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Impact of early-life malaria exposure on childhood stunting: A case-control study in high endemic malaria area, Papua, Indonesia

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Abstract

Papua faces public health challenges as a region with high malaria endemicity and a very high prevalence of stunting. Infectious diseases are one of the risk factors for stunting. The aim of this study was to investigate the effect of early-life malaria exposure on stunting among children in Papua. The study was conducted in 14 public health centers (PHCs) in Papua in 2023. Six hundred eighty-one children (227 stunted and 454 non-stunted) were selected using simple random sampling. The study data were gathered from medical records, structured parent interviews, and direct anthropometric measurements of the children. Chi-square tests were performed to determine unadjusted OR, while adjusted OR was calculated using multivariate analysis. The height-for-age z-score was calculated using WHO Anthro version 3.2.2. The results showed that 45.1% of mothers who had malaria during pregnancy had stunted children. The average z-score height-for-age of children from mothers who experienced malaria during pregnancy vs those who did not was -1.69±1.23 vs -1.41±1.55. Among the 84 children who had malaria under one year old, 45.2% experienced stunting. The average z-score height-for-age of children who had malaria under one year old vs those who did not was -1.83±1.24 vs -1.38±1.6. In the unadjusted analysis, malaria during pregnancy (OR 1.74; 95%CI: 1.06–2.87), malaria in children under one year old (OR 1.78; 95%CI: 1.12–2.83), low birth weight status (OR 1.82; 95%CI: 1.08–3.05), family income (OR 1.75; 95%CI: 1.09–2.81), and mother's ethnicity (OR 1.45; 95%CI: 1.05–2.01) were associated with stunting incidence in children. In the multivariate analysis, mother's ethnicity (aOR 1.41; 95%CI: 1.00–1.97) and low birth weight status (aOR 1.72; 95%CI: 1.00–2.94) were the only risk factor for stunting. This study suggests a potential association between early-life malaria exposure and stunting in children. In malaria-endemic areas, health interventions targeting malaria prevention during pregnancy and early childhood are necessary to reduce the risk of stunting.

Keywords: Malaria, pregnancy, children, malnutrition, stunting

Introduction

Malaria remains one of the world's leading infectious diseases, with 249 million cases globally and 608,000 deaths reported across 85 countries in 2022 [1]. Children under the age of five years account for nearly 80% of all malaria-related deaths globally, with the African region reporting 94% of all malaria cases and 95% of malaria deaths [2]. Papua, a region in Eastern Indonesia, lies

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within tropical and subtropical zones. Papua is highly endemic for malaria, with an annual parasite incidence (API) of 113.7 in 2022, significantly higher than Indonesia's national API of 1.61. In 2022, there were 4,239 malaria cases among pregnant women in Papua, while the incidence of malaria in children under one year old reached 34.6% [3]. In the same year, Papua had the third-highest stunting prevalence in Indonesia, with a rate of 34.6%, marking a 5.1% increase from 2021, when the prevalence was 29.5% [3].

Several previous studies have linked malaria to impaired child growth [4-6]. Stunting, a prevalent issue in many tropical countries, particularly in Africa and Asia, is often used to assess chronic malnutrition, which is a key factor contributing to child morbidity and mortality [7]. Malaria is also known to cause chronic anemia, which hinders children's growth and development [8]. In regions with high malaria transmission, nearly all infants, young children, and a significant proportion of older children and adults experience reduced hemoglobin concentrations due to malaria [9]. Malaria during pregnancy also significantly increases the risk of low birth weight (LBW). Without specific interventions during pregnancy, malaria infections in 33 countries are estimated to cause 914,000 babies to be born with LBW [1].

A 1956 study in Gambia showed that children who received malaria prophylaxis had a better average z-score than those who did not [10]. Similarly, studies in Nigeria, Kenya, Ghana, and Uganda have found an association between malaria, growth outcomes, and the risk of stunting [11-15]. A cohort study conducted in Ethiopia revealed that toddlers who experienced malaria infection had a 1.9 times higher risk of stunting [4]. These findings suggest that children exposed to malaria, particularly during pregnancy or infancy, tend to have a higher risk of stunting, which reflects chronic malnutrition and the cumulative impact of recurrent infections. The aim of this study was to investigate the effect of early-life malaria exposure on stunting among children in Papua. Additionally, the study seeks to inform the development of more effective public health intervention strategies to address the dual burden of malaria and stunting in this region.

