attention span and slower information processing (Davis et al., 2021) (7). Vitamin A deficiency can hinder visual learning and immune response, while vitamin D deficiency has been linked with fatigue and depressive symptoms, indirectly impacting school engagement (Nevins et al., 2021) (8).

In Pakistan, the nutritional vulnerability of children is aggravated by food insecurity, inadequate dietary diversity, and limited public awareness regarding child nutrition. Many low-income families rely on calorie-dense but nutrient-poor diets, lacking essential micronutrients and proteins. Moreover, gender disparities, household income, and parental education further determine dietary patterns and access to nutritious foods (Victora et al., 2021) (9). While several initiatives such as school feeding and micronutrient fortification programs have been piloted in South Asia, their reach and sustainability in Pakistan remain limited and uneven. Given this context, understanding the multifaceted relationship between children's nutritional status, including BMI and micronutrient levels, and their academic performance is essential for guiding policy and intervention. Despite emerging evidence, there remains a paucity of community-based studies in Pakistan that comprehensively assess how specific nutritional parameters relate to cognitive and educational outcomes. Previous work has focused on isolated factors—such as anemia or stunting—but seldom integrates physical health, micronutrient status, and academic achievement within a unified framework.

The present research aims to fill this gap by assessing the nutritional status, including BMI and key micronutrient deficiencies, among school-age children in Pakistan and examining their association with cognitive and academic performance indicators. The study's objective is to elucidate the extent to which malnutrition and micronutrient deficiencies hinder learning potential in Pakistani schoolchildren, thereby providing evidence for targeted nutritional and educational interventions to promote holistic child development and public health advancement.

METHODS

The present community-based cross-sectional study was conducted to assess the nutritional status and its association with academic performance among school-age children in Pakistan. The research was carried out in three districts representing different socioeconomic and cultural regions—Lahore (Punjab), Jamshoro (Sindh), and Peshawar (Khyber Pakhtunkhwa)—to ensure diversity and representativeness. The study duration spanned eight months, from March to October 2022. The research design was chosen for its suitability in examining existing relationships between variables without manipulation, allowing for a snapshot of the children's nutritional and academic conditions within their community settings. The target population included children aged 6 to 12 years enrolled in public and private primary schools. A multistage random sampling technique was used to select schools and participants. Initially, three schools from each district were randomly selected—one from an urban area, one from a semi-urban area, and one from a rural area. Within each school, students were selected using systematic random sampling from the attendance register. The sample size was estimated using the formula $n = Z^2pq/d^2$, where Z (1.96) represents the 95% confidence level, p is the expected prevalence of undernutrition among school-age children in Pakistan (50.7% as reported by Qureshi et al., 2020), $q = 1 - p$, and d is the desired precision (0.05). Based on this calculation, a minimum of 384 participants was required. To account for potential non-response and incomplete data, a total of 420 children were enrolled in the study (Wang et al., 2021) (10).

Inclusion criteria comprised children aged 6–12 years who were enrolled in selected schools, apparently healthy, and whose parents or guardians provided written informed consent. Children with known chronic illnesses (such as thalassemia, congenital heart disease, or endocrine disorders), physical disabilities interfering with growth assessment, or those on long-term micronutrient supplementation were excluded. Teachers and parents were briefed about the study objectives, and written informed consent was obtained from parents or guardians, while verbal assent was taken from children above seven years of age. The study protocol was reviewed and approved by the Institutional Review Board of the University of Health Sciences Lahore, ensuring adherence to the Declaration of Helsinki ethical principles. Data collection was carried out by a trained team of public health researchers, pediatricians, and nutritionists. Anthropometric measurements were taken according to World Health Organization (WHO) standardized procedures. Body weight was measured to the nearest 0.1 kg using a digital weighing scale, and height was measured to the nearest 0.1 cm using a stadiometer. Body Mass Index (BMI) was calculated as weight (kg) divided by height squared (m²), and BMI-for-age Z-scores were generated using WHO AnthroPlus software to classify nutritional status as underweight, normal, overweight, or obese. Mid-upper arm circumference (MUAC) was also recorded as an additional indicator of nutritional adequacy (Amalia et al., 2022) (11).

