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Nutritional status and its association with serum ferritin, vitamin D, and hematological parameters in adolescent girls living in a boarding school

Muniroh Muniroh[1,2*], Yona Mimanda[2], Siti Aisyah Nur Jauharoh[2], Ana Raudah Al Jannah[3], Bellya Affan Roes[2], Fawwaz Amora Sulthan[4], Yusran Tamsyi Sopian[4], Tuty Rizkianti[5], Yanti Susianti[6]

[1]Graduate School Student, UIN Syarif Hidayatullah Jakarta, Indonesia
[2]Department of Clinical Pathology, Faculty of Medicine, UIN Syarif Hidayatullah Jakarta, Indonesia
[3]Department of Community Medicine, UIN Syarif Hidayatullah Jakarta, Indonesia
[4]Faculty of Medicine, UIN Syarif Hidayatullah Jakarta, Indonesia
[5]Department of Clinical Pathology, Faculty of Medicine, UPN Veteran Jakarta, Indonesia
[6]Department of Pediatrics, Faculty of Medicine, UIN Syarif Hidayatullah Jakarta, Indonesia

*Corresponding to:
Muniroh Muniroh; Graduate School Student, UIN Syarif Hidayatullah Jakarta, Indonesia; Department of Clinical Pathology, Faculty of Medicine, UIN Syarif Hidayatullah Jakarta, Indonesia;
dr.muniroh@gmail.com
Phone: +62 81808303888

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ABSTRACT

Introduction: Iron and vitamin D are critical micronutrients for adolescent health, but deficiencies remain highly prevalent in environments with limited sun exposure, such as boarding schools. Evidence regarding the associations between nutritional status and hematological parameters in these settings is limited. This study aimed to examine the association between body mass index (BMI), ferritin, serum vitamin D, and hemoglobin among adolescent girls in a boarding school.

Methods: A cross-sectional study was conducted among 56 adolescent girls aged 16 to 18 years. Nutritional status was assessed using World Health Organization Body Mass Index (BMI)-for-age standards. Serum ferritin, 25(OH)D, and complete blood count were measured using standardized laboratory procedures. Data were analyzed using an independent t-test, Mann–Whitney U test, and Spearman's correlation according to data distribution.

Result: The majority of participants (83.90%) had a normal nutritional status. The median serum vitamin D level was 9.90 ng/mL (IQR: 7.97-11.37), indicating a high prevalence of deficiency. The mean serum ferritin level was 37.31 ± 29.59 ng/mL. No significant correlation was found between BMI and laboratory parameters, including vitamin D ($p = 0.660$), ferritin ($p = 0.706$), and hemoglobin ($p = 0.525$).

Conclusion: Despite adequate nutritional status in most participants, suboptimal vitamin D levels were prevalent. The lack of significant associations suggests other contributing factors, such as lifestyle or sunlight exposure. Routine nutritional assessment and vitamin D monitoring are recommended in institutional settings to support adolescent health.

Keywords: Vitamin D, ferritin, hemoglobin, nutritional status.
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INTRODUCTION

Adolescence is a critical stage of human growth and development that demands increased nutritional intake required to support physical, hormonal, and cognitive changes.[1,2] At this stage, micronutrients such as iron and vitamin D are essential for maintaining hematological function, bone integrity, immune function, and overall well-being.[3] Iron supports hemoglobin synthesis and oxygen transport, whereas vitamin D contributes to calcium and phosphorus metabolism, hematopoiesis, and immune function.[4] Deficiencies in either nutrient can lead to health consequences, including anemia, fatigue, reduced concentration, and higher susceptibility to infection.[5,6]

On a broader scale, iron deficiency remains the most common nutritional deficiency worldwide, which affects mostly female adolescents.[7] Menstrual blood loss, rapid growth, and inadequate dietary intake make adolescent girls highly vulnerable to depleted iron stores.[8] At the same time, vitamin D deficiency has emerged as a public health concern, even in tropical regions.[9,10] Despite abundant sunlight, limited sun exposure due to indoor schooling, cultural clothing practices, and low dietary consumption contribute to insufficient vitamin D levels in adolescents, particularly females.

