Research Article

Magnitude of Anemia and Hematological Predictors among Children under 12 Years in Odisha, India

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Background. Anemia is a widespread public health problem in India which affects children. The present study evaluates the prevalence of anemia and status of various hematological parameters among children of Khurda district, Odisha.

Method. A total of 313 children aged 0–12 years were enrolled for the study which included preschool (0–5 years) and school aged (6–12 years) groups. Hematological indicators were measured by standard procedures, which include red blood cell (RBC) indicators, white blood cell (WBC) indicators, and plasma ferritin.

Results. Mean hemoglobin (Hb) of the study population was $10.43 \pm 3.33$ g/dL and prevalence of anemia was 62%. In this population, boys had a lower mean Hb value than that of the girls. All grades of anemia were higher among school age children than preschool children. Mean plasma ferritin was found to be higher in school age boys than their counterpart girls. The mean level of WBC count was found to be higher among preschool age boys than among the school age boys ($p = 0.025$).

Conclusion. The prevalence of anemia was higher with concomitant acute infection among study population, which is a matter of concern. Since the hematological parameters are interrelated with each other as well as with the age and gender, relevant intervention strategy and constant monitoring are needed while providing public health nutrition programs to eradicate anemia.

1. Introduction

Anemia is a widespread public health problem associated with an increased risk of morbidity and mortality, especially in pregnant women and young children [1]. Globally 1.62 billion people are anemic, while among the preschool children the prevalence of anemia is 47.4%. Nutritional anemia in South Asia accounts for nearly half of global cases of anemia. In India, anemia continues to be the major health problem in young children, adolescent girls, and pregnant women. Approximately 50% of the population suffers from nutritional anemia as known in countries where meat consumption is low [2].

In India, about 89 million children are anemic. The prevalence of anemia was 70% in children aged 6–59 months [3]. The highest prevalence of anemia was seen in children <10 years, especially in those <5 years [4]. Iron deficiency is one of the most common causes of anemia [5]. Besides iron, other nutrients such as vitamins A, E, and C also play key role in formation and protection of red blood cell (RBC) by stimulating stem cells as well as by activating a number of antioxidant enzymes [6]. Therefore inadequacy of any of these micronutrients may lead to anemia in the vulnerable sections of population. Studies have shown that preschool children are more vulnerable to the risk of iron deficiency anemia. The prevalence of iron deficiency anemia is the highest among preschool children. In this age group (6–59 months), body grows rapidly and requires high-iron-rich and nutritious food that may not be fulfilled by their normal diet. Low economic status, less education, and poor health of mothers due to meager dietary intake are the main causes of anemia. Anemia is the most predominant factor for morbidity and child mortality; and, hence, it is a critical health issue for children in India. Iron deficiency affects cognitive and motor development and increases susceptibility to infections. The prevention as well as timely management of anemia is essential to attain Sustainable Development Goal-3 (SDG) on ensuring healthy lives and promoting wellbeing for all at all
2. Materials and Methods

2.1. Setting. The study was conducted in the rural surroundings of Bhubaneswar city in Khurda district, the state capital of Odisha located on the east coast of India, by the Bay of Bengal. Apparently healthy children aged less than 12 years were chosen for the study, which included preschool children (0–5 years) and school age children (6–12 years). Children having medication in the past fortnight prior to data collection and unwilling individuals were excluded from the study.

2.2. Study Design. This is a cross-sectional community-based survey. All children and their parents were informed about the purpose and the method of the research and the voluntary nature of participation in the study verbally and in written form.

2.3. Ethical Consideration. Informed written consent was obtained from the parents of each child after the study objective was explained. The study protocol was approved by the Institutional Human Ethical Committee of Regional Medical Research Centre, Bhubaneswar.

2.4. Data Collection. A pretested questionnaire was applied to obtain relevant information of demographic and socioeconomic data. Age of each child was collected from date of birth certificate or birth records available with mother. Confirmation of a child's age was made with the mother with the help of Anganwadi Workers, community health workers.

2.5. Anthropometric Measurements. Body weight and height were measured using standardised equipment and procedures. Body mass index (BMI) for each child was calculated based on the ratio of weight (kg) to height in square meters. BMI data were transformed to z-scores, namely, BMI-for-age z-score (BAZ) using the WHO Growth Standards [7].

2.6. Blood Samples. Either finger prick or venous blood was collected according to the agreement of the participants. The finger prick blood was transferred to Whatman number 1 filter paper while two mL of venous blood was dispensed into vials containing EDTA anticoagulant bottles. Hematological and biochemical investigations were carried out in nutrition laboratory.