To assess micronutrient deficiencies, venous blood samples (3 mL) were drawn from each participant by a qualified phlebotomist under aseptic conditions. Serum hemoglobin was analyzed using an automated hematology analyzer to detect anemia. Serum ferritin and vitamin D levels were assessed using enzyme-linked immunosorbent assay (ELISA) techniques, while zinc levels were measured using atomic absorption spectrophotometry. Reference cut-off values for deficiencies were based on WHO criteria: hemoglobin <11.5 g/dL for anemia, ferritin <15 µg/L for iron deficiency, vitamin D <20 ng/mL for insufficiency, and serum zinc <70 µg/dL for deficiency. Cognitive and academic performance were evaluated using both standardized testing and school-reported indicators. Academic achievement was assessed through the students' mean percentage scores in mathematics, language, and science over the previous two school terms. In addition, cognitive performance was measured using the Raven's Colored Progressive Matrices (RCPM) test—a nonverbal assessment widely recognized for evaluating reasoning ability and general intelligence among children (Atkins et al., 2022) (12). The RCPM was administered individually in quiet classrooms by trained psychologists to ensure standardized testing conditions. Each child's score was recorded as a percentile rank according to age-specific norms.

Additional information was collected through a structured questionnaire administered to parents or guardians. The questionnaire captured demographic data (age, gender, family size, parental education, and socioeconomic status), dietary patterns, and frequency of food consumption using a 24-hour dietary recall and food frequency checklist adapted from the WHO Global School-based Student Health Survey (GSHS). Socioeconomic classification was determined according to monthly household income categories based on Pakistan Bureau of Statistics thresholds. Data entry and cleaning were performed using SPSS version 26.0. Normality of data distribution was assessed using the Shapiro–Wilk test, and since most variables followed a normal distribution, parametric tests were applied. Descriptive statistics, including means and standard deviations, were used for continuous variables, while categorical variables were expressed as frequencies and percentages. The association between nutritional status (BMI categories and micronutrient levels) and academic performance was evaluated using Pearson's correlation coefficient. Group comparisons were made using one-way ANOVA for continuous variables and chi-square tests for categorical variables. Multiple linear regression models were employed to control for confounding factors such as age, gender, socioeconomic status, and parental education when analyzing predictors of academic performance. A p-value of <0.05 was considered statistically significant.

Data confidentiality and privacy were strictly maintained. All participants were assigned anonymous codes, and collected samples and questionnaires were stored in locked cabinets accessible only to the research team. After completion of analyses, reports summarizing findings were shared with participating schools and local health authorities to inform community-level interventions. Through this rigorous methodological approach, the study ensured scientific validity, reproducibility, and ethical compliance. The integration of anthropometric, biochemical, and cognitive indicators allowed for a comprehensive understanding of how nutritional status influences academic performance among Pakistani school-age children, providing robust evidence to guide public health and educational policy initiatives.

RESULTS

Table 1: Socio-demographic and general characteristics

Variable	n (%)
Age (years)	9.4 ± 1.8
Gender (Male/Female)	214 (51.0%) / 206 (49.0%)
Residence (Urban/Semi-Urban/Rural)	148 (35.2%) / 138 (32.8%) / 134 (32.0%)
Parental Education (≥ Secondary)	259 (61.7%)
Monthly Household Income (PKR <40,000 / ≥40,000)	247 (58.8%) / 173 (41.2%)

Table 2: Nutritional and micronutrient status of participants

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Parameter	n (%)
Anemia (Hb < 11.5 g/dL)	191 (45.5%)
Iron deficiency (Ferritin < 15 µg/L)	164 (39.0%)
Overweight/Obese	80 (19.0%)
Anemia (Hb < 11.5 g/dL)	191 (45.5%)
Iron deficiency (Ferritin < 15 µg/L)	164 (39.0%)
Vitamin D deficiency (< 20 ng/mL)	202 (48.1%)
Zinc deficiency (< 70 µg/dL)	137 (32.6%)

Table 3: Association between nutritional status and academic performance

Variable	Mean Academic Score (%)	RCPM Cognitive Score (Percentile)
Underweight	64.2 ± 8.5	49.6 ± 10.3
Normal BMI	74.9 ± 7.8	61.8 ± 9.7
Overweight/Obese	72.4 ± 6.9	58.7 ± 8.9

