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Analysis of the causative factors of chronic energy deficiency and the health impact on adolescent girls

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A B S T R A C T

Chronic Energy Deficiency (CED) among adolescent girls remains a major public health concern. This condition affects not only physical health but also psychological well-being and overall quality of life, necessitating a comprehensive study of its contributing factors and impacts. This study aimed to identify the factors contributing to CED and assess its impact on the health of adolescent girls. A quantitative design with a descriptive correlational approach was employed. Using stratified random sampling by grade level, 184 respondents were selected using Slovin's formula. Data were collected via standardized questionnaires, Mid-Upper Arm Circumference (MUAC) measurements, and hemoglobin examinations. Data analysis used Pearson's Correlation and multiple linear regression. The prevalence of CED among adolescent girls was 60.9%. Significant factors associated with CED included knowledge, nutritional intake (energy, carbohydrates, protein, fat), sleep quality, stress, and family support ($p < 0.05$), which collectively accounted for 77% of the variance in CED incidence. Conversely, body image showed no significant association. Regarding health impacts, CED was significantly correlated only with self-efficacy ($r = -0.270$; $p < 0.001$); hemoglobin levels, menstrual cycles, and academic performance showed no significant associations. Nutrition education programs are needed to improve balanced dietary intake. Furthermore, strengthening the roles of families and schools is recommended to support the prevention and management of CED among adolescent girls.

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INTRODUCTION

Adolescence represents a critical window of opportunity for physical and cognitive development, making adequate nutritional intake fundamental to the long-term health of this demographic (Hargreaves et al., 2022). During this period, rapid growth and physiological changes necessitate optimal energy and nutrient consumption to support both somatic development and mental maturation (Norris et al., 2022). However, despite the known importance of nutrition during this life stage, adolescent girls remain a vulnerable group, particularly in developing regions where food insecurity and poor dietary habits persist (Basiry et al., 2024). Ensuring nutritional adequacy in this population is not merely a matter of immediate health but is essential for breaking intergenerational cycles of malnutrition and ensuring future reproductive and economic productivity (Uddin et al., 2026).

A significant public health challenge within this demographic is Chronic Energy Deficiency (CED), defined as a state of energy intake insufficient to maintain physical and mental function, thereby increasing the risk of degenerative diseases (Titaley et al., 2024). CED is particularly prevalent among adolescent girls, where the energy demand is high due to growth spurts and the onset of menstruation (Arifah et al., 2025). The condition serves as a marker of broader nutritional insecurity, reflecting a sustained imbalance between energy expenditure and dietary intake (Yulia et al., 2024). Without intervention, CED compromises the physiological reserve required to withstand illness and stress, rendering affected adolescents susceptible to a range of acute and chronic health complications (Walsh & Nicholson, 2022).

The consequences of CED extend beyond simple underweight status, manifesting in severe physical and psychological impairments (Kulathunga et al., 2025). Physiologically, CED is closely linked to micronutrient deficiencies, particularly iron-deficiency anemia, which results in chronic fatigue, compromised immune function, and reduced capacity for daily activities (Kolarš et al., 2025). Furthermore, energy deficiency can disrupt the hypothalamic-pituitary-gonadal axis, leading to menstrual irregularities or amenorrhea that threaten long-term reproductive health (Calcaterra et al., 2024). Psychologically, the burden of CED is equally significant; affected adolescents often experience heightened levels of stress, anxiety, and sleep disturbances (Baumann et al., 2025). These mental health challenges can create a feedback loop, where psychological distress exacerbates poor eating behaviors, further deepening the energy deficit and impairing academic performance (Majali et al., 2025).

The etiology of CED in adolescent girls is multifactorial, stemming from a complex interplay of individual, social, and environmental determinants (Yasin et al., 2024). Primary drivers include limited nutritional knowledge, in which adolescents fail to recognize the importance of a balanced diet, and the adoption of poor eating habits, such as frequent consumption of energy-dense, nutrient-poor fast food (Louey et al., 2024). Socioeconomic constraints often compound these individual behaviors; low-income households may have limited access to nutritious foods, increasing vulnerability among girls in these settings (Wrottesley et al., 2023). Additionally, high academic pressure and societal beauty standards can influence body image, leading to restrictive eating patterns or neglecting nutritional needs in favor of study time (Almoraie et al., 2024). Family support systems also play a pivotal role, as a lack of guidance can leave adolescents ill-equipped to navigate these competing demands (Mukhdi, 2024).

Despite the recognition of these contributing factors, there remains a need to comprehensively analyze how these variables interact to influence CED incidence and subsequent health outcomes in specific populations (Zhao et al., 2025). While individual factors such as dietary intake are well documented, the combined impact of psychosocial factors, including stress, body image, and family support, remains poorly understood and requires further elucidation to design effective interventions (Dimitratos et al., 2022). Therefore, this study aims to analyze the causative factors of Chronic Energy Deficiency and evaluate its impact on the health of adolescent girls. By identifying the specific contributions of nutritional, psychological, and environmental factors, this research seeks to inform targeted prevention and management strategies, ultimately supporting the holistic well-being of adolescent girls (Parajuli & Prangthip, 2025).