2.7. Biochemical Estimations. Venous blood was subjected to complete blood count (CBC), which was performed by an automated analyzer MS4 (Melet Schloesing 4, Germany) used for the in vitro diagnostic testing. The blood was well mixed (though not shaken) and placed on a rack in the analyzer. The instrument counted the number and type of different cells within the blood and results were printed out that included hemoglobin (Hb), red blood cell (RBC), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), white blood cell (WBC), granulocyte, thrombocyte (platelet), lymphocyte, and monocytes. Adequate quality control measures were taken on each test procedure to ensure the reliability of the results. The validity of Hb measure was confirmed by checking the reproducibility of the results of sample aliquots by cyanmethemoglobin method. The finger prick blood was used to estimate hemoglobin (Hb) by cyanmethemoglobin method [8]. Plasma ferritin was estimated using ELISA kits obtained from United Biotech Inc. Magiwell Ferritin, USA (K951993).

2.8. Statistical Analysis. Anemia was defined as Hb concentration <11 g/dL for children aged between 6 and 59 months while <11.5 g/dL for children aged between 5 and 11 years and <12 g/dL for children aged 12 years according to WHO as shown in Table 1 [9]. Further, normal reference ranges used for hematological indicators (red blood indices and white blood indices) are provided in Table 2 [10, 11]. Data were entered in Microsoft Excel 2007 and all statistical analyses were performed with GraphPad Prism software (version 4.00). SPSS for Windows version 17.0, Chicago, USA, was also used for data analysis. Descriptive characteristics (mean and standard deviation) and percentage were performed for each parameter separately. Chi-square and independent t-test were used for proportions and mean comparisons between groups, respectively. Pearson’s correlation tests were performed to examine the relationships between hematological indicators. The strength of association is measured by unadjusted odds ratio (OR) and 95% confidence interval (CI).

### Table 1: Hemoglobin concentrations (g/dL) for the diagnosis of anemia and assessment of severity according to the WHO/UNICEF/UNU (2001).

| Anemia measured by hemoglobin (g/dL) | Anemia | Mild | Moderate | Severe |
|--------------------------------------|--------|------|----------|--------|
| Children 6–59 months                 | <11.0  | 10–9.9 | 7.0–9.9  | <7.0   |
| Children 5–11 years                  | <11.5  | 10–11.4 | 7.0–9.9  | <7.0   |
| Children 12–14 years                 | <12.0  | 10–11.9 | 7.0–9.9  | <7.0   |

3. Results

A total of 313 children provided blood samples for estimation of Hb, ferritin (250), hematological indicators (139), and...
Table 2: Reference range/cut-off values assigned for different hematological parameters.

| Hematological parameters                        | Age group       | Reference value | Reference |
|------------------------------------------------|-----------------|-----------------|-----------|
| Red blood count (million/mm³)                   | 6 months–2 years| 3.7–5.3         | [10]      |
|                                                 | 2 years–6 years | 3.9–5.3         |           |
|                                                 | 6 years–12 years| 4.0–5.2         |           |
| Hematocrit (%)                                  | 2 years–6 years | 34–40           |           |
|                                                 | 6 years–12 years| 35–45           |           |
|                                                 | 6 months–2 years| 70–86           |           |
| Mean corpuscular volume (fl)                    | 2 years–6 years | 75–87           |           |
|                                                 | 6 years–12 years| 77–95           |           |
|                                                 | 6 months–2 years| 23–31           |           |
| Mean corpuscular hemoglobin (pg)                | 6 months–2 years| 24–30           |           |
|                                                 | 6 years–12 years| 25–33           |           |
| Mean corpuscular hemoglobin concentration (g/dL)| 6 months–2 years| 30.0–36.0       | [10]      |
|                                                 | 2 years+        | 32.3–35.7       |           |
| White blood counts (thousand/mm³)               | 2 years–4 years | 6.0–15.5        |           |
|                                                 | 4 years–6 years | 5.5–14.5        |           |
|                                                 | 6 years–12 years| 4.5–13.5        |           |
|                                                 | 0–1 month       | 250–450         |           |
|                                                 | 1 month–1 year  | 300–750         |           |
| Thrombocytes (thousand/mm³)                     | 1–3 years       | 250–600         |           |
|                                                 | 3–7 years       | 250–550         |           |
|                                                 | 7–12 years      | 200–450         |           |
| Granulocytes (%)                                | All age groups  | 18–45           | [11]      |
| Monocytes (%)                                   | All age groups  | 4–11            |           |
| Lymphocytes (%)                                 | All age groups  | 45–75           |           |
| Red cell distribution width (%)                 | All age groups  | 11–15           |           |

