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The Relationship Between Hemoglobin Levels and Erythrocyte Index with the Nutritional Status of Weight Faltering Toddlers at the Pulo Armyn Health Center, Bogor City

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Abstract

Weight faltering in young children may coexist with hematological abnormalities, highlighting the need for accessible laboratory assessments in primary healthcare settings. This study examined the associations between hemoglobin concentrations, erythrocyte indices, and the severity of weight faltering among children attending Pulo Armyn Health Center in Bogor City, Indonesia. This quantitative observational study employed a cross-sectional design and included 80 purposively selected children aged 0–59 months. Anthropometric records were used to classify the severity of weight faltering, while blood samples were analyzed using a Mindray BC-11 hematology analyzer. Associations were assessed using Spearman's rank correlation analysis. Mean hemoglobin concentrations decreased from 10.9 g/dL in children with mild weight faltering to 10.0 g/dL in those with moderate weight faltering and 8.8 g/dL in those with severe weight faltering. The severity of weight faltering was strongly negatively correlated with hemoglobin concentration ($r = -0.929$) and moderately negatively correlated with mean corpuscular volume (MCV; $r = -0.450$), mean corpuscular hemoglobin (MCH; $r = -0.548$), and mean corpuscular hemoglobin concentration (MCHC; $r = -0.540$). These findings indicated that greater weight faltering severity was associated with more pronounced hematological abnormalities, with patterns suggestive of microcytic, hypochromic anemia. However, iron deficiency could not be confirmed because iron status biomarkers were not assessed. Hemoglobin concentrations and erythrocyte indices may complement anthropometric monitoring in children experiencing weight faltering. Nevertheless, further studies incorporating appropriate comparison groups, iron status assessments, and diagnostic accuracy analyses are needed before these hematological parameters can be recommended as screening biomarkers for weight faltering in primary healthcare settings.

INTRODUCTION

Children's health, growth, and development are important indicators of a nation's social and economic progress. According to the World Health Organization (WHO), approximately 150.2 million children under five years of age, representing 23.2% of this population, were affected by stunting in 2024 (United Nations Children's Fund [UNICEF] et al., 2025). Furthermore, the 2025 Global Hunger Index (GHI) ranked Indonesia 70th among 123 countries, with a hunger severity classification of moderate. The GHI incorporates several indicators of nutritional deprivation, including the prevalence of wasting and stunting among children under five years of age (Concern Worldwide & Welthungerhilfe, 2025). These findings highlight the continuing challenges associated with childhood malnutrition and the importance of strengthening early growth monitoring and nutritional interventions.

According to the 2024 Indonesian Nutritional Status Survey (Survei Status Gizi Indonesia, SSGI), the prevalence of stunting among children under five years of age was 15.9% in West Java Province and 21.1% in Bogor City (Ministry of Health of the Republic of Indonesia, 2025). Data from the Bogor City Health Office's fourth-quarter 2025 nutrition program report indicated that 16,016 of the 60,655 children weighed (26.4%) experienced weight faltering, while the reported prevalence of stunting was 7.4%. At Pulo Armyn Community Health Center (Puskesmas Pulo Armyn), 399 of the 2,334 children monitored (17.1%) were identified as experiencing weight faltering. These findings indicate that inadequate weight gain remains a substantial concern in Bogor City and emphasize the importance of early identification and intervention to reduce the risk of subsequent growth impairment (Bogor City Health Office, 2025).

Weight faltering is a common reason for pediatric consultations and hospital admissions, affecting approximately 5%–10% of children in primary care settings and 3%–5% of children in referral healthcare facilities (Kersten et al., 2026). Weight faltering may precede linear growth impairment and is recognized as an important warning sign of nutritional or underlying medical problems. Growth deceleration during early infancy, particularly within the first three months of life, has been identified as a potential predictor of subsequent stunting (Ministry of Health of the Republic of Indonesia, 2022). Several factors may contribute to weight faltering, including inadequate energy intake, nutrient malabsorption, and increased metabolic demands associated with underlying diseases. Iron deficiency and iron deficiency anemia (IDA) may coexist with these conditions and contribute to impaired growth and development, although they are not necessarily direct causes of weight faltering (Ministry of Health of the Republic of Indonesia, 2020).