METHOD

Research Design

This study employed a quantitative research design with a descriptive correlational approach using a cross-sectional framework. Data collection was conducted at a single point in time to assess the relationships between independent variables (knowledge, nutritional intake, sleep quality, stress, family support, and body image) and the dependent variable (Chronic Energy Deficiency status). This design was selected to efficiently examine the prevalence of CED and identify significant predictors and health impacts within the target population without manipulating variables.

Participants

The target population comprised all 340 female students enrolled at Vocational School Y in Depok City. The sample size was calculated using the Slovin formula with a margin of error (α) set at 5%, yielding a minimum requirement of 184 respondents. To ensure representativeness across different academic levels, a Stratified Random Sampling technique was applied. The population was stratified by grade level (X, XI, and XII), and respondents were randomly selected from each stratum in proportion to the stratum's population. This approach ensured that each grade level had an equal and proportional opportunity to be represented in the final sample.

Data Collection

Data were gathered using a combination of standardized instruments and anthropometric measurements. Primary data collection involved structured questionnaires to assess psychosocial and behavioral variables, including nutritional knowledge, stress levels, sleep quality, family support, and body image. All instruments underwent rigorous validity and reliability testing prior to use; item validity was confirmed by calculated r-values exceeding the critical r-values, and internal consistency was established with Cronbach's Alpha coefficients ≥ 0.70, indicating high reliability. Physiological data were obtained by direct measurement of Mid-Upper Arm Circumference (MUAC) to determine CED status and by finger-prick blood sampling to assess anemia status. All measurements were conducted by trained personnel under standardized protocols to minimize measurement bias.

Data Analysis

Data analysis was performed in three sequential stages. First, univariate analysis was conducted to describe the distribution and characteristics of each variable. Second, a bivariate analysis using the Pearson Product-Moment Correlation test was conducted to examine the strength and direction of relationships between the independent variables and CED status. Finally, multivariate analysis using Multiple Linear Regression was employed to identify the most significant predictors of CED and to quantify their combined contribution. Prior to regression modeling, classical assumption tests, including normality (Shapiro-Wilk/Kolmogorov-Smirnov), multicollinearity (Variance Inflation Factor), and heteroscedasticity (Scatterplot/Spearman's rho), were performed to ensure the validity and feasibility of the regression model. Statistical significance was set at $p < 0.05$ for all tests.

Ethical Clearance

This study was conducted in strict adherence to ethical principles for research involving human subjects. Ethical approval was obtained from the Ethics Committee of the Faculty of Health Sciences at the National University of Jakarta. Prior to participation, all respondents and their guardians (for minors) were provided with comprehensive information regarding the study's purpose, procedures, benefits, and risks. Written informed consent was obtained from all participants. Confidentiality was strictly maintained throughout the research process; all data were anonymized, stored securely, and used exclusively for academic purposes. Participants retained the right to withdraw from the study at any time without penalty.

RESULT

Univariate Analysis

Univariate analysis was conducted to describe the frequency distributions and characteristics of the factors causing CED among female adolescents at Vocational School Y, Depok City, as presented in Table 1.

Table 1. Factors causing CED

Status	Frequency (n)	Percentage (%)
Chronic Energy Deficiency		
Yes	112	60.9
No	72	39.1
Total	184	100

Based on Table 1, 112 respondents (60.9%) experienced Chronic Energy Deficiency (CED) based on the measurement of Mid-Upper Arm Circumference (MUAC), while 72 respondents (39.1%) did not experience CED. This relatively high proportion of CED indicates that female adolescents at Vocational School Y, Depok City, are still vulnerable to chronic malnutrition problems that can impact their health and development.

Table 2. Descriptive analysis of factors causing CED

Factors Causing CED	Mean	Standard Deviation	Min	Max
Mid-Upper Arm Circumference	21.71	1.05	18	23
Knowledge	8.95	1.53	2	15
Energy (kcal)	1109.36	222.37	541.75	1679.75
Carbohydrates (g)	129.55	30.03	58.31	239.19
Protein (g)	47.85	16.22	23.41	91.34
Fat (g)	34.86	12.86	18.20	78.27
Body Image	15.79	2.35	9	25
Quality Sleep	5.28	1.28	2	8
Stress	20.33	5.64	6	37
Support Family	53.37	12.80	27	76

Table 2 shows that the average MUAC is 21.71 cm, with a range of 18 to 23 cm. The average knowledge score was 8.95, with 76.8% of respondents in the "sufficient" category. The average energy intake was 1109.36 kcal, only about 52.8% of the daily Nutritional Adequacy Intake (RDA) for adolescent girls. Carbohydrate intake (129.55 g) only reached 43.2% of the requirement, while protein (47.85 g) only reached 73.6%, and fat (34.86 g) was around 49.8% of the RDA. Most adolescents had a negative body image (89.3%), good sleep quality (56.3%), and moderate stress levels (76.8%). Family support was in the good category (58.9%), a protective factor against CED.