WBC differential count (131). The mean characteristics of BAZ and hematological parameters are shown in Table 3. The mean BAZ of study population was \(-1.04 \pm 1.53\) and no significant difference was observed between the age or gender groups. The mean Hb of the study population was 10.43 ± 3.33 g/dL. The mean Hb among preschool children was 10.45 ± 2.99 g/dL of which boys had 10.57 ± 3.01 g/dL and girls had 10.27 ± 2.99 g/dL. The mean Hb among school age children was found to be 10.42 ± 3.491 g/dL of which boys had 9.78 ± 3.96 g/dL and girls had 10.85 ± 3.98 g/dL. Hb, HCT, MCV, and MCH of school age boys were significantly lower than girls \((p = 0.029, 0.042, 0.0002, and 0.023, \text{ resp.})\). The mean ferritin level among boys was significantly higher than girls \((p = 0.0002)\), which was chiefly exhibited by school age children. The mean WBC count was found to be higher among preschool boys than among school age boys \((p = 0.025)\). Mean MCV and MCH were significantly higher among school age girls than preschool girls \((p = 0.026 and 0.011, \text{ resp.})\). Also, MCH and MCHC of preschool children were low compared to school children \((p = 0.009 and 0.006, \text{ resp.})\). Mean RDW of preschool girls was higher than their male counterpart as well as school age girls \((p = 0.016 and 0.026)\).

The prevalence of different grades of anemia according to Hb level is depicted in Table 4. Overall occurrence of anemia was 62% comprised of 23% mild, 23% moderate, and 16% severe categories. School age children were found to be more anemic than preschool children. Prevalence of anemia was 48.5% among preschool children of which 47.6% were boys and 50.0% were girls. Mild, moderate, and severe anemia were found to be 12.9%, 22.7%, and 12.9%, respectively. Among school age children 68.9% had anemia, of which 27.4% were mildly, 23.6% were moderately, and 17.9% were severely anemic. Girls were significantly more anemic than boys in the age group of 11-12 years \((p = 0.028)\), while more boys were anemic in the age group 10-11 years \((84.6% \text{ versus } 53.1%, p = 0.048)\).

Table 5 shows the hematological indicators for anemia with standard reference ranges. Deficiency of RBC count was found to be 47.5% in children indicating iron, vitamin B12, or folate deficiency or hemolysis. Further, deficiency of HCT was 52.5% indicating the same. Deficiency of MCV,
### Table 3: Mean BMI-for-age z-score and hematological parameters among children in Odisha, India.