Iron deficiency anemia and chronic undernutrition can have substantial consequences for children's physical growth, cognitive development, and overall health. Early identification and intervention are particularly important because nutritional deficiencies during critical developmental periods may have lasting effects. The initial laboratory evaluation of suspected anemia commonly includes a complete blood count (CBC), followed by appropriate iron status assessments when clinically indicated. Reduced hemoglobin concentration, mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH) may suggest microcytic, hypochromic anemia, a hematological pattern commonly associated with iron deficiency. However, these findings are not specific to IDA and may also occur in conditions such as

thalassemia and sideroblastic anemia. Therefore, CBC-derived parameters can support preliminary anemia assessment but cannot independently confirm iron deficiency, which requires further evaluation using appropriate biochemical markers and clinical findings (Aksu & Ünal, 2023; Andriastuti et al., 2020; Sungkar et al., 2022; Wahyuni, 2024).

Previous research has demonstrated a potential association between IDA and impaired linear growth. A review reported that 9 of 15 included studies supported an association between IDA and stunting, with an estimated 2.27-fold higher risk of stunting among children with IDA than among those without the condition (Oktarina et al., 2024). Children under five years of age are particularly vulnerable to iron deficiency because of their rapid growth and increased nutritional requirements. In this age group, hemoglobin concentrations below 11 g/dL have commonly been used as an anemia threshold, while serum ferritin concentrations below 12 µg/L have been used to indicate depleted iron stores in the absence of inflammation. However, interpretation of these parameters should consider age-specific diagnostic criteria, inflammatory status, and relevant clinical guidelines (Oktarina et al., 2024; UKK Hematology Pediatric Oncology IDAI, 2024). These findings suggest that hematological assessment may provide useful supplementary information when evaluating children with growth disturbances.

Despite increasing attention to childhood malnutrition and anemia, evidence regarding the relationship between hemoglobin concentrations, erythrocyte indices, and the severity of weight faltering remains limited. Previous studies have frequently emphasized hemoglobin and serum ferritin measurements, whereas the potential associations of routinely available erythrocyte indices with weight faltering have received comparatively less attention. Serum ferritin testing may also be less accessible in primary healthcare settings because of laboratory capacity constraints and additional testing costs. In contrast, hemoglobin measurements and erythrocyte indices are commonly obtained through routine hematological examinations and may provide supplementary information for the clinical evaluation of children with inadequate weight gain. At Pulo Armyn Health Center, these parameters are used to support clinical assessments and referrals for children experiencing weight faltering. Nevertheless, their relationship with the severity of weight faltering in this population has not been adequately investigated. Standardized anthropometric assessment based on the WHO Child Growth Standards remains essential for identifying and monitoring growth disturbances (WHO Multicentre Growth Reference Study Group, 2006).

Pulo Armyn Health Center was selected as the research location because of the relatively high proportion of children experiencing weight faltering within its service area. According to the 2025 nutrition program report, 399 of the 2,334 children monitored at this health center (17.1%) experienced weight faltering, compared with 14.3% reported at other health centers within the same district. Furthermore, Pulo Armyn Health Center serves four urban villages in East Bogor District, providing an opportunity to examine growth-related health concerns among children receiving primary healthcare services. However, the health center's broad service coverage does not necessarily establish the representativeness of the study sample. The findings were expected to provide preliminary evidence to support local clinical assessment practices and inform the development of standard operating procedures (SOPs) for identifying and monitoring children at risk of nutritional and growth disorders.

Based on these considerations, this study aimed to examine the associations between hemoglobin concentrations, erythrocyte indices, and the severity of weight faltering among children aged 0–59 months attending Pulo Armyn Health Center in Bogor City, Indonesia. Specifically, the study investigated whether hemoglobin concentration, MCV, MCH, and mean corpuscular hemoglobin concentration (MCHC) were correlated with the severity of weight faltering. The study sought to contribute evidence regarding the potential role of routine hematological parameters as complementary indicators in the nutritional assessment of children with inadequate weight gain. From a primary healthcare laboratory perspective, these findings may help inform accessible and affordable approaches to clinical monitoring. Nevertheless, hematological parameters should be interpreted alongside anthropometric measurements and clinical assessments, and their potential diagnostic or screening utility requires further validation before routine implementation.