Table 3. Impact analysis of CED

Variables Impact of CED	Mean	Standard Deviation	Min	Max
Hemoglobin Level	11.66	1.48	7.90	14.90
Cycle Menstruation	6.25	1.08	4	10
Academic Achievement	82.41	8.64	8	93
Self-efficacy	8.66	1.64	5	12

Table 3 shows that the average hemoglobin level was 11.66 g/dL, indicating that 52.7% of female students were at risk of anemia (Hb <12 g/dL). Most had normal menstrual cycles (96.4%), moderate academic achievement (91.1%), and moderate self-efficacy (63.4%).

Bivariate Analysis

Based on the bivariate analysis of the independent and dependent variables, the results are presented in Table 4.

Table 4. Kolmogorov-Smirnov normality test results

Variables	p-value	Decision
Mid-Upper Arm Circumference	0.143	Normally distributed
Knowledge	0.051	Normally distributed
Energy	0.062	Normally distributed
Carbohydrate	0.200	Normally distributed
Protein	0.197	Normally distributed
Fat	0.070	Normally distributed
Body image	0.200	Normally distributed
Sleep Quality	0.200	Normally distributed
Stress	0.200	Normally distributed
Family Support	0.172	Normally distributed
Hemoglobin Level	0.200	Normally distributed
Menstrual Cycle	0.200	Normally distributed
Academic Achievement	0.166	Normally distributed
Self-efficacy	0.200	Normally distributed

Table 4 shows that all variables examined in this study had p-values> 0.05 in the normality test, indicating that all data were normally distributed. The variables tested included mid-upper arm circumference (MUAC), factors causing CED such as knowledge, nutritional intake (energy, carbohydrate, protein, and fat), body image, sleep quality, stress, and family support, as well as health impact variables, namely hemoglobin levels, menstrual cycles, academic achievement, and self-efficacy. The test statistic values for each variable ranged from 0.051 to 0.200, and all indicated that there was no significant difference between the distributions of the variable data and the theoretical normal distribution. This indicates that the normality assumption is met, so parametric analysis techniques such as the Pearson correlation test and multiple linear regression can be used legitimately to analyze the relationships and influences among variables in this study.

Table 5. Pearson correlation between causal factors and MUAC

Variables Independent	r	p-value	Strength	Information
Knowledge	0.436	0.000	Currently	Significant
Energy	0.409	0.000	Currently	Significant
Carbohydrate	0.402	0.000	Currently	Significant
Protein	0.419	0.000	Currently	Significant
Fat	0.338	0.000	Low	Significant
Body image	0.143	0.133	Very Low	Not significant
Quality Sleep	0.372	0.000	Low	Significant
Stress	0.220	0.020	Low	Significant
Support Family	0.503	0.000	Currently	Significant

Table 5 shows that most independent variables are statistically significantly associated with Mid-Upper Arm Circumference (MUAC) status in adolescent girls ($p < 0.05$). In contrast, the body image variable is not significant ($p = 0.133$). The highest correlation value is found in family support ($r = 0.503$), with a moderate and significant relationship strength, followed by knowledge ($r = 0.436$), protein ($r = 0.419$), energy ($r = 0.409$), and carbohydrates ($r = 0.402$), which also have a moderate and significant relationship strength. The variables fat ($r = 0.338$), sleep quality ($r = 0.372$), and stress ($r = 0.220$) have low relationship strengths but remain statistically significant. Meanwhile, body image ($r = 0.143$) shows a very low and insignificant relationship strength to MUAC in adolescent girls.

Table 6. Pearson correlation between MUAC and health impact

Variables Dependent	r	p-value	Strength	Information
Hemoglobin Level	-0.106	0.266	Very Low	Not significant
Cycle Menstruation	0.066	0.487	Very Low	Not significant
Academic Achievement	-0.001	0.988	Very Low	Not significant
Self-efficacy	-0.270	0.004	Low	Significant (negative)

Table 6 shows that of the four health impact variables analyzed, only self-efficacy has a statistically significant relationship with the status of the Mid-Upper Arm Circumference (MUAC) in adolescent girls ($p = 0.004$; $p < 0.05$). The correlation between self-efficacy and the outcome variable is $r = –0.270$, indicating a weak negative relationship. Meanwhile, hemoglobin levels ($r = –0.106$; $p = 0.266$), menstrual cycles ($r = 0.066$; $p = 0.487$), and academic achievement ($r = –0.001$; $p = 0.988$) have very weak relationships with MUAC and are not statistically significant.

Multivariate Analysis

Based on the results of multivariate analysis using multiple linear regression tests to see the simultaneous influence of the causal factors of CED, as presented in the following table.