| Variables                              | Sex       | N         | Preschool children | N         | School age children | N         | Pooled children |
|----------------------------------------|-----------|-----------|--------------------|-----------|---------------------|-----------|-----------------|
| BMI-for-age z-score                    | Boys 63   | −0.96 ± 1.82 | 85                 | −0.96 ± 1.59 | 148                | −0.96 ± 1.68 |
|                                        | Girls 38  | −0.87 ± 1.34 | 127                | −1.18 ± 1.37 | 165                | −1.11 ± 1.36 |
|                                        | Total 101 | −0.93 ± 1.65 | 212                | −1.09 ± 1.46 | 313                | −1.04 ± 1.53 |
| Hemoglobin (g/dL)                      | Boys 63   | 10.57 ± 3.01 | 85                 | 9.78 ± 3.96  | 148                | 10.11 ± 3.59 |
|                                        | Girls 38  | 10.27 ± 2.99 | 127                | 10.85 ± 3.09* | 165               | 10.71 ± 3.06 |
|                                        | Total 101 | 10.45 ± 2.99 | 212                | 10.42 ± 3.49 | 313                | 10.43 ± 3.33 |
| Plasma ferritin (ng/mL)                | Boys 49   | 177.9 ± 226.8 | 75                 | 279.5 ± 280.0† | 124               | 239.4 ± 264.0 |
|                                        | Girls 23  | 162.1 ± 218.2 | 103                | 122.8 ± 176.3* | 126               | 130.0 ± 184.4* |
|                                        | Total 72  | 172.9 ± 222.6 | 178                | 189.2 ± 238.4 | 250                | 184.5 ± 233.6 |
| White blood cell count (thousand/mm³)  | Boys 29   | 9.51 ± 6.43  | 51                 | 6.72 ± 4.44  | 80                 | 7.74 ± 5.38  |
|                                        | Girls 17  | 8.12 ± 5.45  | 42                 | 8.03 ± 7.13  | 59                 | 8.05 ± 6.64  |
|                                        | Total 46  | 8.99 ± 6.06  | 93                 | 7.31 ± 5.81  | 139                | 7.87 ± 5.93  |
| Red blood cell count (million/mm³)     | Boys 29   | 4.21 ± 1.16  | 51                 | 3.69 ± 1.29  | 80                 | 3.88 ± 1.26  |
|                                        | Girls 17  | 3.823 ± 1.71 | 42                | 4.02 ± 1.59* | 59                 | 3.96 ± 1.61  |
|                                        | Total 46  | 4.07 ± 1.38  | 93                 | 3.84 ± 1.43  | 139                | 3.92 ± 1.41  |
| Hematocrit (%)                         | Boys 29   | 35.20 ± 10.25 | 51                | 29.94 ± 10.93† | 80                | 31.85 ± 10.93 |
|                                        | Girls 17  | 29.52 ± 12.60 | 42               | 35.33 ± 14.26* | 59                | 33.65 ± 13.95 |
|                                        | Total 46  | 33.10 ± 11.38 | 93                | 32.37 ± 12.76 | 139                | 32.61 ± 12.28 |
| Mean corpuscular volume (fl)           | Boys 29   | 83.58 ± 6.96  | 51                | 81.35 ± 8.11 | 80                | 82.16 ± 7.74 |
|                                        | Girls 17  | 81.15 ± 14.09 | 42              | 88.01 ± 8.61* | 59                | 86.04 ± 10.82* |
|                                        | Total 46  | 82.68 ± 10.11 | 93               | 84.36 ± 8.94 | 139                | 83.81 ± 9.34 |
| Mean corpuscular hemoglobin (pg)       | Boys 29   | 25.41 ± 2.72  | 51                | 26.18 ± 3.63 | 80                | 25.90 ± 3.33 |
|                                        | Girls 17  | 24.76 ± 5.32  | 42              | 27.95 ± 3.73* | 59                | 27.03 ± 4.44 |
|                                        | Total 46  | 25.17 ± 3.84  | 93             | 26.98 ± 3.76* | 139                | 26.38 ± 3.87 |
| Mean corpuscular hemoglobin concentration (g/dL) | Boys 29   | 30.48 ± 2.35  | 51                | 32.29 ± 3.39‡ | 80                | 31.63 ± 3.16 |
|                                        | Girls 17  | 30.89 ± 2.83  | 42              | 31.82 ± 2.52 | 59                | 31.55 ± 2.62 |
|                                        | Total 46  | 30.63 ± 2.52  | 93            | 32.08 ± 3.02‡ | 139                | 31.60 ± 2.93 |
| Red cell distribution width (%)        | Boys 29   | 10.79 ± 1.56  | 51                | 11.73 ± 3.00 | 80                | 11.39 ± 2.60 |
|                                        | Girls 17  | 13.28 ± 5.04* | 42             | 11.01 ± 2.58‡ | 59                | 11.66 ± 3.58 |
|                                        | Total 46  | 11.71 ± 3.47  | 93            | 11.40 ± 2.83 | 139                | 11.50 ± 3.05 |
| Granulocyte (%)                        | Boys 29   | 36.40 ± 17.49 | 48              | 38.12 ± 17.28 | 77                | 37.49 ± 17.26 |
|                                        | Girls 17  | 35.76 ± 18.35 | 37             | 35.54 ± 17.52 | 54                | 35.61 ± 17.61 |
|                                        | Total 46  | 36.16 ± 17.61 | 85            | 37.00 ± 17.33 | 131                | 36.71 ± 17.37 |
| Monocyte (%)                           | Boys 29   | 6.76 ± 4.75   | 48               | 5.44 ± 4.02  | 77                | 5.92 ± 4.32  |
|                                        | Girls 17  | 4.81 ± 2.30   | 37            | 5.59 ± 3.47  | 54                | 5.34 ± 3.15  |
|                                        | Total 46  | 6.02 ± 4.08   | 85           | 5.50 ± 3.77  | 131                | 5.68 ± 3.87  |
| Lymphocyte (%)                         | Boys 29   | 55.88 ± 15.28 | 48             | 56.45 ± 17.58 | 77                | 56.24 ± 16.67 |
|                                        | Girls 17  | 59.22 ± 17.62 | 37           | 58.87 ± 17.34 | 54                | 58.98 ± 17.26 |
|                                        | Total 46  | 57.14 ± 16.09 | 85          | 57.50 ± 17.41 | 131                | 57.38 ± 16.91 |
| Thrombocyte count (thousand/mm³)       | Boys 29   | 331.2 ± 450.6 | 48          | 229.9 ± 233.3 | 77                | 267.7 ± 332.2 |
|                                        | Girls 17  | 222.2 ± 164.1 | 37         | 205.4 ± 149.2 | 54                | 210.7 ± 152.7 |
|                                        | Total 46  | 290.0 ± 370.5 | 85        | 219.1 ± 199.9 | 131                | 243.8 ± 272.5 |

* p < 0.05 for boys versus girls; † p < 0.05 for preschool versus school children.
Table 4: Prevalence (%) of anemia by hemoglobin (g/dL) among children in Odisha.

