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Chronic Energy Deficiency Mediates the Effect of Socioeconomic Status on Anemia in Pregnancy: A Case-Control Study in Rural Gorontalo

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ABSTRACT

Anemia during pregnancy remains an important public health problem and is closely associated with socioeconomic inequality and maternal nutritional status. This study aimed to examine the role of chronic energy deficiency (CED) as a potential mediator in the relationship between socioeconomic status and anemia among pregnant women in rural Gorontalo, Indonesia. An observational analytic study with a case–control design was conducted involving 168 pregnant women, consisting of 56 anemia cases and 112 non-anemic controls, selected using consecutive sampling. Cases were defined as pregnant women with hemoglobin levels <11 g/dL, while controls were pregnant women with hemoglobin levels ≥11 g/dL. Data were obtained from primary data collection and maternal health records. Causal mediation analysis guided by a directed acyclic graph (DAG) was performed using logistic regression to estimate the adjusted total effect, natural direct effect, and natural indirect effect. After adjustment for potential confounders, low socioeconomic status was significantly associated with anemia during pregnancy, with a total effect of aOR = 4.05; 95% CI: 1.841–8.896. The natural indirect effect through CED was also statistically significant, with aOR = 1.31; 95% CI: 1.018–1.693, accounting for 23.76% of the total effect. The natural direct effect remained significant, with aOR = 3.08; 95% CI: 1.351–7.030. These findings indicate that CED partially mediates the relationship between socioeconomic status and anemia during pregnancy. Anemia prevention strategies should therefore integrate maternal nutritional interventions with broader socioeconomic and antenatal care approaches, particularly for pregnant women from socioeconomically disadvantaged backgrounds.

Keywords**:** Anemia; Chronic energy deficiency; Mediation; Pregnancy; Socioeconomic status

INTRODUCTION

Globally, anemia during pregnancy remains a serious public health problem. Estimates from 2019 indicate that approximately 33.77% of women of reproductive age (15–49 years) are affected by anemia, while the prevalence among pregnant women reaches about 36%.[1,2] The burden of anemia is disproportionately higher in low- and middle-income countries, with analyses from 46 countries reporting a prevalence of anemia among pregnant women of 45.2%.[3] World Health Organization (WHO) classifies anemia as a severe public health problem when its prevalence reaches 40% or higher, a condition that remains common in many low-income countries, particularly in Africa and South Asia.[1,4]

In South and Southeast Asia, anemia among women of reproductive age remains highly prevalent. Estimates from seven countries indicate that the prevalence of anemia in this population reaches approximately 52.5%, with substantial variation across countries ranging from 22.7% to 63%.[5] In Indonesia, the 2023 Indonesia Health Survey reported that anemia among pregnant women remains a public health concern, with a prevalence of 27.7%. Nevertheless, this figure represents a considerable decline compared with the 2018 Basic Health Research (Riskesdas), which documented an anemia prevalence of 48.9% among pregnant women, corresponding to an absolute reduction of 21.2%. The prevalence of anemia in rural areas was also reported to be higher, at 31.3%, compared with urban areas, where the prevalence was 25.5%.[6] Meanwhile, the prevalence of anemia in Gorontalo Province was reported in the 2024 Health Profile to be 19%, making it the second most common pregnancy complication after chronic energy deficiency, which had a prevalence of 38%.

Anemia during pregnancy is associated with an increased risk of several serious maternal complications. Global meta-analyses have shown that pregnant women with anemia have a higher risk of postpartum hemorrhage, with an estimated increase of approximately 1.5 to 2.7 times, and a substantially greater need for blood transfusion, reaching up to three- to fourfold.[7–9] In addition, maternal anemia has been linked to an elevated risk of preeclampsia and hypertensive disorders of pregnancy, as well as preterm birth.[7–9] More severe consequences have also been reported, including an increased risk of maternal mortality and a higher incidence of obstetric complications such as premature rupture of membranes, emergency cesarean delivery, admission to intensive care units, and shock, leading to longer hospital stays.[9,10] Beyond these clinical outcomes, anemia during pregnancy is also associated with greater maternal fatigue, increased susceptibility to infections, and a reduced quality of life throughout pregnancy.[10]