Table 7. Residual normality test

Regression Model	Test Statistics	p-value	Information
CED Regression Model	1.112	0.169	Normal

Based on Table 7, the results of the residual normality test in the multivariate regression model indicate a test statistic of 1.112 and a p-value of 0.169. Since the p-value is greater than 0.05, the residuals of the regression model are normally distributed. Thus, the assumption of residual normality is met, allowing the multiple linear regression analysis to continue and the estimation results to be interpreted legitimately.

Table 8. Multicollinearity test

Independent Variables	Tolerance	VIF	Information
Knowledge	0.910	1.099	No multicollinearity
Energy	0.416	2.401	No multicollinearity
Carbohydrate	0.417	2.397	No multicollinearity
Protein	0.863	1.159	No multicollinearity
Fat	0.726	1.378	No multicollinearity
Body image	0.900	1.111	No multicollinearity
Sleep Quality	0.889	1.124	No multicollinearity
Stress	0.885	1.131	No multicollinearity
Family Support	0.952	1.050	No multicollinearity

Table 8 shows the results of the multicollinearity test conducted on all independent variables in the multivariate regression model. All variables have Tolerance values above 1 and Variance Inflation Factor values above 1. The Variance Factor (VIF) is below 10. Tolerance values range from 0.416 to 0.952, while VIF values range from 1.050 to 2.401. This criterion indicates that there are no multicollinearity issues among the independent variables in the model. This means that each variable provides unique information and does not overlap statistically. This ensures that the regression model is stable and its interpretation is reliable.

Table 9. Heterogeneous statistical test

Independent Variables	p-value	Information
Knowledge	0.628	No heteroscedasticity
Energy	0.304	No heteroscedasticity
Carbohydrate	0.888	No heteroscedasticity
Protein	0.726	No heteroscedasticity
Fat	0.941	No heteroscedasticity
Body image	0.992	No heteroscedasticity
Sleep Quality	0.714	No heteroscedasticity
Stress	0.951	No heteroscedasticity
Family Support	0.196	No heteroscedasticity

Based on Table 9, it shows that the results of the heteroscedasticity test on all independent variables show a p-value > 0.05, including knowledge (0.628), energy (0.304), carbohydrates (0.888), protein (0.726), fat (0.941), body image (0.992), sleep quality (0.714), stress (0.951), and family support (0.196). Since all p-values exceed 0.05, the regression model does not exhibit heteroscedasticity. This means that the residual variance is constant across the independent variable values (homoscedasticity), so the regression model meets one of the important assumptions, and the estimation results are efficient and can be interpreted legitimately.

Table 10. Multiple linear regression test of factors causing CED

Independent Variables	Coefficient B	p-value	Information
Knowledge	0.392	0,000	Significant
Energy (kcal)	0.579	0.027	Significant
Carbohydrates (g)	0.622	0.015	Significant
Protein (g)	0.411	0.016	Significant
Fat (g)	0.466	0.002	Significant
Body image	0.029	0.196	Not significant
Sleep Quality	0.065	0,000	Significant
Stress	0.019	0.026	Significant
Family Support	0.039	0,000	Significant

Table 10 shows that the results of multiple linear regression analysis indicate that most independent variables have a significant effect on MUAC in adolescent girls ($p < 0.05$), except for the body image variable, which has a p-value of 0.196 (not significant). The highest B coefficient value is found in the carbohydrate variable (B = 0.622), followed by energy (B = 0.579), fat (B = 0.466), protein (B = 0.411), and knowledge (B = 0.392). Then, the variables of sleep quality (B = 0.065), stress (B = 0.019), and family support (B = 0.039) also have a significant effect on MUAC. However, the resulting B coefficient value is smaller than the nutritional intake variable. Overall, all significant variables in this model have a positive relationship, meaning that higher values of the variables are associated with higher CED prediction scores.

Table 11. Multivariate regression summary model of factors causing CED

R	R Square	Adjusted R Square	Standard Error of Estimate
0.877	0.770	0.749	0.45710

Table 11 shows that the R value of 0.877 indicates a very strong and positive relationship between the independent and dependent variables in this study. Furthermore, the R-square value of 0.770 indicates that this regression model explains 77% of the variation in MUAC; the remaining 23% may be due to factors not included in the model. The Adjusted R Square value of 0.749 indicates that approximately 74.9% of the variation in MUAC can be explained by the variables of knowledge, nutritional intake, body image, sleep quality, stress, and family support. However, 25.1% of the remaining impact variations outside the variables used in this study may be factors contributing to CED. Furthermore, the Standard Error of the Estimate value of 0.45710 indicates that knowledge, nutritional intake, body image, sleep quality, stress, and family support can explain the factors underlying CED.

Based on the results of multivariate analysis using multiple linear regression tests to see the simultaneous influence of health impact variables on young women, which are presented in the following table.

Table 12. Residual normality test

Regression Model	Test Statistics	p-value	Information
CED Impact Model	0.781	0.576	Normal

Based on Table 7, the results of the residual normality test in the multivariate regression model indicate a test statistic of 0.781 and a p-value of 0.576. Because the p-value is greater than 0.05, the residuals of the regression model are normally distributed. Thus, the assumption of residual normality is met, allowing the multiple linear regression analysis to continue and the estimation results to be interpreted legitimately.