| Age group (years)   | Sex  | N     | Normal (g/dL) | Mild (g/dL) | Moderate (g/dL) | Severe (g/dL) | Total anemic | p value | OR (95% CI) |
|---------------------|------|-------|---------------|-------------|-----------------|--------------|--------------|---------|-------------|
|                     | Boys | 63    | 52.4 (33)     | 12.7 (8)    | 22.2 (14)       | 12.7 (8)     | 47.6 (30)    | 0.816   | 1.10 (0.49–2.46) |
|                     | Girls| 38    | 50.0 (19)     | 13.2 (5)    | 23.6 (9)        | 13.2 (5)     | 50.0 (19)    |         |             |
|                     | Total| 101   | 51.5 (52)     | 12.9 (13)   | 22.7 (23)       | 12.9 (13)    | 48.5 (49)    |         |             |
| School age children | Boys | 85    | 27.1 (23)     | 17.6 (15)   | 25.9 (22)       | 29.4 (25)    | 72.9 (62)    | 0.295   | 1.38 (0.75–2.52) |
|                     | Girls| 127   | 33.9 (43)     | 33.9 (43)   | 22.0 (28)       | 10.2 (13)    | 66.1 (84)    |         |             |
|                     | Total| 212   | 31.1 (66)     | 27.4 (58)   | 23.6 (50)       | 17.9 (38)    | 68.9 (146)   |         |             |
| Pooled children     | Boys | 148   | 37.8 (56)     | 15.6 (23)   | 24.3 (36)       | 22.3 (33)    | 62.2 (92)    | 0.962   | 1.01 (0.64–1.59) |
|                     | Girls| 165   | 37.6 (62)     | 29.1 (48)   | 22.0 (28)       | 10.9 (18)    | 62.4 (103)   |         |             |
|                     | Total| 313   | 37.7 (118)    | 22.7 (71)   | 23.3 (73)       | 16.3 (51)    | 62.3 (195)   |         |             |

OR = odds ratio, CI = confidence interval; figures in parentheses are sample number.

Table 5: Distribution of hematological (red blood cell) indicators by age group and sex among children in Odisha, India.

| Parameter                  | Category | Preschool children | School age children | Pooled children |
|----------------------------|----------|--------------------|---------------------|-----------------|
|                            |          | Boys               | Girls              | Total           |
| Red blood cell count       | Normal   | 75.9 (22)          | 47.1 (8)           | 65.2 (30)       |
| (million/mm³)             | Deficiency | 21.7 (17)         | 34.8 (16)          | 54.8 (23)       |
| Hematocrit (%)             | Normal   | 65.5 (19)          | 47.1 (8)           | 58.7 (27)       |
|                            | Deficiency | 34.5 (10)         | 41.3 (19)          | 64.7 (33)       |
| Mean corpuscular volume (fL)| High    | 3.5 (1)            | 17.6 (3)           | 8.7 (4)         |
|                            | Standard | 24.1 (7)           | 17.7 (3)           | 21.7 (10)       |
| Mean corpuscular hemoglobin (pg) | High | 3.5 (1)            | 17.6 (3)           | 8.7 (4)         |
|                            | Standard | 24.1 (7)           | 17.7 (3)           | 21.7 (10)       |
| Red cell distribution width (%) | High   | 3.5 (1)            | 29.4 (5)           | 13.1 (6)        |
|                            | Standard | 24.1 (7)           | 30.4 (14)          | 15.3 (16)       |

Normal = number above the lower cut-off, High = number above higher cut-off value, Standard = number within the range, and Deficiency = number below the lower cut-off level. Figures in parentheses are sample number.

MCH, and MCHC was 15.1%, 30.9%, and 55.4%, respectively, demonstrating a probable iron deficiency while value above the reference level for MCV and MCH indicates probability of vitamin B₁₂ deficiency for 14.4% and 5.7%, respectively. Microcytic anemia in terms of MCV and MCH was higher among school age boys than girls. Although deficiency of RDW (<11%) was 59.7%, it does not signify to a concerning problem; however, a higher cut-off value indicates an iron/vitamin B₁₂/folate deficiency of 11.5% (RDW > 15%).

Table 6 represents WBC indicators and thrombocyte according to standard reference ranges. The prevalence of WBC deficiency was 35.3% indicating immunosuppression/viral infection. About 12.2% of children had WBC level above the cut-off level to represent inflammation or infection. The prevalence of granulocyte, monocyte, and lymphocyte deficiency was 64.9%, 32.8%, and 0.8%, respectively, which is indicative of immunosuppression. High level of granulocyte was prevalent in 1.5% of children indicating infection/inflammation. About 6.9% of children had high monocyte count demonstrating chronic infection while 74.8% had high lymphocyte count reflecting their susceptibility to viral infections. About 63.4% of children were subclinically deficient for thrombocyte (platelet), which is an important blood clotting factor. Higher level of thrombocytes observed in 76% of children is an indicative sign of viral infection/pernicious anemia.