Methods

Study design and setting

A case-control study was conducted in Jayapura, Indonesia, at 14 public health centers (PHCs), known as *Puskesmas* in Indonesia, from May to September 2023. The study compared a group of children who experienced stunting (cases) with a group of children who did not experience stunting (controls) based on their history of malaria exposure, both during the mother's pregnancy and within the child’s first year of life.

Sampling strategy

The sample size was determined using the Lemeshow’s formula [16], with a 95% confidence interval, 80% power (0.84), and an odds ratio (OR) of 1.9 [4]. The sample calculation resulted in 227 participants for the case group. With a case-to-control sample ratio of 1:2, the control group included 454 participants, bringing the total sample size to 681. Sample selection was conducted using proportional simple random sampling to allocate the sample size for each PHCs based on the stunting burden. By using this method, PHCs with higher stunting prevalence received a larger sample. Allocating the sample size based on the stunting burden is also important to ensure that variations in stunting prevalence between PHCs can be measured accurately.

Participants

This study included children aged over one year old, living in the service areas of PHCs in Jayapura, with available health records from under one year old, and whose mothers had complete health history records during pregnancy. Children were excluded if they had significant congenital abnormalities affecting growth, a history of chronic diseases other than malaria (such as HIV/AIDS), incomplete malaria history data during the mother's pregnancy or under one year old, or if they had migrated, were not permanent residents in malaria-endemic areas, or had moved during the observation period.

The case group comprised of children under five years old being categorized as stunted, defined by a z-score for height-for-age (H/A) less than -2.00 standard deviations (SD), following

WHO standard [17]. Meanwhile, the control group consisted of children under five years old who were not categorized as stunted. The classification of children into case and control groups was based on data from the Community-Based Nutrition Recording and Reporting System (*elektronik Pencatatan Pelaporan Gizi Berbasis Masyarakat* (e-PPGBM)), an application developed by the Ministry of Health of the Republic of Indonesia. This application records and reports children's nutritional status, categorizing them as stunted or non-stunted based on age and sex, along with details such as name and address.

Study variables

In this study, the outcome variable was the incidence of stunting in children. The primary exposure variables included the incidence of malaria during pregnancy, determined from the mother's medical history or malaria treatment records, and the incidence of malaria in children under one year old, obtained through medical records or parental reports. Additionally, this study measured several predictors that may potentially influence stunting, such as sex, LBW status (classified as birth weight below 2500 grams), exclusive breastfeeding (exclusive or non-exclusive), immunization status (complete or incomplete), mother's ethnicity (Papuan or non-Papuan), mother's age (considered at risk if <20 years or >35 years), mother's employment status (employed or unemployed), family income (measured by the regional minimum wage, ≥minimum wage or <minimum wage), and other infections besides malaria (yes or no).

Data collection

The data in this study were obtained from various sources, including medical records of mothers and children, structured interviews with parents, and direct anthropometric measurements of the children. Trained healthcare professionals performed direct height measurements of the children using a stadiometer, ensuring an accuracy of 0.1 cm. Malaria incidence during pregnancy was collected from medical records at PHCs or hospitals that documented malaria diagnoses during pregnancy or from interviews with mothers regarding their malaria history and treatment during pregnancy. For children under the age of one, malaria incidence data were obtained from their medical records, which documented laboratory results or malaria treatment and further validated through interviews with the mothers. Data on other infections besides malaria, such as acute respiratory infection, gastrointestinal infections/diarrhea [18], worm infection[19], and tuberculosis [20], were obtained through medical records and validated through interviews with mothers.

The child's sex was documented based on information from the parents or medical records. LBW status was taken from medical records. Information about exclusive breastfeeding was collected through interviews with mothers, where exclusive breastfeeding was defined as feeding only breast milk without any additional food or drink during the first six months. Immunization status was obtained from immunization cards or medical records, with children categorized as fully immunized if they had received all basic immunizations according to schedule and not fully immunized if they missed one or more of the basic immunizations based on Indonesian Ministry of Health guidelines [21]. The mother's ethnicity was classified as Papuan or non-Papuan based on interviews.