Table 13. Multicollinearity test

Independent Variables	Tolerance	VIF	Information
Academic Achievement	0.992	1.008	No multicollinearity
Hemoglobin Level	0.999	1.001	No multicollinearity
Menstrual Cycle	0.958	1.044	No multicollinearity
Self-efficacy	0.951	1.051	No multicollinearity

Table 13 shows the results of the multicollinearity test conducted on all independent variables in the multivariate regression model. All variables have Tolerance values above 0.1, and Variance Inflation Factor (VIF) values below 10. The Tolerance value ranges from 0.951 to 0.999, while the VIF value ranges from 1.001 to 1.051. This criterion indicates that there are no multicollinearity issues among the independent variables in the model. This ensures that the regression model is stable and its interpretation results are reliable.

Table 14. Heterogeneous statistical test

Independent Variables	p-value	Information
Academic Achievement	0.663	No heteroscedasticity
Hemoglobin Level	0.397	No heteroscedasticity
Menstrual Cycle	0.978	No heteroscedasticity
Self-efficacy	0.806	No heteroscedasticity

Table 14 shows that the heteroscedasticity test results for all independent variables are p-values> 0.05, including academic achievement (0.663), hemoglobin level (0.397), menstrual cycle (0.978), and self-efficacy (0.806). Since all p-values exceed 0.05, the regression model does not exhibit heteroscedasticity. This means that the residual variance is constant across values of the independent variables (homoscedasticity), so the regression model meets one of the important assumptions, and the estimation results are efficient and can be interpreted legitimately.

Table 15. Multiple linear regression test of the impact of chronic energy deficiency on health

Independent Variables	Coefficient B	p-value	Information
Academic Achievement	-0.002	0.978	Not significant
Hemoglobin Level	0.064	0.462	Not significant
Menstrual Cycle	0.010	0.355	Not significant
Self-efficacy	-0.241	0,000	Significant

Table 15 shows that hemoglobin levels have a Beta coefficient of -0.002 and a p-value of 0.978. Then, the menstrual cycle variable has a Beta coefficient of 0.064 with a significance value of 0.462. Next, the academic achievement variable has a Beta coefficient of 0.010 and a significance value of 0.355; finally, the self-efficacy variable has a beta coefficient of -0.241 and a significance value of p = 0.000. The results of the multiple linear regression analysis show that self-efficacy has the strongest influence on MUAC, with a Beta coefficient of -0.241 and p = 0.000. A negative regression coefficient indicates an inverse relationship between self-efficacy and MUAC. In other words, the higher adolescents' self-efficacy, the more likely they are to have a normal MUAC. Conversely, adolescents with low self-efficacy are at higher risk of having a low MUAC. Meanwhile, other variables did not show a statistically significant effect, although the menstrual cycle had a larger effect size than hemoglobin levels and academic achievement.

Table 16. Summary model of multivariate regression of the impact of chronic energy deficiency

R	R Square	Adjusted R Square	Standard Error of Estimate
0.406	0.165	0.134	0.97916

Table 16 shows that the R value of 0.406 indicates a moderate correlation between MUAC and its impact on health. The R-square value of 0.165 indicates that this regression model explains 16.5% of the variation in the health impact of MUAC; the remaining 83.5% may be due to other factors not included in this model. The Adjusted R Square value of 0.134 indicates that approximately 13.4% of the variation in the health impact of MUAC can be explained by hemoglobin levels, menstrual cycles, academic achievement, and self-efficacy. However, 86.6% of the variation in other impacts beyond the variables used in this study can still be attributed to CED. Furthermore, the Standard Error of the Estimate value of 0.97916 indicates that hemoglobin levels, menstrual cycles, academic achievement, and self-efficacy can explain the health impact of MUAC.

DISCUSSION

Factors Causing CED

Knowledge

The results demonstrated a strong, significant positive correlation between nutritional knowledge and Mid-Upper Arm Circumference (MUAC) among adolescent girls at Vocational School Y in Depok City ($r = 0.436$; $p < 0.001$), indicating that lower knowledge levels were associated with smaller MUAC measurements and, consequently, suboptimal nutritional status. Multiple linear regression confirmed knowledge as a significant predictor of MUAC ($\beta = 0.392$; $p < 0.001$), a finding contextualized by the observation that the majority of respondents exhibited suboptimal nutritional knowledge (17 poor, 86 sufficient, and only 9 good out of 112 students). This suggests that limited understanding of balanced nutrition, macronutrient needs, and the health consequences of energy deficiency serves as a key modifiable risk factor for Chronic Energy Deficiency in this population. While socioeconomic conditions, food access, and lifestyle factors also influence nutritional outcomes, the strong association between knowledge and MUAC underscores the potential impact of targeted health education interventions. Therefore, integrating comprehensive, culturally appropriate nutrition education into school and community programs to improve knowledge, shape positive attitudes, and promote balanced dietary behaviors is a critical strategy for enhancing MUAC measurements and overall nutritional status among adolescent girls (Bhamani et al., 2025).