METHOD

This quantitative observational study employed a cross-sectional design to examine the associations between hemoglobin concentrations, erythrocyte indices (MCV, MCH, and MCHC), and the severity of weight faltering among children aged 0–59 months. Weight faltering severity was assessed using anthropometric records and classified as mild, moderate, or severe based on changes in growth z-scores. Hemoglobin concentrations and erythrocyte indices were measured using a Mindray BC-11 hematology analyzer (Dosen Teknologi Laboratorium Medik Indonesia, 2019).

The study population comprised 399 children aged 0–59 months who experienced inadequate weight gain within the service area of Pulo Armyn Health Center, Bogor City, according to the 2025 nutrition program records. A sample of 80 children was determined using Slovin's formula and recruited through purposive sampling. The inclusion criteria were age 0–59 months, residence within the study area, participation in routine monthly anthropometric monitoring, and no weight gain or a decrease in weight over three consecutive months. Children older than 59 months, those receiving tuberculosis treatment, and those diagnosed with thalassemia were excluded.

Data were collected from primary and secondary sources. Primary data included venous blood samples collected in ethylenediaminetetraacetic acid (EDTA) tubes (Rosita et al., 2019; Yuniarty et al., 2024) and information obtained through parental interviews. Secondary data were retrieved from maternal and child health (Kesehatan Ibu dan Anak, KIA) handbooks and medical records. Following participant screening and informed consent, blood samples were collected using standardized procedures and analyzed for hemoglobin concentration and erythrocyte indices. Laboratory quality control was performed using three levels of control materials before sample analysis (Kiswari, 2014).

Data were analyzed using the Shapiro–Wilk test to assess normality and Spearman's rank correlation coefficient (Spearman's rho) to evaluate associations between weight faltering severity and hematological parameters. Statistical significance was established at $p < 0.05$. The study followed the ethical principles of autonomy, beneficence, nonmaleficence, and justice (Beauchamp & Childress, 2013). Data collection was conducted at the Pulo Armyn Health

Center Laboratory and four integrated health service posts (Pos Pelayanan Terpadu, Posyandu) in Bogor City from August 6 to 13, 2026.

RESULTS AND DISCUSSION

The results of this study showed that the higher the degree of weight faltering in toddlers, the lower the level of hemoglobin (Hb) and erythrocyte index. In the light weight faltering group , an average of Hb of 10.9 g/dL, MCV of 75.8 fL, MCH of 25.3 pg, and MCHC of 33.5 g/dL. In the moderate degree, it decreased to Hb 10.0 g/dL, MCV of 73.9 fL, MCH of 24.0 pg, and MCHC of 32.5 g/dL. Meanwhile, the average weight level decreased, namely Hb 8.8 g/dL, MCV 66.7 fL, MCH 21.1 pg, and MCHC 31.8 g/dL. This pattern shows that the worse the nutritional status of toddlers, the more likely it is that there will be impaired formation of erythrocytes and hemoglobin (Gallagher, 2022).

The results of Spearman's rho correlation analysis also showed a negative relationship between the degree of weight faltering with Hb (r = -0.929), MCV (r = -0.450), MCH (r = -0.548), and MCHC (r = -0.540). The negative relationship showed that the increase in the degree of weight faltering was followed by a decrease in Hb levels and erythrocyte index. These findings support that weight loss disorders in toddlers not only describe problems in anthropometric results, but also related to the condition of hematological parameters that reflect inadequate nutritional intake, especially iron (Smith et al., 2023).

Biologically, weight faltering is a condition when a child's weight gain does not match the expected growth pattern due to an imbalance between nutrient needs and intake. This condition can occur due to insufficient energy and protein intake, recurrent infections, absorption disorders, increased metabolic needs, as well as social factors and less than optimal diet. Recent literature on growth faltering confirms that this condition is multifactorial and can be an early manifestation of chronic malnutrition (Smith et al., 2023).