The mother's age was documented through interviews and categorized as at risk (<20 years or >35 years) or not at risk (20–35 years) [22]. The mother's employment status was collected through interviews and classified as employed if the mother had income-generating work or unemployed if she did not have income-generating work. Family income was measured based on parental interviews and classified as either at least the regional minimum wage (*upah minimum regional* (UMR)) or below the UMR, based on the prevailing UMR standard in the study area.

All measurements were conducted uniformly by a trained research team, ensuring consistency and reliability throughout the study. Data were obtained from consistent sources to enhance the validity of the findings. Data collection was carried out during activities at the community health posts (*Posyandu*). In instances where a sampled child did not attend the *Posyandu*, home visits were conducted to gather the necessary data. The data collection process was assisted by enumerators, who were trained nutrition officers from the local PHCs.

Study bias

In this study, several steps were taken to minimize potential sources of bias during data collection and analysis. Selection bias was addressed using inclusion and exclusion criteria and a systematic sampling process. The researchers created a sample frame of stunted and non-stunted children based on data from the e-PPGBM. All children who met the inclusion and exclusion criteria were included without exception, ensuring proper representation of both case (stunted) and control (non-stunted) groups. To reduce information bias, data collection was conducted by trained healthcare professionals using standardized procedures, particularly in height measurements and recording of nutritional status. All measurements were performed using calibrated equipment, and interviews with parents were conducted using structured questionnaires.

Recall bias related to malaria history during pregnancy and the child's disease history was minimized by prioritizing the use of medical records as the primary data source. When medical records were unavailable, additional information from parents was obtained through interviews, which were conducted carefully to ensure the accuracy of their reports. To prevent observation bias, those assessing stunting status were blinded to which group (case or control) the child belonged to (blinded assessment). During analysis, confounding bias was addressed by performing multivariate analysis to control for covariates that could influence the relationship between malaria exposure and stunting incidence, such as the child's nutritional status, breastfeeding practices, and primary immunization status.

Statistical methods

In this study, statistical analysis was performed to evaluate the relationship between various sociodemographic factors and malaria exposure on the incidence of stunting in children. Data were analyzed using SPSS (SPSS Inc., Chicago, USA) version 20 and WHO Anthro version 3.2.2 (Department of Nutrition, WHO, Geneva, Switzerland).

Univariate analysis was performed using the Chi-squared test for categorical variables to assess the relationship between sociodemographic factors and malaria exposure with stunting incidence. Odds ratios (OR) and 95% confidence intervals (95%CI) were calculated to determine the relative risk of factors associated with stunting, both in unadjusted and adjusted conditions. Multivariate logistic regression analysis was used to control confounding factors. This logistic regression model incorporated variables with p=0.25 in the univariate analysis and clinically relevant factors, such as LBW status, exclusive breastfeeding, immunization status, mother's ethnicity, maternal age, maternal employment, and family income. Adjusted OR (aOR) with 95%CI was presented to evaluate the independent relationship between these variables and the incidence of stunting.

The H/A z-score was calculated using WHO Anthro version 3.2.2. This calculation was based on the WHO child growth standards, allowing for comparison with international reference data. The age groups were divided into five categories in months, based on the default standard for grouping ages 0–60 months by WHO, as outlined in the WHO Anthro for Personal Computers Manual [23]. The groupings consist of 6–11 months, 12–23 months, 24–35 months, 36–47 months, and 48–60 months. The analysis compared the H/A z-scores between children who had malaria under one year old and those who did not, as well as between children whose mothers had malaria during pregnancy and those whose mothers did not. Additionally, a sub-analysis was conducted based on sex to explore differences in the impact of malaria on growth between boys and girls.

Results

Characteristics of the participants

A total of 681 children were included in the study, as presented in **Table 1**. Just more than half of the children under five were male (50.1%). Based on nutritional status, the vast majority of children fell into the non-LBW category (90.5%). Among all of the children, 57.4% of the children received non-exclusive breastfeeding. Additionally, the majority of children (84.6%) had other infections besides malaria, such as acute respiratory infection, diarrhea, worm infection, and tuberculosis. Additionally, 85.2% of the children were reported to have received complete basic immunizations. About 55.1% of the mothers were of Papuan ethnicity, with 83.4% in the non-risk age category, 83.4% not employed, and 83.8% had an income below the regional minimum wage.