Nutritional Intake

The study revealed that the average energy and macronutrient intake among adolescent girls at Vocational School Y in Depok City fell substantially below the Recommended Dietary Allowance (RDA) for ages 16–18: mean energy intake was 1109.36 kcal (52.8% of the 2100 kcal RDA), carbohydrates 129.55 g/day (43.2% of 300 g), protein 47.85 g/day (73.6% of 65 g), and fat 34.86 g/day (49.8% of 70 g). Pearson correlation analysis demonstrated statistically significant, moderate positive relationships between Mid-Upper Arm Circumference (MUAC) and intake of energy ($r = 0.409$), carbohydrates ($r = 0.402$), protein ($r = 0.419$), and fat ($r = 0.338$), all with $p < 0.001$. Multiple linear regression further confirmed that these macronutrients significantly predicted MUAC, with carbohydrates exerting the strongest influence ($\beta = 0.622$), followed by energy ($\beta = 0.579$), fat ($\beta = 0.466$), and protein ($\beta = 0.411$). These findings underscore the critical role of adequate energy and macronutrient intake in maintaining optimal nutritional status, as protein supports tissue repair and enzymatic function. In contrast, sufficient energy intake sustains metabolic balance and physical capacity. The observed deficits likely reflect limited access to diverse, nutrient-dense foods and insufficient nutritional knowledge, highlighting the urgent need for integrated interventions, such as school-based nutrition education and improved food access, that emphasize balanced macronutrient consumption to prevent Chronic Energy Deficiency and support healthy growth in this vulnerable population (Soliman et al., 2022).

Body Image

Among 112 adolescent girls at Vocational School Y in Depok City, body image perception was predominantly negative (100 students) compared to positive (12 students), suggesting a widespread tendency toward unfavorable self-perception. However, Pearson correlation analysis revealed no statistically significant relationship between body image and Mid-Upper Arm Circumference (MUAC) ($r = 0.143$; $p = 0.133$), a finding corroborated by multiple regression analysis, which showed body image did not significantly predict MUAC ($\beta = 0.029$; $p = 0.196$). This indicates that, within this sample, subjective body perception operates independently of objective anthropometric nutritional status. Researchers posit that the high prevalence of negative body image is likely driven by psychosocial factors, such as exposure to unrealistic media beauty standards, peer comparison, and social pressure, rather than by actual physical condition or energy deficiency. Additionally, limited nutritional literacy may contribute to distorted self-perception, wherein adolescents misinterpret healthy body diversity as inadequacy. Consequently, effective interventions should adopt a multidimensional approach: while addressing nutritional deficits through dietary support remains essential, parallel efforts in psychological counseling, media literacy education, and fostering supportive school and family environments are critical to promoting a realistic, healthy body image and safeguarding both the physical and mental well-being of adolescent girls (Merino et al., 2023).

Sleep Quality

Among 112 adolescent girls at Vocational School Y in Depok City, nearly half (49 students) had suboptimal sleep quality, highlighting a prevalent yet often overlooked risk factor for poor nutritional status. Pearson correlation analysis revealed a significant, moderate positive relationship between sleep quality and Mid-Upper Arm Circumference (MUAC) ($r = 0.372$; $p < 0.001$), indicating that poorer sleep quality was associated with lower MUAC. Multiple regression analysis confirmed sleep quality as a significant, albeit secondary, predictor of MUAC ($\beta = 0.065$; $p < 0.001$), underscoring its independent contribution alongside dietary factors. Physiologically, inadequate or fragmented sleep disrupts the regulation of appetite-related hormones—such as leptin and ghrelin—promoting irregular eating patterns and imbalanced nutrient intake. In contrast, elevated cortisol levels from poor sleep may induce oxidative stress, impairing hemoglobin synthesis and metabolic recovery. Contributing factors identified include poor sleep hygiene, excessive gadget use, late-night habits, and psychological stress, all of which compromise sleep duration and restorative quality. Researchers hypothesize that sleep quality functions not merely as a peripheral factor but as a crucial modifiable determinant of nutritional status: when sleep is insufficient, the body loses critical opportunities for metabolic regulation, nutrient assimilation, and physiological repair, thereby increasing vulnerability to energy deficiency. Consequently, promoting healthy sleep habits through education on sleep hygiene, screen time management, and stress reduction should be integrated into multidimensional interventions to improve MUAC and overall nutritional well-being among adolescent girls (Vasco et al., 2025).