The relationship between weight faltering and Hb levels can be explained through the mechanism of iron deficiency and other micronutrients needed for erythropoiesis. Iron is the main ingredient in the formation of heme, while protein is needed for the synthesis of globin. In children with weight faltering, inadequate food intake causes the body's iron reserves to decrease, so that heme formation is disrupted. If the deficit persists, hemoglobin synthesis will also be inhibited and Hb levels in the blood decrease. This condition is the basis for iron deficiency anemia (Moscheo et al., 2022).

Pathophysiologically, iron deficiency anemia begins with the depletion of the body's iron reserves stored in the form of ferritin. When this reserve decreases, serum iron levels are reduced and transferin is no longer able to transport iron adequately to the bone marrow. As a result, the process of heme and hemoglobin formation is disrupted, making erythropoiesis ineffective. The resulting erythrocytes are smaller than normal in size and contain less hemoglobin. This mechanism is in accordance with the decrease in MCV, MCH, and MCHC found in this study (Moscheo et al., 2022; National Research and Innovation Agency [BRIN], 2023).

A decrease in MCV indicates the presence of microcytosis, which is a smaller than normal size of erythrocytes. A decrease in MCH describes a decrease in the amount of hemoglobin in each erythrocyte, while a decrease in MCHC indicates a decrease in the

concentration of hemoglobin in red blood cells. The combination of these three parameters is a typical picture of hypochromic microcytic anemia, which is most often caused by iron deficiency. Thus, the results of this study strongly lead to iron deficiency anemia as a condition that accompanies weight faltering in toddlers (Buliani & Mustakim, 2025; Gajbhiye & Aate, 2023; Gallagher, 2022).

In this study, it was also found that the average RDW-SD value increased in line with the deterioration of the degree of weight faltering, namely 39.1 fL in mild degrees, 40.0 fL in moderate degrees, and 42.9 fL in severe degrees. RDW-SD describes the degree of variation in erythrocyte size (anisocytosis) the higher the value, the more heterogeneous the red blood cell size. A number of studies show that RDW tends to increase in iron deficiency anemia due to the mixture of older normocytic erythrocytes and newly formed microcytic erythrocytes, resulting in greater variation in cell size. The combination of decreased Hb, low erythrocyte index, and increased RDW-SD reflects the picture of hypochromic microcytic anemia with anisocytosis typical of iron deficiency anemia. This pattern is different from the thalassemia trait, which generally shows low MCV with relatively normal or only slightly increased RDW. The highest increase in RDW-SD in the weight-faltering group in this study reinforces the suspicion that heavier nutritional status disorders are related to the unstable erythropoiesis process due to insufficient iron and other nutrients (Krawiec & Pac-Kożuchowska, 2020; Sazawal et al., 2014).

Erythropoiesis is a process of erythrocyte formation in the bone marrow that requires the availability of iron, amino acids, folate, vitamin B12, and erythropoietin stimulation. In an iron-deficient state, erythroblasts continue to undergo cell division, but are unable to synthesize sufficient amounts of hemoglobin. As a result, mature erythrocytes become smaller, paleer, and less functional. Physiologically, the body tries to compensate by stimulating erythropoiesis, but without an adequate iron substrate, the response is ineffective (Gallagher, 2022; Suryanty et al., 2005; Ţichil et al., 2024).

In the synthesis of hemoglobin, heme and globin must be available in sufficient quantities for hemoglobin to form normally. Heme requires iron, while globin is composed of amino acids resulting from protein metabolism. In weight-faltering toddlers, the energy and protein deficits that often accompany iron deficiency can worsen the formation of Hb. Therefore, the decrease in Hb in this study is likely not only due to iron deficiency, but also due to a general lack of nutritional intake that affects the process of hemoglobin biosynthesis (Moscheo et al., 2022; Sitanggang et al., 2024).

Factors that cause weight faltering that can contribute to this condition include inadequate food intake, improper feeding of breast milk companions, recurrent infectious diseases, absorption disorders, and a history of low or premature birth weight. In addition, socioeconomic conditions, parenting style, and eating habits of children also play a role. If these factors persist for a long time, the need for iron increases while the intake is insufficient, so the risk of iron deficiency anemia becomes greater (Smith et al., 2023).