Table 1. Characteristics of the children below five years old included in the study (n=681)

Characteristics	Frequency	Percentage
Sex		
Male	341	50.1
Female	340	49.9
Low birth weight (LBW) status		
LBW	65	9.5
Non-LBW	616	90.5
Breastfeeding		
Exclusive	290	42.6
Non-exclusive	391	57.4
Basic immunization status		
Complete	580	85.2
Incomplete	101	14.8
Mother's ethnicity		
Papuan	375	55.1
Non-Papuan	306	44.9
Mother's age		
At risk	113	16.6
Not at risk	568	83.4
Mother's employment status		
Employed	113	16.6
Unemployed	568	83.4
Family income		
≥Minimum wage (UMR)	110	16.2
<Minimum wage (UMR)	571	83.8
Malaria during pregnancy		
Yes	71	10.4
No	610	89.6
Malaria under one year old		
Yes	84	12.3
No	597	87.7
Other infections besides malaria		
Yes	576	84.6
No	105	15.4

Predictors of stunting

In the unadjusted analysis, LBW status (OR: 1.82; 95%CI: 1.08–3.05), family income (OR: 1.75; 95%CI: 1.09–2.81), and mother's ethnicity (OR: 1.45; 95%CI: 1.05–2.01) were associated with stunting incidence in children. In the multivariate analysis, LBW status (aOR: 1.72; 95%CI: 1.00–2.94) and the mother's ethnicity (aOR 1.41; 95%CI: 1.00–1.97) were the only risk factor for stunting in children (**Table 2**).

Effect of malaria exposure on stunting

In the unadjusted analysis, malaria during pregnancy (OR: 1.74; 95%CI: 1.06–2.87) and malaria in children under one year old (OR: 1.78; 95%CI: 1.12–2.83) were identified as risk factors for stunting in children (**Table 3**). Children born to mothers who had malaria during pregnancy faced a 1.74 times higher risk of stunting compared to children born to mothers who did not have malaria. Similarly, children who had malaria under one year old had a 1.78 times higher risk compared to those who did not experience malaria. However, in the adjusted multivariate analysis with other infections, malaria during pregnancy (aOR: 1.50; 95%CI: 0.86–2.61) and malaria in children aged under one year (aOR: 1.39; 95%CI: 0.83–2.33) were not a predictor for stunting (**Table 3**).

Comparison of height-for-age z-scores among children based on malaria status and maternal malaria during pregnancy

Among 84 children who suffered from malaria under one year old, 20.2% were below -3SD, while 42.9% were below -2SD, with an average z-score of -1.83±1.24 (**Table 4**). The highest percentage of stunting below -2SD was observed in the 12–13 months age group, reaching 52.6%, which also had the lowest mean z-score of -2.2±1.06 (**Table 4**).

Table 2. Sociodemographic factors associated with stunting incidence in children below five years old (n=681)

Characteristics	Stunting (n=227) n (%)	Non-stunting (n=454) n (%)	Unadjusted OR (95%CI)	*p*-value	Adjusted OR (95%CI)	*p*-value
Sex						
Male	123 (36.1)	218 (63.9)	0.78 (0.56–1.07)	0.151	0.76 (0.54–1.06)	0.106
Female (reference)	104 (30.6)	236 (69.4)				
Low birth weight (LBW) status						
LBW	30 (46.2)	35 (53.8)	1.82 (1.08–3.05)	0.030*	1.72 (1.00–2.94)	0.048*
Non-LBW (reference)	197 (32.0)	419 (68.0)				
Breastfeeding						
Exclusive	94 (32.4)	196 (67.6)	1.07 (0.77–1.48)	0.722	1.03 (0.73–1.44)	0.859
Non-exclusive (reference)	133 (34.0)	258 (66.0)				
Basic immunization status						
Complete	186 (32.1)	394 (67.9)	1.44 (0.93–2.23)	0.118	1.43 (0.91–2.23)	0.115
Incomplete (reference)	41 (40.6)	60 (59.4)				
Mother's ethnicity						
Papuan	139 (37.1)	236 (62.9)	1.45 (1.05–2.01)	0.027*	1.41 (1.00–1.97)	0.046*
Non-Papuan (reference)	88 (28.8)	218 (71.2)				
Maternal age						
At risk	44 (38.9)	69 (61.1)	0.74 (0.49–1.13)	0.202	1.36 (0.88–2.10)	0.155
Not at risk (reference)	183 (32.2)	385 (67.8)				
Mother's employment status						
Employed	30 (26.5)	83 (73.5)	1.46 (0.93–2.3)	0.117	1.30 (0.76–2.22)	0.327
Unemployed (reference)	197 (34.7)	371 (65.3)				
Family income						
≥Minimum wage (UMR)	26 (23.6)	84 (76.4)	1.75 (1.09–2.81)	0.025*	1.48 (0.85–2.56)	0.157
<Minimum wage (UMR) (reference)	201 (35.2)	370 (64.8)				