Recent research has suggested a biological link between vitamin D and iron metabolism.[11–13] Vitamin D has been proposed to influence the regulation of hepcidin, a hormone that inhibits iron absorption and mobilization. Theoretically, by suppressing hepcidin expression, adequate vitamin D levels may improve iron bioavailability and storage. However, results from previous studies remain inconsistent, with some studies reporting a significant association between vitamin D and ferritin, but others failing to show the correlation.[14] These inconsistencies may be attributed to variations in age groups,

ethnicity, geographic location, and the influence of confounding factors such as inflammation, infection, or malnutrition.

In Indonesia and other developing countries, many female adolescents pursue education in Islamic boarding schools, where limited dietary variety and restricted outdoor activities increase the risk of micronutrient deficiencies. This risk is further intensified among students who wear the hijab or niqab, as low skin exposure to ultraviolet B limits endogenous vitamin D synthesis. Previous studies have shown that such clothing practices are associated with lower serum 25(OH) D levels, independent of BMI, education, or supplement use.[15–17] However, there remains a lack of population-specific studies that examine the nutritional and hematologic status of female adolescents living in Islamic boarding schools, particularly in the Indonesian context.

Although the importance of iron and vitamin D is well established, few studies have examined their interaction in relation to nutritional status and hematological parameters in adolescent girls, especially in institutional environments. Clarifying this association is important for detecting subclinical deficiencies and guiding targeted nutritional interventions.

Therefore, the present study aimed to examine the association between nutritional status, serum vitamin D, ferritin, and hematological parameters among adolescent girls in a boarding school. By focusing on a population that faces dietary and environmental limitations, this study seeks to generate evidence that can inform school-based nutrition policies and preventive health strategies.

METHODS

Study Design and Participants

This study used an analytical cross-sectional observational design based on stored serum samples. The samples were originally collected from Darul Qur'an Mulia Islamic boarding school in Bogor, Indonesia, between October and November 2023 as part of a preliminary study. The school was selected due to its structured communal living environment, where students have limited control over dietary intake and sun exposure, which are the two factors related to iron and vitamin D metabolism.

A total of 56 adolescent girls aged 16 to 18 years were included using total sampling. The inclusion criteria were healthy students residing in the boarding school, with no history of chronic illnesses, no ongoing supplementation of iron or vitamin D, and willingness to participate. Exclusion criteria included a history of chronic disease, recent infection or inflammation, and refusal to provide informed consent.

Anthropometric and Nutritional Assessment

Body weight and height were measured using a calibrated digital scale and stadiometer. Body mass index (BMI) was calculated (kg/m^2) and categorized according to WHO 2007 BMI-for-age standards: normal (-2 to +1 S.D.), overweight (> +1 to +2 S.D.), and obese (> +2 S.D.). No participants were classified as underweight (<-2 S.D.).

Sample Collection and Storage

Venous blood samples (5 mL) were collected into EDTA vacutainer tubes and plain tubes without anticoagulant by trained phlebotomists. Samples were centrifuged at 3000g for 15 minutes, and serum aliquots were separated. All aliquots were immediately frozen and stored at -80°C in the laboratory. Samples were stored from November 2023 until the time of laboratory analysis.

Biochemical Measurements

Serum 25-hydroxyvitamin D [25(OH) D] levels were measured using a direct competitive chemiluminescence immunoassay (CLIA) method on the DiaSorin LIAISON® analyzer with the LIAISON® 25 OH Vitamin D TOTAL assay reagent. This method quantitatively determines the total 25(OH)D, including D2 and D3 forms, through a direct competitive binding mechanism where vitamin D in the sample competes with a labeled analog for antibody binding sites. The resulting chemiluminescence signal is inversely proportional to the concentration of vitamin D.

Ferritin levels were determined using Enzyme-Linked Fluorescent Assay (ELFA), which combines a one-step enzyme immunoassay sandwich with a final fluorescent detection. All the assay steps were performed automatically using the VIDAS® Ferritin analyzer.

Sample analyses were conducted at South Tangerang Public Hospital and the Research and Development Division, Prodia Clinical Laboratory, Jakarta, Indonesia, by following the manufacturers' protocols and quality control procedures. Serum vitamin D levels were expressed in ng/mL and classified according to the Endocrine Society guidelines, which define deficiency as <20 ng/mL.