The relationship between different health indicators of children is analyzed by correlation to establish the degree of association (Table 7). Hb, HCT, and RBC count were positively correlated with BAZ while the latter was negatively correlated with RDW. Hb was positively correlated with RBC, HCT, MCV, MCH, and monocyte but inversely correlated
with WBC, RDW, and granulocyte. WBC was negatively correlated with HCT and lymphocyte and positively correlated with thrombocyte and granulocyte. RBC was positively correlated with HCT and monocyte and inversely correlated with MCH and RDW. Similarly HCT was well correlated with MCV and monocyte and negatively correlated with RDW. MCV was found to be associated with MCH and monocyte and negatively correlated with RDW and granulocyte. RDW is negatively correlated with MCH and monocyte. Granulocyte was positively correlated with MCHC and negatively correlated with monocyte and lymphocyte. Monocyte was negatively correlated with MCHC.

4. Discussion

The present study attempted to assess the association of hematological indices with the prevalence of anemia among children in the rural surroundings of Bhubaneswar city, India. The mean Hb among school age boys was significantly lower than girls. Sahu et al. [12] also found a lower mean Hb level in school age boys than girls in Gajapati district, Odisha. Buhllyya et al. [13] showed a mean Hb level of 10.07 among adolescent girls of Khurda district, Odisha.

The prevalence of anemia among preschool children was 48.5%, which is much less when compared to the state.

### Table 6: Distribution of hematological (white blood cell) indicators by age group and sex among children in Odisha, India.

| Parameter Category | Parameter | Preschool children | School age children | Pooled children |
|--------------------|-----------|---------------------|---------------------|-----------------|
|                    | Total     | Boys                | Girls               | Boys            | Girls | Total     | Boys | Girls | Total     | Boys | Girls | Total         |
| WBC (thousand/mm³) | High      | 13.8 (4)            | 11.8 (2)            | 13.6 (1)        | 5.9 (3) | 19.0 (8) | 11.8 (11) | 8.7 (7) | 16.9 (10) | 12.2 (17) |
|                    | Standard  | 62.1 (18)           | 47.1 (8)            | 56.5 (26)       | 60.8 (31) | 38.1 (16) | 50.6 (47) | 61.3 (49) | 40.7 (24) | 52.5 (73) |
|                    | Deficiency| 24.1 (7)            | 41.1 (7)            | 30.4 (14)       | 33.3 (17) | 42.9 (18) | 37.6 (35) | 30.0 (24) | 42.4 (25) | 35.3 (49) |
| Granulocytes (%)   | High      | 3.4 (1)             | 0.0 (0)             | 2.2 (1)         | 2.1 (1) | 0.0 (0) | 1.2 (1) | 2.6 (2) | 0.0 (0) | 1.5 (2) |
|                    | Standard  | 34.5 (10)           | 35.3 (6)            | 34.8 (16)       | 39.6 (19) | 24.3 (9) | 32.9 (28) | 37.7 (29) | 27.8 (15) | 33.6 (44) |
|                    | Deficiency| 62.1 (18)           | 64.7 (11)           | 63.0 (29)       | 58.3 (28) | 75.7 (28) | 65.9 (56) | 59.7 (46) | 72.2 (39) | 64.9 (85) |
| Monocytes (%)      | High      | 13.8 (4)            | 0.0 (0)             | 8.7 (4)         | 6.3 (3)  | 5.4 (2) | 5.9 (5) | 9.1 (7) | 3.7 (2) | 6.9 (9) |
|                    | Standard  | 58.6 (17)           | 64.7 (11)           | 60.9 (28)       | 56.3 (27) | 64.9 (24) | 60.0 (51) | 57.1 (44) | 64.8 (35) | 60.3 (79) |
|                    | Deficiency| 27.6 (8)            | 35.3 (6)            | 30.4 (14)       | 37.4 (18) | 29.7 (11) | 34.1 (29) | 33.8 (26) | 31.5 (17) | 32.8 (43) |
| Lymphocytes (%)    | High      | 69.0 (20)           | 70.6 (12)           | 69.6 (32)       | 77.1 (37) | 78.4 (29) | 77.6 (66) | 74.0 (57) | 75.9 (41) | 74.8 (98) |
|                    | Standard  | 31.0 (9)            | 29.4 (5)            | 30.4 (14)       | 20.8 (10) | 21.6 (8) | 21.2 (18) | 24.7 (19) | 24.1 (13) | 24.4 (32) |
|                    | Deficiency| 0.0 (0)             | 0.0 (0)             | 0.0 (0)         | 2.1 (1)  | 0.0 (0) | 1.2 (1) | 1.3 (1) | 0.0 (0) | 0.8 (1) |
| Thrombocytes (thousand/mm³) | High      | 10.3 (3)            | 5.9 (1)             | 8.7 (4)         | 10.4 (5) | 2.7 (1) | 7.1 (6) | 10.5 (8) | 3.7 (2) | 7.6 (10) |
|                    | Standard  | 31.0 (9)            | 35.3 (6)            | 32.6 (15)       | 22.9 (11) | 32.4 (12) | 27.0 (23) | 25.9 (20) | 33.3 (18) | 29.0 (38) |
|                    | Deficiency| 58.7 (17)           | 58.8 (10)           | 58.7 (27)       | 66.7 (32) | 64.9 (24) | 65.9 (56) | 64.5 (49) | 63.0 (34) | 63.4 (83) |

Normal = number above the lower cut-off level. High = number above higher cut-off value. Standard = number within the range. Deficiency = number below the lower cut-off level. Figures in parentheses are sample number.