* Statistically significant at p=0.05

Table 3. Effect of malaria exposure and other infections on stunting incidence

Malaria exposure	Stunting (n=227) n (%)	Non-stunting (n=454) n (%)	Unadjusted OR (95%CI)	*p*-value	Adjusted OR (95%CI)	*p*-value
During pregnancy						
Yes	32 (45.1)	39 (54.9)	1.74 (1.06–2.87)	0.037*	1.50 (0.86–2.61)	0.145
No	195 (32.0)	415 (68.0)				
Under one year old						
Yes	38 (45.2)	46 (54.8)	1.78 (1.12–2.83)	0.019*	1.39 (0.83–2.33)	0.209
No	189 (31.7)	408 (68.3)				
Other infections in infants						
Yes	196 (34.0)	380 (66.0)	1.23 (0.78–1.93)	0.431	1.13 (0.70–1.81)	0.609
No	31 (29.5)	74 (70.5)				

* Statistically significant at p=0.05

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For children who did not experience malaria under one year old (n=597), 12.2% were below -3SD and 34.2% were below -2SD (**Table 4**). The 36–47 months age group had the highest percentage below -2SD, at 42.4%, with the lowest average z-score of -1.78±1.31. The distribution of z-scores for children who experienced malaria had a peak distribution shifted to the left (more negative) and a more spread-out curve compared to the WHO standard, both overall and by sex (**Figure 1**).

Table 4. Height-for-age z-score of children with vs without malaria infection under one year old

Age groups (month)	Frequency	Percentage < -3SD; (95%CI)	Percentage < -2SD; (95%CI)	Z-score (mean±SD)
With malaria (n=84)				
6–11	7	0; (0–7.1)	0; (0–7.1)	-0.72±0.4
12–13	19	15.8; (0–34.8)	52.6; (27.5–77.7)	-2.2±1.06
24–35	20	40; (16–64)	50; (25.6–74.4)	-1.92±1.62
36–47	24	20.8; (2.5–39.2)	45.8; (23.8–67.9)	-1.87±1.21
48–60	14	7.1; (0–24.2)	35.7; (7–64.4)	-1.67±0.94
Total	84	20.2; (11.1–29.4)	42.9; (31.7–54)	-1.83±1.24
No malaria (n=597)				
6–11	42	4.8; (0–12.4)	11.9; (0.9–22.9)	-0.47±1.78
12–13	257	13.2; (8.9–17.6)	31.1; (25.3–37)	-1.21±1.77
24–35	135	14.8; (8.5–21.2)	42.2; (33.5–50.9)	-1.76±1.4
36–47	92	15.2; (7.3–23.1)	42.4; (31.7–53)	-1.78±1.31
48–60	71	4.2; (0–9.6)	32.4; (20.8–44)	-1.31±1.2
Total	597	12.2; (9.5–14.9)	34.2; (30.3–38.1)	-1.38±1.6