Clinically, toddlers with iron deficiency anemia may show symptoms of paleness, lethargy, fatigue, decreased appetite, and lack of activity. In this study, the heavy weight faltering group had the lowest average Hb, which was 8.8 g/dL, which clinically indicated a more pronounced risk of anemia than the mild and moderate groups. Meanwhile, the lower

MCV value at the weight level showed that the erythrocytes formed were getting smaller, which reinforced the suspicion of hypochromic microcytic anemia due to iron deficiency (Gallagher, 2022).

These results are in line with the theory that weight loss disorders in children are closely related to long-term nutritional status and the possibility of micronutrient deficits. Weight faltering is not only an indicator of stunted growth, but can also be an early sign of a wider range of nutritional problems, including anemia. Therefore, Hb and erythrocyte index checks in toddlers with weight faltering are essential as part of early detection to prevent further impacts on children's growth and development (Smith et al., 2023).

The results of this study show that hemoglobin (Hb) levels and erythrocyte index have the potential as hematological biomarkers for early detection of weight faltering in toddlers. This is supported by the finding that the heavier the weight faltering degree, the lower the levels of Hb, MCV, MCH, and MCHC, which indicates the occurrence of erythropoiesis disorders and hypochromic microcytic anemia patterns consistent with iron deficiency. Clinically, this change is important because iron deficiency is one of the conditions that often accompanies child growth disorders and contributes to the risk of stunting (Budiailmiawan et al., 2024).

Decreased Hb levels indicate that toddlers with weight faltering are in a physiological condition that is not optimal to support growth. Hb is the main component of oxygen transport, so its decrease can disrupt the oxygen supply of tissues and reduce the efficiency of energy metabolism, protein synthesis, and linear growth processes. Thus, Hb not only reflects hematologic status, but can also be seen as an early indicator of chronic nutritional disorders that have the potential to continue into stunting (Budiailmiawan et al., 2024).

Erythrocyte indices, particularly MCV, MCH, and MCHC, also showed a pattern of decline that was consistent with the degree of weight faltering. Decreased MCV indicated microcytosis, while decreased MCH and MCHC indicated hypochromia, both of which are typical hallmarks of iron deficiency anemia. Since iron deficiency has been reported to be associated with growth disorders, decreased cognitive function, and increased susceptibility to infection, erythrocyte index parameters may serve as additional markers to identify toddlers who have begun to enter the stage at risk of stunting (Budiailmiawan et al., 2024).

One of the exclusion criteria in this study is thalassemia patients. To ensure that the sample is not a thalassemia trait sufferer, the researcher used the Mentzer Index, which is a discriminative erythrocyte index calculated using the MCV/RBC formula and used to distinguish iron deficiency anemia from thalassemia traits, specifically □-thalassemia trait. In general, the Mentzer Index value > 13 leads to iron deficiency anemia, while the < value of 13 leads to thalassemia trait. In the latest study in the Indonesian population, the optimal cut-off of the Mentzer Index was reported to be around 13.23, with a sensitivity of 71.05% and a specificity of 82.93%. Nevertheless, the conventional limit of >13 is still considered relevant to lead to iron deficiency anemia (Chaber et al., 2024) .

Based on the data from the calculation of the Mentzer Index on 80 respondents in all categories, the highest score was obtained of 18 with the lowest value of 14. All of these values are above the conventional reference limit and the latest optimal limit reported in the Indonesian population. This shows that the research sample is more consistent with iron

deficiency anemia and is less likely to be thalassemia trait. This finding is important because thalassemia trait can also provide a microcytic picture of hypochrome, but the mechanism is different, namely due to impaired globin synthesis, not iron deficiency. Thus, the results of the Mentzer Index in this study support that the sample is in accordance with the research criteria and the relationship found between weight faltering and decreased Hb and erythrocyte index can be interpreted as the impact of poor nutritional status on iron deficiency anemia (Chaber et al., 2024).