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In addition to its impact on maternal health, anemia during pregnancy is consistently associated with a range of adverse perinatal outcomes. Evidence from observational studies and meta-analyses indicates that maternal anemia increases the risk of low birth weight, preterm birth, and infants being small for gestational age.[7,9,11] Higher risks of perinatal and neonatal mortality have also been reported among infants born to anemic mothers.[7,12] Clinically, these conditions are associated with lower Apgar scores, a greater incidence of asphyxia and respiratory distress, and an increased susceptibility to infections, ultimately leading to a higher likelihood of neonatal intensive care admission.[9]

The occurrence of anemia during pregnancy is influenced by multiple interrelated factors, including nutritional, infectious, obstetric, and socioeconomic determinants. From a nutritional perspective, chronic energy deficiency (CED), commonly indicated by a mid–upper arm circumference (MUAC) of less than 23.5 cm, along with dietary patterns low in iron and essential micronutrients, plays a major role.[13] Infectious factors, such as intestinal parasitic infestations and malaria, also contribute through chronic blood loss and impaired iron metabolism.[14] Obstetric factors are likewise important, including maternal age at the extremes (<20 years or >35 years), multiparity, short interpregnancy intervals (<2 years), pregnancy in the second and third trimesters characterized by increased iron requirements, and multiple gestations.[15,16] In addition, social and health service–related factors influence anemia risk, whereby low educational attainment and socioeconomic status, residence in rural areas, suboptimal utilization of antenatal care services, and limited maternal knowledge regarding nutrition and maternal health contribute to the high prevalence of anemia among pregnant women.[17,18]

Socioeconomic inequality is closely associated with nutritional deficits and a high burden of anemia. Low socioeconomic status may limit pregnant women's access to nutritious food, dietary diversity, health information, and antenatal care, thereby increasing the risk of CED. CED was selected as a mediator because it is conceptually positioned within the causal pathway between socioeconomic disadvantage and anemia, and is biologically plausible in increasing susceptibility to anemia through reduced energy-protein reserves and deficiencies in micronutrients involved in erythropoiesis. Empirically, previous studies have shown that low socioeconomic status is associated with CED, CED is associated with an increased risk of anemia during pregnancy, and socioeconomic status is associated with anemia.[18–20] Therefore, this study tested the hypothesis that CED partially mediates the association between low socioeconomic status and anemia among pregnant women. Causal mediation analysis was used to quantify the extent to which the effect of socioeconomic status on anemia during pregnancy is mediated by CED.

MATERIALS AND METHODS

This study employed an analytic observational design with a case–control approach and was conducted in rural areas of Gorontalo Province, Indonesia. The source population comprised all pregnant women who were registered and received antenatal care services in the study area during the study period. The case group consisted of pregnant women diagnosed with anemia, while the control group included pregnant women without anemia during the same period.

Sampling was conducted using a consecutive sampling method. The case-to-control ratio was set at 1:2 to increase the statistical power of the study. This approach was intended to improve statistical efficiency and the precision of the estimates, particularly because the number of anemia cases available during the study period was relatively limited. The sample size was calculated using 80% statistical power and a 95% confidence level. Based on this calculation, the minimum required sample size was 56 pregnant women in the case group and 112 pregnant women in the control group, resulting in a total sample size of 168 pregnant women. The case group consisted of pregnant women with anemia during pregnancy, as determined based on the applicable hemoglobin criteria. The control group consisted of pregnant women who did not have anemia during pregnancy during the same study period. The inclusion criteria were pregnant women with a gestational age of ≥12 weeks, complete data on anemia status and maternal nutritional status, including chronic energy deficiency, and willingness to participate in the study. The exclusion criteria were pregnant women with a history of chronic disease or medical conditions that could directly affect hemoglobin levels, such as thalassemia or chronic kidney disease, as well as those with severe pregnancy complications that could acutely affect nutritional status or hemoglobin levels.