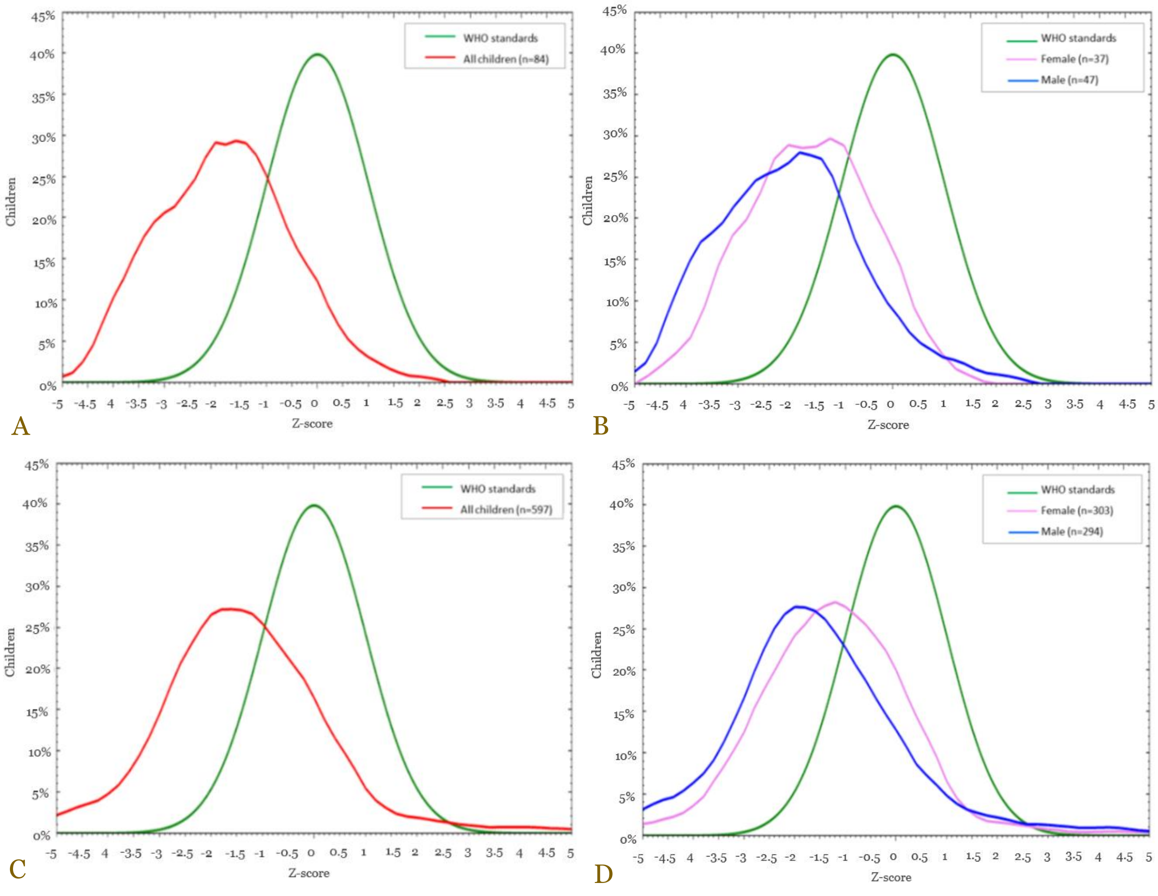

Figure 1. Comparison of z-scores (height-for-age) between children with and without malaria infection under one year old. (A) Children with malaria under one year old; (B) children with malaria under one year old, based on sex; (C) children without malaria under one year old; and (D) children without malaria under one year old, based on sex.

In the group of children whose mothers experienced malaria during pregnancy (n=71), 15.5% were below -3SD, and 38% were below -2SD (**Table 5**). The highest percentage of stunting below

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-2SD was observed in the 12–13-month age group, at 41.7%. Meanwhile, among children whose mothers did not experience malaria during pregnancy (n=610), 12.6% were below -3SD, and 34.6% were below -2SD, with an average z-score of -1.41±1.55) (**Table 5**). The distribution of z-scores for children whose mothers experienced malaria during pregnancy showed a peak distribution shifted to the left (more negative) and a more spread-out curve compared to children whose mothers did not experience malaria (**Figure 2**).

Table 5. Height-for-age z-score of children of pregnant mothers with vs without malaria