Stress

Among 112 adolescent girls at Vocational School Y in Depok City, stress levels were predominantly moderate (86 students), with smaller proportions in the low (11 students) and high (15 students) categories; even moderate stress, however, emerged as a significant correlate of nutritional status. Pearson correlation analysis revealed a statistically significant, albeit weak-to-moderate, positive relationship between stress levels and Mid-Upper Arm Circumference (MUAC) ($r = 0.220$; $p = 0.020$), indicating that higher psychological stress was associated with lower MUAC measurements. Multiple regression analysis confirmed stress as a significant, though secondary, predictor of MUAC ($\beta = 0.019$; $p = 0.026$), suggesting that psychological factors independently contribute to nutritional vulnerability alongside dietary and behavioral variables. Physiologically, chronic stress activates the hypothalamic-pituitary-adrenal axis, elevating cortisol levels that can suppress appetite, disrupt eating patterns, induce gastrointestinal discomfort, and promote fatigue. These mechanisms collectively reduce energy intake and impair nutrient absorption. Furthermore, stress often co-occurs with academic pressure, sleep disturbances, and limited social support, creating a synergistic burden that exacerbates energy imbalance. Researchers hypothesize that stress functions not in isolation but as an integral component of a broader psychosocial-nutritional pathway: when unmanaged, it undermines dietary consistency and metabolic stability, thereby increasing susceptibility to Chronic Energy Deficiency. Consequently, effective nutritional interventions for adolescent girls should integrate stress-management strategies, such as mindfulness training, counseling support, and school-based mental health promotion, alongside dietary education, to holistically address the behavioral and physiological determinants of optimal MUAC and long-term well-being (Rodríguez-Rojo et al., 2024).

Family Support

Among 112 adolescent girls at Vocational School Y in Depok City, family support levels were predominantly good (66 students) or sufficient (43 students), with only a small minority reporting inadequate support (3 students). Nevertheless, even within this generally supportive context, variations revealed meaningful associations with nutritional outcomes. Pearson correlation analysis demonstrated a strong, statistically significant positive relationship between family support and Mid-Upper Arm Circumference (MUAC) ($r = 0.503$; $p < 0.001$), indicating that adolescents receiving lower emotional, educational, and material support from their families were more likely to exhibit poorer nutritional status. Multiple regression analysis confirmed family support as a significant independent predictor of MUAC ($\beta = 0.039$; $p < 0.001$), underscoring its role beyond mere food provision, encompassing the early formation of healthy eating patterns, consistent mealtime routines, and ongoing guidance on food choices. Researchers hypothesize that families function as foundational agents of nutritional socialization: when parental support is limited, adolescents may lack direction in selecting nutrient-dense foods, develop irregular eating habits, and experience reduced accountability in meeting daily energy needs, patterns often established in childhood and perpetuated into adolescence. Importantly, this study concludes that no single factor determines MUAC status among adolescent girls; rather, it emerges from a dynamic interplay of modifiable determinants, with nutritional knowledge exerting the strongest influence, followed by sleep quality and family support, while stress, body image, and macronutrient intake contribute additional explanatory power. Consequently, sustainable improvements in adolescent nutritional status require a comprehensive, multi-sectoral strategy that integrates school-based nutrition education, active family engagement, sleep hygiene promotion, and psychosocial support to foster enduring healthy behaviors and optimize growth outcomes during this critical developmental window (Hargreaves et al., 2022).

Impact of Chronic Energy Deficiency on Health

Hemoglobin Level

Among 112 adolescent girls at Vocational School Y in Depok City, hemoglobin levels were nearly evenly distributed, with 53 students in the normal range and 59 in the abnormal (anemic) category, indicating a substantial prevalence of potential iron deficiency. However, statistical analysis revealed no significant association between Mid-Upper Arm Circumference (MUAC) and hemoglobin levels: Pearson correlation showed a very weak, non-significant negative relationship ($r = -0.106$; $p = 0.266$), and multiple regression confirmed that MUAC did not significantly predict hemoglobin concentration ($\beta = -0.002$; $p = 0.978$). This dissociation suggests that general energy-protein nutritional status, as reflected by MUAC, operates independently of iron-status biomarkers in this population. Researchers attribute this finding to several protective factors, including routine iron supplementation programs administered by local community health centers, adequate dietary intake of hemoglobin-forming micronutrients (iron, folate, and vitamin B12), and possible physiological adaptations to local environmental conditions. Consequently, adolescents with low MUAC did not necessarily exhibit anemia, underscoring that hemoglobin synthesis depends more on the quality and micronutrient density of the diet than on overall energy balance alone. These results reinforce that anemia cannot serve as a standalone proxy for general nutritional status in adolescents; instead, a multidimensional assessment, integrating anthropometric indicators, dietary quality, micronutrient intake, and contextual health interventions, is essential for accurately identifying and addressing the complex determinants of adolescent health (Putri et al., 2025).