Maternal sociodemographic characteristics and reproductive history, including maternal education, maternal age, and parity, were obtained from the Maternal and Child Health handbook, while pregnancy interval and socioeconomic status were collected using a questionnaire. The risk of chronic energy deficiency was determined based on a MUAC of <23.5 cm, according to the standard criteria of the Indonesian Ministry of Health. Socioeconomic status was classified according to the minimum wage of Gorontalo Province in 2023, and anemia during pregnancy was determined based on a hemoglobin level of <11 g/dL. Descriptive analysis was performed to describe the characteristics of respondents in the case and control groups. Subsequently, causal mediation analysis was conducted within a causal framework to estimate the total effect of socioeconomic status on anemia during pregnancy and to decompose this effect into the natural direct effect and the natural indirect effect through maternal nutritional status. All statistical analyses were performed using STATA software, with the level of statistical significance set at $p < 0.05$.

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The causal framework of this study was developed using a directed acyclic graph (DAG) to illustrate the causal relationships among socioeconomic status, maternal nutritional status, and anemia during pregnancy, as well as to guide variable selection in the mediation analysis (Figure 1). To ensure the assumption of temporality in the case–control design, this study positioned socioeconomic status as a relatively stable structural determinant that conceptually precedes and is associated with maternal nutritional status. Maternal nutritional status, represented by chronic energy deficiency, was positioned as a maternal nutritional condition that develops before or during pregnancy and precedes the occurrence of anemia, as formulated in the causal framework based on the DAG. Adjustments were also made for potential confounders in the relationship between socioeconomic status and anemia, namely maternal age and maternal education, as well as for potential confounders in the relationship between chronic energy deficiency and anemia, namely parity and pregnancy interval.

This study obtained ethical approval from the Health Research Ethics Committee of Universitas Negeri Gorontalo through the main research protocol. The analysis presented in this article remained within the scope of the approved protocol, with ethical approval number: 183C/UN47.B7/KE/2025.

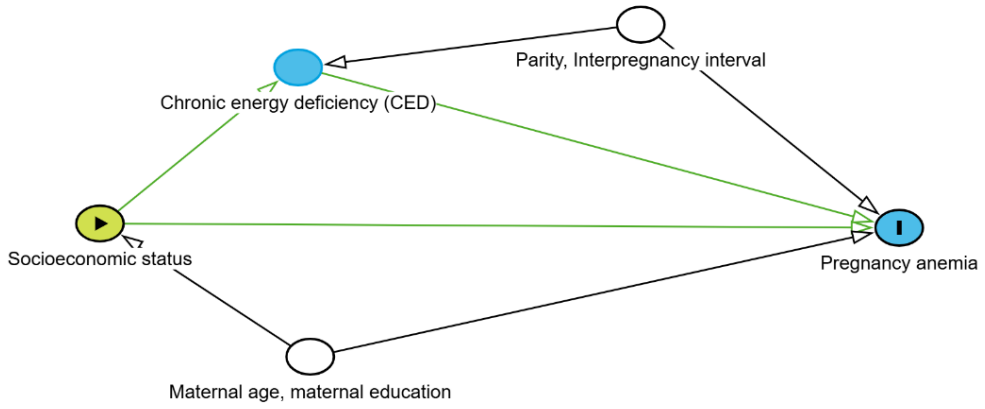

Figure 1. Directed acyclic graph (DAG) illustrating the assumed causal relationships among study variables

RESULTS

Table 1. General characteristics and study variables of pregnant women

Characteristics	Anemia		Non-anemia	
	n (56)	%	n (112)	%
Maternal age (years)				
< 20 atau > 35	10	17.86	16	14.29
20-35	46	82.14	96	85.71
Maternal education				
Low	40	71.43	75	66.96
High	16	28.57	37	33.04
Socioeconomic status				
Lower–middle	46	82.14	60	53.57
Upper–middle	10	17.86	52	46.43
Parity				
Grand multipara	26	46.43	46	41.07
Multipara or primipara	30	53.57	66	58.93
Interpregnancy interval (months)				
< 24 atau > 60	8	14.29	18	16.07
24–59	48	85.71	94	83.93
Chronic energy deficiency (CED)				
Yes	20	35.71	13	11.61
No	36	64.29	99	88.39