Age groups (month)	Frequency	Percentage < -3SD; (95%CI)	Percentage < -2SD; (95%CI)	Z-score (mean±SD)
Malaria during pregnancy (n=71)				
6–11	7	0; (0–7.1)	14.3; (0–47.4)	-0.86±0.84
12–13	24	16.7; (0–33.7)	41.7; (19.9–63.5)	-1.87±1.18
24–35	20	20; (0–40)	40; (16–64)	-1.67±1.45
36–47	15	13.3; (0–33.9)	40; (11.9–68.1)	-1.75±1.07
48–60	5	20; (0–65.1)	40; (0–92.9)	-1.86±1.39
Total	71	15.5; (6.4–24.6)	38; (26–50)	-1.69±1.23
No malaria during pregnancy (n=610)				
6–11	42	4.8; (0–12.4)	9.5; (0–19.6)	-0.45±1.76
12–13	252	12.7; (8.4–17)	31.3; (25.4–37.3)	-1.24±1.7
24–35	135	17; (10.3–23.7)	43; (34.2–51.7)	-s1.77±1.4
36–47	101	16.8; (9–24.6)	43.6; (33.4–53.7)	-1.81±1.32
48–60	80	3.8; (0–8.5)	32.5; (21.6–43.4)	-1.34±1.15
Total	610	12.6; (9.9–15.3)	34.6; (30.7–38.4)	-1.41±1.55

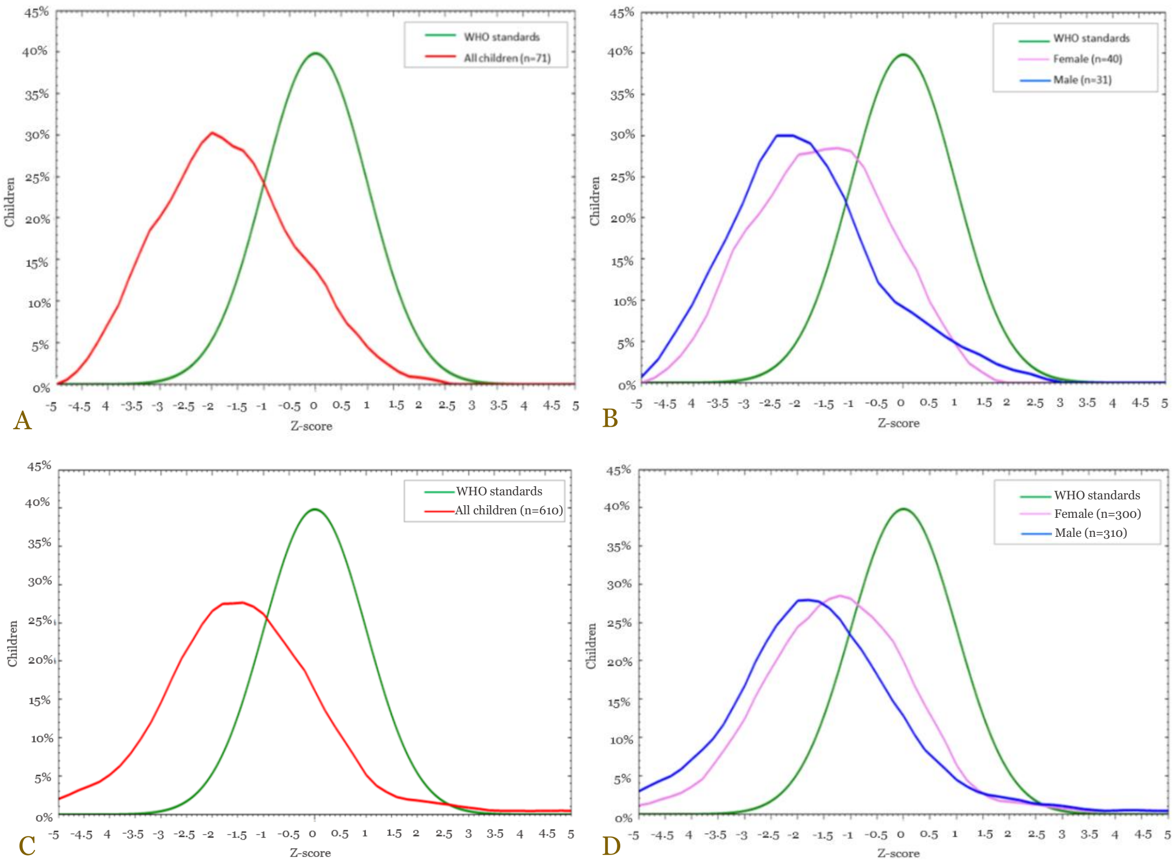

Figure 2. Comparison of z-scores (height-for-age) between children whose mothers experienced or did not experience malaria infection during pregnancy. (A) Children whose mothers had malaria during pregnancy; (B) children whose mothers had malaria during pregnancy, based on sex; (C) children whose mothers did not have malaria during pregnancy; and (D) children whose mothers did not have malaria during pregnancy, based on sex.