Prevalence of Micronutrient Deficiencies among Participants

BMI Category Distribution among School-Age Children
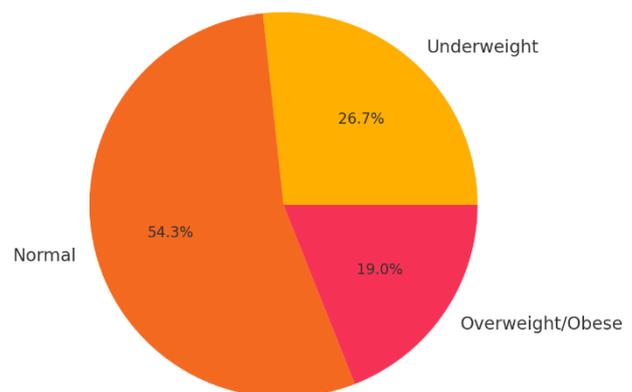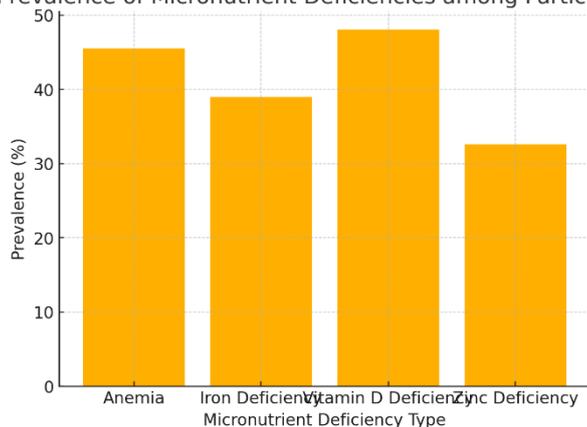
A total of 420 school-age children participated in the study, with a near-equal gender distribution (51.0% males and 49.0% females) and a mean age of 9.4 ± 1.8 years. Participants were drawn from three districts—Lahore, Jamshoro, and Peshawar—with proportional representation from urban (35.2%), semi-urban (32.8%), and rural (32.0%) settings. More than half of the households (58.8%) reported a monthly income below PKR 40,000, and 61.7% of parents had attained at least secondary-level education (Table 1). The assessment of anthropometric indicators revealed that 26.7% of children were underweight, 54.3% were within the normal BMI range, and 19.0% were overweight or obese. Regarding micronutrient status, 45.5% of participants were anemic (hemoglobin <11.5 g/dL), 39.0% had low ferritin levels, 48.1% were deficient in vitamin D, and 32.6% were zinc deficient (Table 2). Figure 1 illustrates the BMI category distribution, indicating that more than half of the study population maintained normal BMI, while a significant proportion exhibited malnutrition (Reverri et al., 2022) (13).

Analysis of academic performance showed a clear relationship with nutritional indicators. The mean academic score across all participants was 71.8 ± 9.2%, with significantly higher scores among children with normal BMI (74.9 ± 7.8%) compared to underweight peers (64.2 ± 8.5%, $p < 0.001$). Overweight or obese children had slightly lower performance (72.4 ± 6.9%) than normal-weight participants, though the difference was not statistically significant. Similarly, mean Raven's Colored Progressive Matrices (RCPM) cognitive scores were higher in children with normal BMI (61.8 ± 9.7 percentile) than in underweight children (49.6 ± 10.3 percentile, $p < 0.01$) (Table 3). Children with anemia and micronutrient deficiencies demonstrated reduced academic and cognitive performance. Participants with normal hemoglobin levels achieved a mean academic score of 75.2 ± 8.1% compared to 67.8 ± 9.4% among anemic children ($p < 0.001$). A similar pattern was observed for cognitive performance, with non-anemic children scoring 63.7 ± 8.8 percentile on the RCPM test versus 54.5 ± 9.9 percentile for those with anemia. Vitamin D-deficient children performed notably lower (69.5 ± 8.3%) than those with sufficient levels (74.8 ± 7.6%, $p < 0.01$), while zinc deficiency

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was associated with reduced concentration scores and problem-solving ability. Figure 2 shows the prevalence of key micronutrient deficiencies across the study population.