Table 1 shows that the majority of pregnant women in both the anemia and non-anemia groups were aged 20–35 years. However, the proportion of women in the high-risk age category (<20 years or >35 years) was slightly higher in the anemia group (17.86%) compared with the non-anemia group (14.29%), although the difference was not pronounced. With respect to maternal education, most respondents in both groups had a low educational level. The proportion of women with low education was higher among anemic women (71.43%) than

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among non-anemic women (66.96%), suggesting that anemia tended to occur more frequently among women with lower educational attainment. Most anemic women belonged to the lower–middle socioeconomic group (82.14%), whereas this proportion was considerably lower in the non-anemia group (53.57%).

In terms of parity, nearly half of the women in the anemia group were grand multiparous (46.43%), which was slightly higher than in the non-anemia group (41.07%). Conversely, primiparous or multiparous women were more prevalent in the non-anemia group. Regarding interpregnancy interval, most respondents in both groups had an optimal interval of 24–59 months, with relatively similar proportions between the anemia and non-anemia groups, indicating a fairly even distribution of this variable. The most pronounced difference was observed in maternal nutritional status. The proportion of women with CED was substantially higher in the anemia group (35.71%) compared with the non-anemia group (11.61%). In contrast, women without CED were more commonly found in the non-anemia group (88.39%).

Table 2. Direct and indirect effects of socioeconomic status on anemia during pregnancy through chronic energy deficiency

Effect	OR	95% CI	p-Value	Proportion mediated (%)
Natural indirect effect	1.32	1.025-1.688	0.031	24.14
Natural direct effect	3.03	1.349-6.803	0.007	-
Total effect	3.98	1.830-8.681	0.000	-

The natural indirect effect indicates that the effect of socioeconomic status on anemia during pregnancy operating through CED was statistically significant (OR = 1.32; 95% CI: 1.025–1.688; p = 0.031). This finding suggests that maternal nutritional status plays a mediating role in the relationship between socioeconomic status and anemia during pregnancy. The proportion mediated of 24.14% indicates that approximately one-quarter of the total effect of socioeconomic status on anemia during pregnancy operates through the pathway of maternal nutritional status, while the remaining effect is attributable to other mechanisms.

The natural direct effect demonstrates that socioeconomic status also influences anemia during pregnancy through direct pathways or via mechanisms independent of maternal nutritional status (OR = 3.03; 95% CI: 1.349–6.803; p = 0.007). This result indicates that chronic energy deficiency functions as a partial mediator, rather than the sole mechanism underlying the association between socioeconomic status and anemia during pregnancy.

The total effect confirms that socioeconomic status is associated with anemia during pregnancy through both direct and indirect pathways. Specifically, pregnant women with lower socioeconomic status had 3.98 times higher odds of developing anemia compared with those of higher socioeconomic status (OR = 3.98; 95% CI: 1.830–8.681; p < 0.001).

The effects of socioeconomic status on anemia during pregnancy through chronic energy deficiency after adjustment for other variables, as guided by the prespecified DAG, are presented in Table 3.

Table 3. Effects of socioeconomic status on anemia during pregnancy through chronic energy deficiency after adjustment for covariates

Effect	aOR*	95% CI	p-Value	Proportion mediated (%)
Natural indirect effect	1.31	1.018-1.693	0.036	23.76
Natural direct effect	3.08	1.351-7.030	0.007	-
Total effect	4.05	1.841-8.896	0.001	-

*Adjusted for maternal age, maternal education, parity, and interpregnancy interval.

The results of the adjusted causal mediation analysis indicate that the association between socioeconomic status and anemia during pregnancy remained statistically significant after controlling relevant covariates. The total effect showed that pregnant women with low socioeconomic status had approximately fourfold higher odds of experiencing anemia compared with those with higher socioeconomic status (aOR = 4.05; 95% CI: 1.841–8.896; p = 0.001).