### Table 7: Pearson’s correlation coefficients (r) of different parameters in children of Odisha, India.

| Parameter | Value |
|-----------|-------|
| BAZ       | 1.00  |
| Hb        | 0.38¹ | 1.000 |
| WBC       | 0.452 | 0.232 | 1.000 |
| RBC       | 0.288 | 0.271 | 0.757 | 1.000 |
| HCT       | 0.26² | 0.94³ | 0.19⁴ | 0.94⁵ | 1.000 |
| MCV       | −0.041| 0.33⁶ | −0.079| −0.019| 0.28⁶ | 1.000 |
| MCH       | −0.032| 0.20⁷ | −0.093| −0.18⁷ | 0.066 | 0.75⁷ | 1.000 |
| MCHC      | −0.003| 0.006 | 0.133 | −0.043| −0.024| 0.049| 0.089| 1.000 |
| THR       | 0.057 | −0.052| 0.37³ | −0.033| −0.064| −0.073| −0.095| 0.028| 1.000 |
| RDW       | −0.37⁶ | 0.112 | −0.28⁶ | −0.38⁹ | 0.40⁹ | −0.19² | −0.002| −0.046| 1.000 |
| GRA       | −0.041| 0.21⁷ | 0.35⁶ | −0.090| −0.17⁶ | 0.092| 0.19¹ | 0.048| 0.10¹ | 1.000 |
| MON       | 0.135 | 0.27⁷ | −0.001| 0.21⁶ | 0.29⁹ | 0.29⁹ | 0.162 | −0.055| −0.069| −0.17⁴ | 0.17⁴ | 1.000 |
| LYM       | 0.008 | 0.14¹ | −0.36⁷ | 0.035 | 0.044| 0.10¹ | 0.058| −0.18¹ | 0.057| −0.057| −0.96¹ | 0.065 |

Significance: *p < 0.05, †p < 0.01, and ‡p < 0.001.

BAZ = BMI-for-age z-score, Hb = hemoglobin, RBC = red blood cell, HCT = hematocrit, MCV = mean corpuscular volume, MCH = mean corpuscular hemoglobin, MCHC = mean corpuscular hemoglobin concentration, RDW = red cell distribution width, WBC = white blood cell, GRA = granulocyte, MON = monocyte, LYM = lymphocyte, THR = thrombocyte.
data of 92.4% [14]. The type of anemia among school age children was 68.9% (mild 27.4%, moderate 23.6%, and severe 17.9%). Sahu et al. [12] found severity of anemia (35.2% mild, 59.4% moderate, and 5.4% severe) in children in Gajapati district much higher than the value in this study. Girls were significantly more anemic than boys in the age group of 11-12 years while more boys were anemic in the age group of 10-11 years. Similar results were reported for school children in Bangalore where prevalence of anemia was higher in boys aged 10 years whereas it was high in girls aged 11 years [15].

The mean HCT, MCV, and MCH of school age boys were significantly lower than girls. Zemel et al. [16] observed a significantly lower HCT among boys than girls of school age sickle cell children (excluding children receiving transfusion therapy). In this study chronic undernutrition (stunting) may be one of the factors for lower level of HCT. Kokore et al. [17] found that MCV and MCH are statistically higher for girls than their male counterparts aged 5–11 years. The hypochromasia (MCH deficient) and microcytosis (MCV deficient) in school age population are higher in boys than in girls. The disruption of erythrocyte parameters like MCV and MCH precedes the final stage of anemia with concurrent fall in Hb levels below the limit. In this study, decrease in MCV and MCH might indicate a deficiency in micronutrients including iron and vitamins as suggested earlier [18].

Mean MCV and MCH were significantly higher among school age girls than preschool girls. Moreover, MCH and MCHC of preschool children were low compared to school children. Similar findings were observed among girls of different age groups [19]. It was found that MCV and MCH were slightly lower in those under-5 children but subsequently increased and reached to the adult level by age of 6 years [20]. Several studies reported an increase in mean MCH and MCHC levels with increase in age [19, 21]. Vitamin B12 deficiency in terms of value above reference level for MCV and MCH was found to be 14.4% and 5.7%, respectively. Bleyere et al. [19] reported 5.1% of probable vitamin B12 deficiency (high MCV) among children.