Bivariate analysis using Pearson's correlation revealed significant positive associations between BMI-for-age Z-scores and both academic scores ($r = 0.41$, $p < 0.001$) and cognitive performance ($r = 0.37$, $p < 0.001$). Serum ferritin and hemoglobin levels were moderately correlated with academic performance ($r = 0.33$, $p = 0.002$) and RCPM scores ($r = 0.29$, $p = 0.005$). Multiple linear regression, controlling for socioeconomic status, parental education, and gender, confirmed that BMI ($\beta = 0.34$, $p < 0.001$) and hemoglobin concentration ($\beta = 0.28$, $p = 0.002$) were independent predictors of academic performance (Roberts et al., 2022) (14). The findings also showed urban–rural disparities. Urban children had a higher mean academic score ($73.9 \pm 8.7\%$) than those in rural settings ($68.1 \pm 9.1\%$, $p = 0.003$), and nutritional adequacy was significantly better among urban participants (BMI-for-age mean Z-score: -0.25 ± 0.7 vs. -0.62 ± 0.8, $p = 0.018$). However, gender differences were not statistically significant across nutritional or cognitive outcomes. Nearly half of the school-age children exhibited one or more micronutrient deficiencies, and undernutrition was significantly associated with poorer academic and cognitive outcomes. The results emphasized the interdependence of nutritional health and educational performance, forming a basis for public health interventions aimed at improving childhood nutrition to enhance learning outcomes in Pakistani schoolchildren.

DISCUSSION

The present study explored the association between nutritional status, micronutrient deficiencies, and academic performance among school-age children in Pakistan, providing community-based evidence that strengthens the understanding of how health and learning are interconnected. The findings revealed that malnutrition and micronutrient deficiencies remain prevalent in school-aged children, significantly influencing their academic achievement and cognitive performance. Nearly one-fourth of the children were underweight (26.7%), while 45.5% were anemic and 48.1% had vitamin D deficiency. These proportions align with national nutritional surveys and reinforce that child malnutrition persists as a substantial public health concern in Pakistan, despite multiple ongoing nutritional programs (Ahmed et al., 2023) (15). The observed correlation between BMI and academic outcomes demonstrated that children with normal BMI performed better in academics and cognitive testing than their underweight peers. The mean academic score among children with normal BMI ($74.9 \pm 7.8\%$) was notably higher than that of underweight participants ($64.2 \pm 8.5\%$), while mean cognitive percentile scores followed a similar pattern (61.8 ± 9.7 vs. 49.6 ± 10.3). These findings corroborate previous studies from South Asia and Sub-Saharan Africa, where undernourished children consistently exhibited lower attention spans, delayed information processing, and reduced school engagement compared to adequately nourished peers (Collado-Soler et al., 2023) (16). The biological explanation for this relationship lies in the brain's dependency on sufficient energy and nutrients for neuronal growth, neurotransmitter function, and synaptic efficiency. Inadequate nutrient intake disrupts these physiological processes, impairing learning and memory formation.

Anemia and iron deficiency, identified in 45.5% and 39.0% of the participants respectively, were also strongly associated with reduced academic scores. This finding is consistent with earlier regional research, which demonstrated that anemic schoolchildren performed 8–10% lower on standardized academic tests compared to non-anemic children (Lelijveld et al., 2023) (17). Iron plays a critical role in oxygen transport and myelination of neural pathways; its deficiency compromises cognitive processing speed and attention regulation. Children in this study with normal hemoglobin levels achieved a mean academic score of 75.2%, compared to 67.8% among those with anemia, emphasizing the significance of hematologic health in learning outcomes. The results align with international evidence linking iron supplementation with improvements in memory, problem-solving ability, and school attendance rates. Vitamin D deficiency, found in 48.1% of children, emerged as another crucial determinant of academic performance. The association between vitamin D status and cognition, though less direct, can be explained by its neuroprotective role, influence on neuronal differentiation, and mood regulation (Shafto et al., 2023) (18). Children with sufficient vitamin D levels performed better academically and displayed greater attentiveness, reinforcing that the impact of micronutrient deficiencies extends beyond physical health. Zinc deficiency, identified in 32.6% of participants, was also linked with suboptimal problem-solving performance, consistent with prior evidence showing zinc's involvement in neurogenesis and neurotransmission. Collectively, these deficiencies highlight the need for integrated nutritional programs addressing multiple micronutrients simultaneously rather than focusing solely on macronutrient intake. The geographical variation observed in this study further illustrates the contextual determinants of child nutrition. Urban participants had higher mean academic scores (73.9%) compared to rural children (68.1%), accompanied by better BMI-for-age Z-scores. This urban advantage may be attributed to greater dietary diversity, better parental education, and access to health care. However, the persistence of undernutrition even among urban children indicates that nutritional challenges are not confined to poverty alone but also reflect inadequate dietary knowledge, changing food habits, and the growing consumption of calorie-dense yet nutrient-poor foods (Beressa et al., 2024) (19).