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Discussion

The results of this study indicate that malaria exposure, both during pregnancy and in children under one year old, was associated with a higher risk of stunting in the unadjusted analysis. Expressly, the unadjusted analysis indicated that children whose mothers had malaria during pregnancy had a 1.74 times higher risk of stunting, while children who experienced malaria under one year of age had a 1.78 times higher risk of stunting. However, after adjusting for potential confounders, including LBW status, exclusive breastfeeding, and immunization status, malaria exposure was no longer a statistically significant risk factor for stunting. This suggests that other factors, such as socioeconomic conditions, LBW status, and mother's ethnicity, may have a more pronounced influence on stunting outcomes in Papua.

The relationship between malaria and stunting has long been considered complex and multifactorial. Previous research, such as the systematic review [24], has shown inconsistent findings regarding the association between malaria and malnutrition. While acute malnutrition (wasting) was not consistently linked to malaria, chronic malnutrition, especially stunting, was more often associated with severe malaria cases, such as those involving high parasitemia levels or anemia. In this study, we found that children who had malaria under one year had lower mean z-scores for height-for-age (-1.83±1.24) compared to children who did not experience malaria (-1.38±1.16). Similarly, children born to mothers who had malaria during pregnancy also had lower mean z-scores (-1.69±1.23) compared to those whose mothers did not have malaria (-1.41±1.55).

Several studies support the notion that malaria can negatively affect child growth. For instance, studies have found that recurrent malaria infections can lead to chronic inflammation, which disrupts growth hormone signaling and increases serum levels of inflammatory markers such as C-reactive protein [5,25]. This chronic inflammatory state could explain why children in malaria-endemic regions like Papua are at increased risk of stunting. Moreover, malaria can increase the body's metabolic demands, leading to protein catabolism and redirecting energy away from growth and toward the immune response [5].

However, not all studies have found a direct link between malaria and stunting. Two cohort studies reported that malaria was not associated with stunting [26,27]. Another study also found no significant differences in weight or height gain between children with malaria and those without in rural Gambia [27]. Similarly, our adjusted analysis did not find malaria to be a significant risk factor for stunting after controlling for confounders, highlighting the importance of considering other factors, such as socioeconomic status and the presence of other infections, which can also contribute to stunting [18].

There are many potential confounders and effect modifiers, including micronutrient status, b-globin genotype, HIV status, diet, socioeconomic status, and the presence of other infections [28-31]. This study analyzed variables such as low birth weight, basic immunization status, and exclusive breastfeeding as potential confounders that might influence the relationship between malaria and stunting. After performing multivariate adjustments, it was found that low birth weight and mother's ethnicity status had a significant association with stunting.

Conclusion

This study found a significant association between malaria exposure and stunting in the unadjusted analysis, with higher stunting risk observed among children exposed to malaria during pregnancy or in their first year of life. However, the association became insignificant after adjusting for confounding factors such as LBW status, exclusive breastfeeding, immunization status, and socioeconomic status. This suggests that malaria alone may not directly cause stunting but interacts with other factors that more strongly influence growth outcomes. Although malaria exposure was not a direct risk factor for stunting after adjustment, children exposed to malaria had lower height-for-age z-scores compared to those not exposed, indicating potential growth delays. Given these findings, interventions targeting malaria prevention in pregnant women and infants should be integrated with broader public health programs to address the multifactorial causes of stunting. Further research, particularly longitudinal studies, is needed to better understand the complex interactions between malaria and other factors contributing to stunting, especially in high-prevalence regions like Papua.

Ethics approval

This study was approved by the Health Research Ethics Committee of the Poltekkes Kemenkes Jayapura (reference number 109/KEPK-J/V/2023) and conducted following the principles of the Declaration of Helsinki. Before data collection, all respondents were provided with a full explanation of the study's purpose and benefits. Confidentiality was strictly maintained. The identities and personal information of the respondents were anonymized and kept confidential, and they were used solely for research analysis purposes. The collected data were securely stored, with access restricted to the research team only. Additionally, respondents were given the right to withdraw their consent without any consequences. All respondents who agreed to participate in the study expressed their consent by signing a written informed consent form. They were also allowed to ask questions about the study, and their rights as participants were thoroughly explained.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

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