Menstrual Cycle

Among 112 adolescent girls at Vocational School Y in Depok City, menstrual cyclicity was predominantly regular, with 108 students reporting normal patterns and only four exhibiting irregularities. Despite the theoretical link between energy deficiency and reproductive function, statistical analysis revealed no significant association between menstrual cycle regularity and Mid-Upper Arm Circumference (MUAC): Pearson correlation indicated a negligible, non-significant relationship ($r = 0.066$; $p = 0.487$), and multiple regression confirmed that menstrual status did not significantly predict MUAC ($\beta = 0.064$; $p = 0.462$). These findings suggest that, within this sample, variations in menstrual cyclicity are not primarily driven by general energy-protein nutritional status as captured by MUAC. Researchers attribute this dissociation to the multifactorial etiology of menstrual regulation, wherein factors such as psychological stress, sleep quality, dietary composition (particularly fat intake), physical activity levels, and individual hormonal variability may exert stronger influences than anthropometric status alone. Consequently, while severe malnutrition can theoretically disrupt hypothalamic-pituitary-ovarian axis function, the absence of a statistically significant relationship in this study underscores that menstrual irregularity cannot serve as a reliable standalone indicator of nutritional status among adolescent girls. A comprehensive assessment of adolescent health must therefore integrate menstrual history with multidimensional evaluations, including dietary quality, psychosocial well-being, and clinical biomarkers, to accurately identify and address the diverse determinants of reproductive and nutritional health (Dhillon, 2024).

Academic Achievement

Among 112 adolescent girls at Vocational School Y in Depok City, academic achievement was predominantly medium (102 students), with fewer in the low (7 students) and high (3 students) categories. Despite theoretical expectations that nutritional status may influence cognitive function and academic performance, statistical analysis revealed no significant association between Mid-Upper Arm Circumference (MUAC) and academic achievement: Pearson correlation indicated a negligible, non-significant relationship ($r = -0.001$; $p = 0.988$), and multiple linear regression confirmed that MUAC status did not significantly predict academic outcomes ($\beta = 0.000$; $p = 0.978$). These findings suggest that, within this sample, variations in energy-protein nutritional status, as reflected by MUAC, do not translate into measurable differences in school performance. Researchers attribute this dissociation to the multifactorial determinants of academic achievement, which encompass internal factors (motivation, learning strategies, psychological well-being), external influences (family support, teaching quality, socioeconomic context), and methodological considerations (the use of aggregate grade averages that may mask subtle cognitive effects). While severe malnutrition can theoretically impair concentration, stamina, and information processing, the absence of a statistically significant relationship in this study underscores that MUAC alone is insufficient as a proxy for academic capability among adolescent girls. Consequently, assessments of educational outcomes should adopt a holistic framework that integrates nutritional indicators with psychosocial, environmental, and pedagogical variables to fully understand and support adolescent learning and development (Shinde et al., 2025).

Self-efficacy

Among 112 adolescent girls at Vocational School Y in Depok City, self-efficacy levels were predominantly moderate (71 students) or high (30 students), though a notable minority reported low self-efficacy (11 students); critically, statistical analysis revealed a significant inverse relationship between self-efficacy and Mid-Upper Arm Circumference (MUAC), with Pearson correlation indicating a moderate negative association ($r = -0.270$; $p < 0.001$) and multiple regression confirming self-efficacy as the most dominant psychological predictor of MUAC in the model ($\beta = -0.241$; $p < 0.001$). This finding suggests that adolescents with lower MUAC, a marker of Chronic Energy Deficiency, tend to report reduced confidence in their ability to manage health-related behaviors, potentially due to physiological sequelae such as fatigue, diminished concentration, and lowered stamina that undermine motivation and self-perception. Conversely, higher self-efficacy appears to support proactive health behaviors, including consistent selection of nutritious foods, adherence to balanced eating patterns, and sustained engagement in physical activity, thereby contributing to better anthropometric outcomes. Notably, this significant psychosocial link contrasts with the absence of meaningful associations between MUAC and other health indicators in this sample, namely hemoglobin levels, menstrual cyclicity, and academic achievement, underscoring that nutritional status, as captured by MUAC, operates through distinct pathways. Researchers therefore posit that self-efficacy functions not merely as a correlate but as a modifiable mediator in the nutrition–behavior cycle: low energy status may erode psychological resources necessary for healthy decision-making, while strengthened self-belief can foster resilience and adherence to positive lifestyle practices. Consequently, effective interventions to improve MUAC among adolescent girls should adopt an integrated approach that combines targeted nutritional support with evidence-based strategies to enhance self-efficacy, such as goal-setting training, peer modeling, and motivational counseling, thereby empowering adolescents to sustainably manage their nutritional well-being amid the complex physical, emotional, and social transitions of this developmental stage (Mancone et al., 2024).

CONCLUSION

Chronic Energy Deficiency (CED) remains highly prevalent among adolescent girls in this study population and is driven by a complex interplay of modifiable factors. Adequate macronutrient intake, nutritional knowledge, family support, sleep quality, and stress management significantly influence nutritional status, whereas body image perception does not. In terms of health impacts, CED is significantly associated with reduced self-efficacy, suggesting that energy deficiency undermines adolescents' confidence in managing their health; however, no significant associations were found with hemoglobin levels, menstrual regularity, or academic achievement. These findings underscore that effective interventions must extend beyond dietary supplementation to adopt a holistic approach, integrating nutrition education, family engagement, sleep hygiene, stress reduction, and psychological empowerment to sustainably improve the nutritional well-being of adolescent girls.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this study.

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