After adjustment, chronic energy deficiency was found to exert a significant indirect effect on anemia during pregnancy, as reflected by a statistically significant natural indirect effect (aOR = 1.31; 95% CI: 1.018–1.693; p = 0.036). The proportion mediated was 23.76%, indicating that nearly one-quarter of the effect of socioeconomic status on anemia during pregnancy could be explained through the pathway of chronic energy deficiency, the remaining effect may be explained by other mechanisms not examined in this study.. In addition, the natural direct effect of socioeconomic status on anemia during pregnancy remained significant after adjustment (aOR = 3.08; 95% CI: 1.351–7.030; p = 0.007), suggesting that CED acts as a partial mediator in this association.

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DISCUSSION

The findings of this study indicate that the effect of socioeconomic status on anemia during pregnancy operates partly through maternal nutritional status, as reflected by the significant indirect effect via chronic energy deficiency (CED) after controlling for confounding factors. This suggests that disadvantaged socioeconomic conditions contribute to an increased risk of anemia during pregnancy by first influencing maternal energy adequacy and overall nutritional status. The remaining effect may reflect non-nutritional and structural mechanisms, including delayed access to or poor quality of antenatal care, suboptimal adherence to iron–folic acid supplementation, low dietary diversity and micronutrient intake not captured by mid-upper arm circumference, infection or inflammation, depletion of maternal reserves due to high parity or short pregnancy intervals, low health literacy, poor sanitation, and broader household-level constraints.

These findings are consistent with evidence from the Global Burden of Disease Study 2019, which demonstrated that nutritional deficiencies, including anemia, are strongly shaped by socioeconomic inequality. Countries with lower levels of socioeconomic development bear a substantially higher burden of nutritional deficiencies, both in terms of prevalence and their impact on population health.[18] This inequality is particularly evident for key micronutrient deficiencies, such as iron deficiency, which represents the leading cause of anemia, especially among women of reproductive age. Other studies have similarly shown that anemia is more prevalent among individuals from lower socioeconomic backgrounds.[21] This pattern has been observed in both urban and rural settings, where low income and poor living conditions contribute to a higher risk of anemia.

Individuals from low-income households often have limited access to foods with adequate nutritional quality, resulting in insufficient energy intake among pregnant women.[22] Previous studies have emphasized that socioeconomic factors influence nutritional status through restricted access to nutritious foods and adequate nutrient sources. Chronic energy deficiency reflects long-term inadequacy of energy and protein intake and is frequently accompanied by deficiencies in iron, folate, and other vitamins essential for erythropoiesis.[23] During pregnancy, iron requirements increase substantially to support expanded blood volume and fetal growth. When maternal nutrient reserves are already depleted, the body is unable to meet these increased demands, thereby elevating the risk of anemia.[24,25]

Chronic energy deficiency induces a range of physiological changes that can impair the body's ability to produce healthy red blood cells, thereby contributing to the development of anemia.[26] This condition is associated with hormonal imbalances as well as a reduced capacity to absorb and utilize nutrients. Deficits in energy and protein intake may disrupt intestinal mucosal function and decrease the efficiency of iron and other micronutrient absorption.[27] These effects are further exacerbated by hormonal disturbances commonly observed in malnutrition, such as reduced thyroid hormone levels and impaired regulation of erythropoietin, both of which play a critical role in stimulating erythropoiesis.[25,27] In addition, CED leads to a depletion of body protein reserves, which adversely affects globin synthesis, a key component of hemoglobin. In the absence of adequate protein availability, hemoglobin synthesis becomes suboptimal even when iron intake is relatively sufficient.[28,29] Over time, these mechanisms increase the susceptibility of pregnant women to anemia, particularly during pregnancy when nutritional demands are substantially elevated. However, the biological mechanisms described above should be interpreted with caution in the context of this study. Chronic energy deficiency was assessed using a mid-upper arm circumference of <23.5 cm, which identifies pregnant women at risk of chronic energy deficiency rather than confirming the presence of severe malnutrition. Therefore, the observed indirect effect should not be interpreted as evidence that severe malnutrition is the primary biological driver of anemia in this population.