Hematological Analysis

A complete blood count (CBC) was performed using a Sysmex XN-450 hematology analyzer. The parameters assessed included hemoglobin (Hb), hematocrit (Hct), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). These analyses were conducted at the Clinical Pathology Laboratory.

Statistical Analysis

All data were analyzed using SPSS version 26.0. Normally distributed numerical variables were expressed as means ± standard deviation (S.D.), and non-normally distributed variables were expressed as medians and interquartile ranges (IQR). The Kolmogorov-Smirnov test was used to assess normality.

Bivariate comparisons between groups were analyzed using an independent t-test and the Mann-Whitney U. Correlation between continuous variables was assessed using Spearman's correlation coefficient. Simple linear regression was performed to evaluate the predictive association between vitamin D and ferritin, as well as between BMI and vitamin D levels. A two-tailed p-value < 0.05 was considered statistically significant.

In this study, nutritional status was initially classified into five categories (severely undernourished, undernourished, normal, overweight, and obese). Since no participants were identified as undernourished or severely undernourished, only three categories

remained (normal, overweight, and obese). For analytical purposes, these categories were then recategorized into "normal" (normal status) and "abnormal" (overweight/obese) groups. This approach was adopted to facilitate binary logistic regression and to ensure an adequate sample size per group for statistical analysis.

Ethical Consideration

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Ethical approval for the analysis of vitamin D was obtained from the Health Research Ethics Committee under ethical approval number B-056/F12/KEPK/TL.00/8/2023. The subsequent analysis of ferritin using the same stored samples was approved under clearance number B-020/F12/KEPK/TL.00/08/2025. Written informed consent was obtained from all participants and their guardians prior to participation. To ensure participant confidentiality, all samples were anonymized prior to laboratory analysis.

RESULTS

A total of 56 adolescent girls aged 16 to 18 years participated in this study. The mean age was 16.40 ± 0.5 years. Based on anthropometric assessment using the WHO BMI-for-age standard, most participants (83.90%) had normal nutritional status, 14.30% were overweight, and one participant (1.80%) was categorized as obese. No cases of undernutrition were found in this sample. The mean BMI of the study population was 21.75 ± 3.24 kg/m² (Table 1).

For micronutrient profiles, the median serum vitamin D level was 9.90 ng/mL (IQR: 7.97-11.37 ng/mL), which indicated a widespread deficiency, as all values were below the commonly accepted sufficiency threshold of 20 ng/mL. The mean serum ferritin level was 37.31 ± 29.59 ng/mL. The mean hemoglobin concentration was 12.83 ± 1.03 g/dL, and red blood cell count averaged 4.68 ± 0.34 million/µL (Table 2).

The analysis revealed no significant correlations between body mass index (BMI) and the examined laboratory parameters. As shown in Table 3, BMI exhibited a weak negative correlation with both serum ferritin (r = –0.052, p = 0.706) and vitamin D levels (r = –0.060, p = 0.660), and a weak positive correlation with hemoglobin concentration (p = 0.087, p = 0.525).

Simple linear regression was performed to assess the association between serum vitamin D and ferritin concentrations. The results showed no statistically significant association, with a regression coefficient (B) of 0.351 and a p-value of 0.633. The 95% confidence interval ranged from -1.112 to 1.814, which included zero and indicated a lack of predictive association. Similarly, regression analysis between BMI and vitamin D showed no significant

Table 1. Characteristics of the respondents (n = 56)

Variable	Mean ± S.D. / n (%)	Median [IQR]
Age (years)	-	17 (16-18)
Body Mass Index (kg/m²)	21.75 ± 3.24	-
Nutritional status (BMI-for-age)		
- Severely thin (<-3 SD)	0 (0)	
- Thin (−3 S.D. to < −2 SD)	0 (0)	
- Normal (−2 SD to +1 SD)	47 (83.90)	
- Overweight (+1 SD to +2 SD)	8 (14.30)	
- Obese (> +2 SD)	1 (1.80)	

†Values are presented as mean ± standard deviation (S.D.), median [interquartile range, IQR], or number (percentage) as appropriate. BMI = Body mass index; S.D. = Standard deviation; IQR = Interquartile range.