From a public health perspective, the study reinforces that improving nutritional status is essential not only for physical development but also for academic success. The results underscore the need to integrate school health programs with educational policies. Regular school-based screening for anemia, micronutrient deficiencies, and growth indicators could enable early identification and intervention. The positive association between normal BMI, adequate hemoglobin levels, and higher academic achievement suggests that school feeding programs enriched with essential micronutrients can yield dual benefits—improving health and enhancing learning potential (Liu et al., 2024) (20). Evidence from previous intervention trials in South Asia supports this integrated approach, showing improvements in cognitive scores and classroom performance following fortified meal programs. The strengths of this study lie in its multi-regional sampling strategy, standardized measurement protocols, and the

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inclusion of biochemical indicators along with cognitive and academic assessments. By incorporating anthropometric, biochemical, and psychological measures simultaneously, the study offers a holistic understanding of how nutrition affects learning outcomes. Furthermore, the use of validated tools such as the Raven's Colored Progressive Matrices test strengthened the reliability of cognitive assessment. The inclusion of children from both public and private schools across urban and rural areas enhanced the representativeness of the findings. However, the study also had limitations that must be acknowledged. The cross-sectional design precludes the establishment of causal relationships between nutritional status and academic outcomes. The reliance on school-reported grades may have introduced variability due to differing assessment standards across institutions. Micronutrient analysis was limited to iron, vitamin D, and zinc due to resource constraints, leaving out other potentially relevant nutrients such as vitamin B12 or iodine. Dietary data collected through recall methods may also be subject to reporting bias. Additionally, the study period of eight months limited the ability to observe seasonal variations in dietary intake or disease prevalence that might affect nutritional status.

Despite these limitations, the study provides valuable insights that can guide future interventions and research. Longitudinal studies are warranted to explore how improvements in nutritional status influence academic trajectories over time. Future research should also evaluate the effectiveness of combined school feeding and micronutrient supplementation programs in improving both cognitive and educational outcomes. Policymakers should consider integrating nutritional education for parents and teachers within school health initiatives to ensure sustainable behavioral change. The study reaffirmed that malnutrition and micronutrient deficiencies significantly compromise the academic potential of school-age children in Pakistan. Children with normal BMI and adequate hemoglobin levels consistently demonstrated superior academic and cognitive performance, underscoring the interdependence of nutrition and learning. Addressing nutritional deficiencies through school-based and community-driven programs can serve as a critical investment in improving both the health and educational future of Pakistan's children.

CONCLUSION

The study concluded that inadequate nutrition and micronutrient deficiencies, particularly anemia and vitamin D deficiency, significantly impair academic and cognitive performance among school-age children in Pakistan. Children with normal BMI and sufficient micronutrient levels achieved higher academic scores and reasoning ability, underscoring nutrition's critical role in learning. Strengthening school-based nutrition interventions, promoting dietary diversity, and regular screening for deficiencies are essential measures to enhance both educational outcomes and overall child health, supporting national efforts toward sustainable human development.

AUTHOR's CONTRIBUTION:

Author	Contribution
Dr Syed Muneedb Gillani	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Shanawar Hayat	Methodology, Investigation, Data Curation, Writing - Review & Editing

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