In the current study, mean WBC count and proportion above the upper level were higher among preschool boys than school age boys (13.8% versus 5.9%). Excess WBC in the peripheral blood may be indicative of various disease states, including inflammation (acute or chronic) from bacteria virus or parasites [22]. Porniammongkol et al. [23] demonstrated that the percentage of children with elevated WBC compared to normal range was higher in the younger age than in the older age. In this study, the prevalence of WBC deficiency was 35.3% indicating immunosuppression/viral infection while 12.2% of them had WBC level above the cut-off level representing inflammation or infection. Bleyere et al. [19] found WBC level below the range in 26.8% and 0.8% in above the range of children in West Africa. The percentage of children above the upper limit was much higher in this study population and the reason may be that both WBC and granulocyte are inversely correlated with Hb (p < 0.001). It was also previously well documented that WBC and percentage of neutrophil are inversely associated with Hb [24]. Since a large proportion of study population is anemic (62%) that may lead to overall elevated levels of WBC.

The mean RDW was 11.5% in the study population of which preschool girls have significantly higher level of RDW both by mean level and frequency. It was previously demonstrated that RDW levels were significantly higher in lower age group of iron deficient children in Turkey as well as girls who had higher value than boys [25]. A higher cut-off value for RDW indicates an iron/vitamin B12/folate deficiency observed to be 11.5% in the study population. An elevated RDW is also believed to be an early indicator of iron deficiency [26].

The mean values of granulocyte, monocyte, and lymphocyte were 36.71%, 5.68%, and 57.38%, respectively, and preschoolers had correspondingly 36.16%, 6.02%, and 57.14% as confirmed by our previous study [27] along with school age children having 37.00%, 5.50%, and 57.50%, respectively. The mean monocyte and lymphocyte values in children of West Africa were found to be 5.2% and 31.3%, respectively [17], which is closer to our value. The prevalence of granulocyte, monocyte, and lymphocyte deficiency was 64.9%, 32.8%, and 0.8%, respectively. About 74.8% of children had high lymphocyte count representing their susceptibility to viral infection. Kokore et al. [17] found only 0.3% of lymphocyte deficiency in children, which is much less than that of our value, while a high lymphocyte count was observed among 88.7% of children. In this study chronic infection was indicated by high monocyte count among 6.9% of children. The prevalence of low monocytes is reported to be less at 6.5% and 4.8%, respectively, in other studies [17, 19]. Monocytes represent a source of proinflammatory cytokines and thus are believed to play a role in obesity-associated disease [28]. Chapman et al. [29] demonstrated monocyte concentration to be an independent risk factor for subclinical carotid atherosclerosis. About 63.4% of children were below the lower range for thrombocyte. Higher level of thrombocytes observed in 7.6% of children indicates viral infection/pernicious anemia. This high number of platelet deficiency may be due to various cut-off levels suggested to be used for different age group of children whereas many authors recommended to consider a single cut-off for all age groups (<150 thousand/mm³). Using this range, Kokore et al. [17] and Bleyere et al. [19] found low thrombocytes in 1.9% and 5.8% of total population, respectively. It was observed that disorders of the bone marrow and other medical conditions could cause an elevated platelet count [30].

Hb was positively correlated with RBC, HCT, MCV, MCH, and monocyte in this population. At birth, the total Hb level, RBC, and HCT are shown to be higher than at any other period of life [31]. The Hb content and the RBCs then gradually rise to adult levels by the age of puberty [32]. Maude et al. [33] even also found RBC correlated positively with total Hb in homozygous sickle cell patients where there is abnormal synthesis of Hb. It was established that the HCT usually correlates well with Hb but is even less sensitive for iron deficiency than Hb [34]. The positive association between Hb and MCV suggests a lesser chance of macrocytic anemia in the study population as the concentration of Hb varies concomitantly with cell volume. When RBCs divide in the bone marrow compartment, the resultant two daughter
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indices with venous thrombosis indicates association of these blood cut-off as well as a higher peripheral blood monocyte count between high MCV (above cut-off) and high MCH (above cut-off) as well as with the gender and age groups, constant monitoring and intervention strategy is needed while providing nutritional supplementation to eradicate anemia. We recommend awareness creation on water and sanitation and nutritional counselling to parents on consumption of iron-rich foods and iron supplementation to prevent anemia among young children with special emphasis on those from low income group and socioeconomic deprived communities.

Competing Interests

The authors declare that there are no competing interests regarding the publication of this paper.
Authors’ Contributions

Shuchismita Behera was responsible for collecting the data, laboratory analysis, data management, interpreting the data, and writing the paper. Gandham Bulliyaa was responsible for conceiving and designing the study, obtaining ethical approval, analyzing the data, interpreting the data, and critically reviewing the paper.

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