In addition, the findings of this study indicate that the overall effect of socioeconomic status on anemia during pregnancy remains strong, even after accounting for the role of maternal nutritional status and other confounding variables. The magnitude of the total effect suggests that socioeconomic status is an important determinant of anemia during pregnancy, operating through multiple pathways that are not limited to maternal nutritional status alone. These findings are consistent with a study conducted in rural western India, which reported that women from households with low socioeconomic status had a significantly higher risk of anemia.[20] Other studies have likewise demonstrated that social determinants, including poverty and social inequality, contribute substantially to the burden of anemia among pregnant women.[30]

This total effect reflects the broad influence of socioeconomic status on multiple aspects of maternal health. Beyond its impact on nutritional status, socioeconomic conditions play an important role in shaping access to antenatal care services, adherence to iron supplementation, the quality and diversity of dietary intake, and exposure to infections and unhealthy environmental conditions.[31–33] These factors may directly reduce hemoglobin levels without necessarily operating through changes in overall energy nutritional status. Therefore, although maternal nutritional status acts as a meaningful mediator, the effect of socioeconomic status on anemia during pregnancy remains multidimensional and complex. However, comparative mediation studies examining chronic energy deficiency (CED) as a pathway linking socioeconomic status to anemia during pregnancy remain limited in Indonesia and Southeast Asian countries. Accordingly, the present findings should be interpreted as preliminary evidence and require confirmation through longitudinal studies.

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This study has several limitations that should be considered. Some potential determinants of anemia during pregnancy, such as daily micronutrient intake, adherence to iron supplementation, and history of infection, were not measured in the available data. Nevertheless, adjustment for key confounders identified through the causal framework is expected to have minimized substantial bias. Moreover, the consistency in the direction and magnitude of the estimated effects after adjustment supports the robustness of the study findings. Future research is recommended to employ longitudinal study designs to strengthen temporal inference between socioeconomic status, maternal nutritional status, and anemia during pregnancy. In addition, more comprehensive assessments of nutritional status, including micronutrient indicators, as well as the exploration of additional mediators such as antenatal care utilization and supplementation adherence, may provide deeper insight into the mechanisms underlying this association.

CONCLUSION AND RECOMMENDATIONS

Socioeconomic status is associated with anemia during pregnancy through both direct pathways and indirect pathways operating via maternal nutritional status, as reflected by CED. CED was shown to be one of the mechanisms underlying this relationship, although it does not fully account for the overall effect of socioeconomic status on anemia during pregnancy. Acting as a partial mediator, CED explains approximately one-quarter of the total effect of socioeconomic status on anemia during pregnancy. These findings are mainly generalizable to pregnant women in rural areas with characteristics similar to those in Gorontalo.

It is recommended that the prevention of anemia during pregnancy be strengthened through the development of more integrated antenatal care programs that are oriented toward vulnerable groups. In addition to iron–folic acid supplementation, antenatal care services should include nutrition education, dietary intake monitoring, early screening of hemoglobin levels and mid-upper arm circumference, and referral to social or food assistance programs for pregnant women from low-income households. These efforts require multisectoral collaboration among community health centers, integrated health posts, the social sector, the food sector, and village governments to ensure that pregnant women from low socioeconomic backgrounds receive supplementation, nutrition counseling, access to nutritious food, and continuous support.

AUTHOR'S CONTRIBUTION STATEMENT

St. Surya Iindah Nurdin led the conceptualization and design of the study, developed the methodology, coordinated the investigation, managed data curation, performed the formal analysis, prepared the visualization, administered the project, and drafted the original manuscript. Sitti Mukarramah contributed to the methodological refinement, validation of the analytical approach, and overall supervision of the study. Zul Fikar Ahmad contributed to field investigation, data curation, and provision of research resources. Yuliandary Yunus contributed to methodological guidance, validation, and academic supervision. All authors critically reviewed and edited the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

CONFLICT OF INTEREST

The authors declare that they have no financial or non-financial conflicts of interest related to this study.

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