Table 2. Mean ferritin, vitamin D, and hematological parameters

Laboratory Parameter	Mean ± SD	Median [IQR]
Ferritin (ng/mL)	37.31 ± 29.59	-
Vitamin D (ng/mL)	-	9.9 [7.97-11.37]
Hemoglobin (g/dL)	-	12.70 [11.7-13.3]
Hematocrit (%)	37.96 ± 2.81	-
Red Blood Cells (×10⁶/µL)	4.57 ± 0.30	-
White Blood Cells (×10³/µL)	7.24 ± 1.65	-
Platelets (×10³/µL)	331.30 ± 66.66	-
MCV (fL)	-	86.5 [80.57-88.20]
MCH (pg)	-	28.15 [25.95-29.40]
MCHC (g/dL)	32.66 ± 1.39	-

†Values are presented as mean ± standard deviation (S.D.) or median [interquartile range, IQR] as appropriate. MCV = mean corpuscular volume (fL); MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; IQR = Interquartile range; S.D. = Standard deviation.

Table 3. Correlation between body mass index (BMI) and laboratory Parameters (ferritin, vitamin D, and hemoglobin)

Laboratory parameter	r (Spearman's rho)	p-value
Ferritin	–0.052	0.706
Vitamin D	–0.060	0.660
Hemoglobin	0.087	0.525

†Correlation was assessed using Spearman's rank correlation test. r = correlation coefficient. p < 0.05 was considered statistically significant; p = probability.

Table 4. Association between serum vitamin D, ferritin, and body mass index (BMI) based on linear regression analysis

Variable	Predictor	B	SE	Standardized Beta (β)	t	p-value	95% CI for B
Ferritin (ng/mL)	(Constant)	33.474	8.92	–	3.75	0.000	15.595 to 51.354
	Vitamin D (ng/mL)	0.351	0.73	0.065	0.481	0.633	–1.112 to 1.814
Vitamin D (ng/mL)	(Constant)	11.897	5.08	–	2.34	0.023	1.708 to 22.086
	BMI (kg/m²)	–0.044	0.231	–0.026	–0.191	0.849	–0.507 to 0.419

†Linear regression analysis was performed using the enter method.B = unstandardized regression coefficient; SE = standard error; CI = confidence interval; BMI = body mass index; $p < 0.05$ was considered statistically significant.

association, with a B coefficient of -0.044, a p-value of 0.849, and a 95% confidence interval from -0.482 to 0.393 (Table 4).

DISCUSSION

This study aimed to examine the association between nutritional status and serum ferritin, vitamin D levels, and hematological parameters among adolescent girls living in a boarding school. Although these micronutrients play a role in hematological and metabolic processes, no significant associations with nutritional status were observed.

Linear regression analysis showed no significant association between serum vitamin D and ferritin levels ($p = 0.633$) and between BMI ($p = 0.849$), although a weak positive trend was observed (B = 0.351). The 95% confidence interval for this association included zero (-1.112 to 1.814). These findings indicate no evidence of a linear association between nutritional status and either serum vitamin D or ferritin levels in this study population. Vitamin D has been proposed to influence iron metabolism through the suppression of hepcidin, which is a hormone derived from the liver that inhibits intestinal iron absorption and promotes iron sequestration in macrophages.[12,13] A study by Bacchetta et al. (2014) showed that vitamin D supplementation can reduce hepcidin levels and potentially increase iron availability.[11] However, these effects are context-dependent and may be moderated by systemic inflammation, chronic disease states, or coexisting micronutrient deficiencies, none of which were assessed in the present study.

The results of this study are consistent with those of El-Adawy et al. (2019), who also found no significant correlation between vitamin D and ferritin among adolescents. This suggests that the association may not be straightforward in healthy, non-anemic populations.[14,18] Furthermore, the limited variability in vitamin D status in this study, where nearly all participants were deficient (median = 9.90 ng/mL), may have reduced the statistical power to detect a true effect.