A number of studies have stated that exclusive breastfeeding plays a role in maintaining iron and hemoglobin status in early life. In addition to hematological parameters, this study also assessed the history of exclusive breastfeeding in toddlers with weight faltering. Data showed that the percentage of toddlers who did not receive exclusive breastfeeding was highest in the weight faltering weight category with a percentage of 75% compared to the light category of only 3% and medium 26.7%. This pattern indicates that the non-fulfillment of exclusive breastfeeding has the potential to contribute to the nutritional status of toddlers. Exclusive breastfeeding during the first 6 months of life is the main source of energy, protein, and micronutrients. Babies who do not get exclusive breastfeeding or get it for a shorter duration tend to be more susceptible to inadequate iron intake and recurrent infections, so the need for iron increases while the reserves are limited. This condition contributes to the occurrence of iron deficiency anemia, which in this study is illustrated by a decrease in Hb, MCV, MCH, MCHC. Thus, a history of exclusive breastfeeding that is less than optimal can be seen as one of the factors that aggravates weight faltering while increasing the risk of anemia and long-term growth disorders, including stunting (Erwani et al., 2023).

This study shows that Hb and erythrocyte index tests have the potential to be used in primary health care as a practical, inexpensive, and easy-to-apply screening tool to detect children with weight faltering before chronic malnutrition occurs. In the context of stunting prevention, this approach is important because weight faltering appears earlier than stunting, so changes in hematological parameters can be an early biological signal that the child is on an underoptimal growth path. Thus, Hb and erythrocyte index can be considered as supporting biomarkers to identify high-risk children and faster nutritional interventions (Budiailmiawan et al., 2024).

The disadvantage of this study is that it does not use healthy toddler populations as a control population to obtain hemoglobin levels and erythrocyte index. So that hemoglobin and new erythrocyte index can be said to be "potentially" to be screening biomarkers. If there is a healthy and weight faltering control population, the results of hemoglobin and erythrocyte index in both populations can be statistically tested directly using ROC (Receiver Operating Characteristic) which functions to assess discriminatory ability, determine cut-off value, sensitivity, specificity, and AUC (Area Under the Curve) of an examination or biomarker in distinguishing two conditions or groups. So that it can be more strongly known whether hemoglobin and erythrocyte index can really be used as a screening parameter for weight faltering.

CONCLUSION

Based on the findings of this study, conducted from August 6 to 13, 2026, at Pulo Armyn Health Center in Bogor City, Indonesia, significant negative correlations were identified between the severity of weight faltering and hemoglobin concentrations and erythrocyte indices, including mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), among children aged 0–59 months. Greater weight faltering severity was associated with lower hemoglobin concentrations and reduced erythrocyte index values. The strongest negative correlation was observed between weight faltering severity and hemoglobin concentration, whereas MCV, MCH, and MCHC demonstrated moderate negative correlations. These findings suggest that more severe weight faltering is associated with more pronounced hematological abnormalities, highlighting the potential relevance of routine hematological assessments in evaluating children with growth disturbances.

The findings indicate that hemoglobin concentrations and erythrocyte indices may serve as complementary hematological indicators in the clinical assessment and nutritional monitoring of children experiencing weight faltering. Incorporating these parameters alongside routine anthropometric measurements may support the early identification of associated hematological abnormalities and facilitate timely nutritional and clinical interventions. However, the cross-sectional design does not establish causality, and the observed associations do not confirm the diagnostic accuracy of these parameters as screening biomarkers for weight faltering or stunting. Further prospective studies with appropriate comparison groups and diagnostic validation are needed to determine their clinical utility. Strengthening integrated anthropometric and hematological monitoring in primary healthcare settings may contribute to broader efforts to prevent childhood growth impairment and reduce the risk of stunting.

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CONFLICT OF INTEREST

The author states that there is no conflict of interest in the preparation of this article.

AUTHOR CONTRIBUTION

All authors contributed to conceptualization, search and synthesis of literature, interpretation of results, manuscript preparation, and critical review of manuscripts. All authors have read and approved the final version of the manuscript.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

The authors declare that Generative Artificial Intelligence (Generative AI) was used solely to assist with language refinement, grammatical correction, and improvement of manuscript readability. All scientific concepts, interpretations, literature synthesis, analyses, and conclusions were developed by the authors. All AI-assisted content was carefully reviewed, verified, and revised by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript.

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