No significant correlation between body mass index (BMI) and laboratory parameters, including ferritin, vitamin D, and hemoglobin levels, among adolescent girls living in a boarding school ($p > 0.05$). The weak and non-significant correlation suggests that variations in BMI within this population may not strongly influence micronutrient and hematological status. This is in contrast to previous studies that have reported a negative correlation, where lower serum vitamin D levels in overweight and obese individuals were attributed to sequestration of the vitamin within adipose tissue.[21,22] Previous studies have demonstrated an inverse association between obesity and iron status, attributed to low-grade chronic inflammation and increased hepcidin expression, which impairs iron absorption and mobilization.[19] However, the small number of participants in the overweight and obese groups may have limited the detection of trends, which may also be influenced by differences in diet, sun exposure, and menstrual patterns among adolescents.

However, similar findings were reported in a study of Lebanese osteoporotic women, that BMI was not an independent predictor of 25(OH)D inadequacy among Muslim participants. The study indicated that other factors, such as clothing practices and vitamin D supplementation, may have a more substantial influence on this subgroup.[15] In the present study, the limited variation in BMI in this sample, where 83.90% of participants were classified as normal weight, may have contributed to the non-significant result.

Although statistically significant associations were not observed, the findings of this study have several clinical implications. The median serum vitamin D level of 9.90 ng/mL reflected widespread deficiency among the participants, which may result from insufficient sun exposure, limited dietary intake of vitamin D, or a combination of both. Such conditions are commonly found in institutional settings such as boarding schools. Similar evidence from institutional settings, including adolescent psychiatric facilities, shows that restricted sunlight exposure and uniform meal plans contribute significantly to vitamin D deficiency. These situations support the need for proactive screening and supplementation programs in boarding school populations.[23]

This study has several limitations. First, the relatively small sample size and predominance of participants with normal nutritional status reduced the statistical power to detect associations, particularly within subgroups such as overweight participants or those with abnormal erythrocyte morphology. Second, the cross-sectional design precludes causal inference between nutritional status, vitamin D, and hematological parameters. Longitudinal studies would be better suited to clarify these temporal associations. Third, important confounders such as dietary intake, physical activity, menstrual history, and inflammatory markers (e.g., CRP, hepcidin) were not assessed, which limits interpretation of whether deficiencies were primarily related to intake, absorption, or inflammation. Lastly, laboratory analyses were conducted in two different facilities, raising the possibility of minor inter-laboratory variability,

although standardized protocols and quality control procedures were followed.

Despite these limitations, the study provides valuable insight into micronutrient status among adolescent girls in a boarding school setting. This study assessed vitamin D status among adolescent girls in a boarding school, offering focused insights into a specific population. However, the findings should be interpreted cautiously due to limited external validity. Key lifestyle factors influencing vitamin D, such as physical activity, diet, and sun exposure, were not examined and may confound the results. Future studies should include these determinants and compare various school settings to enhance generalizability.

CONCLUSION

This study highlights the presence of suboptimal vitamin D levels among adolescent girls living in a boarding school, despite most participants having a normal BMI. No significant associations were observed between serum vitamin D, ferritin, nutritional status, and hematological parameters. However, the high prevalence of vitamin D deficiency and subtle hematological variations underscore the importance of early screening and targeted nutritional interventions in institutional settings to mitigate potential long-term health risks.

DISCLOSURES

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Conflict of Interest

The authors declare no conflicts of interest.

Author Contribution

MM contributed to conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, and writing original draft.

YM contributed to conceptualization, methodology, data curation, validation, investigation, resources, data curation, and writing review & editing, and funding acquisition.

SANJ contributed to conceptualization, methodology, validation, investigation, resources, data curation, visualization, supervision, and funding acquisition.

ARA contributed to investigation, resources, data curation, and formal analysis as the project administrator.

BAR contributed to validation, resources, and investigation.

FAS contributed to software and data curation, visualization

YTS contributed to writing, software, formal analysis, data curation, writing original draft, review & editing, and visualization

TR contributed to formal analysis, writing review & editing, and funding acquisition.

YS contributed to supervision, data curation, project administration, writing-review & editing, and funding acquisition, supervision, funding acquisition.

All authors have read and approved the final manuscript.

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