Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2024; 24(9): 24611-24655 https://doi.org/10.18697/ajfand.134.24835

Date	Submitted	Accepted	Published
	30th April 2024	17th August 2024	4th October 2024

RISK FACTORS OF ANEMIA AMONG CHILDREN AGED 6-59 MONTHS IN MADAGASCAR

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Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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ABSTRACT

While child anemia remains an uncontrolled health issue in developing and underdeveloped countries, the public health burden of child anemia is high in Madagascar. Using cross-sectional data from Madagascar Demographic and Health Survey 2021 (Madagascar DHS 2021), this study aims to examine the prevalence and risk factors of child anemia by region and socioeconomic status in the country. A total of 5,048 children aged 6-59 months with hemoglobin (Hb) concentration data were used for the study. First, the associations between child anemia (Hb< 11.0g/dl) and the household, parental, and child characteristics were tested by univariate logistic regression analysis. Variables with a p-value <0.05 in the univariate were included in the multivariate regression analysis, and sub-group analysis was conducted for six provinces. A heatmap was provided to visualize the distribution of common risk factors for the child anemia across six provinces. The prevalence of child anemia was 47 %. Child anemia was negatively associated with older age, and positively associated with maternal anemia in a dose-response manner, maternal younger age (<25 years old), underweight (BMI<18.5), low education level, history of fever or diarrhea in the past two weeks and high birth order (5^{th} or higher, compared to the 1^{st}). There was a regional variation in anemia (3.8% to 56.3%) with a higher prevalence in the Southern provinces compared to Antananarivo province, the capital area. The age of the child and the maternal anemia status consistently determined child anemia status in all six provinces, with certain region-specific factors such as female child, poor wealth, maternal obesity, women's empowerment, and iron supplementation. The prevalence of child anemia across Madagascar was found to be closely linked to both the age of the child and the maternal status, including health related, and socioeconomic conditions, which need to be more comprehensively examined. Further research is required to explore the pathways by which child anemia is related to maternal anemia and varies by regional location is required. Interventions targeting both anemic mother-child pairs, vulnerable populations, and young children are recommended to strengthen national nutrition programs in the country.

Key words: Anemia prevention, anemia control, Madagascar, child health, public health

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INTRODUCTION

Anemia is a deficiency in red blood cells, or hemoglobin, which results in a decreased oxygen-carrying capacity of blood to human body [1]. Anemia leads to serious impacts on the health of pregnant women and fetuses, specifically regarding vitamin B12 and folate deficiencies. Anemic conditions can lead to a significant increase in the prevalence of anemic mothers, which can negatively impact the prevalence of preterm birth, low birth weight, and infant mortality [2]. Child anemia is extended from the fetus period. A mother's body typically requires additional iron and vitamins during pregnancy to produce more red blood cells for the increased blood volume [3] with additional fluid being produced to support the growth and development of the fetus. Thus, the physiological risk of anemia can increase if nutritional requirements are not met with these increasing changes in the mother's body [4]. Breast milk of an anemic mother has lower levels of essential minerals, such as iron, zinc, and folate, as well as vitamins A and B12, which affect the Hb levels of the breastfed child [5].

Child anemia remains a public health issue not being addressed effectively. According to the World Health Organization (2019), the global anemia prevalence among children aged 6-59 months is 39.8% [6]. Child anemia leads to various health risks of increased morbidity and mortality, irrevocable cognitive and developmental delays, growth faltering and other micronutrient deficiencies in infancy; poor study performance at school; and low labor productivity in adulthood. If anemia among female children is not addressed, their reproductive health threatens the next generation's health [7].

In Madagascar, the prevalence of under-five children decreased from 69% in 2003-04 to 47% in 2021 but the prevalence is still unacceptably high [8]. Until now systematic epidemiology about the prevalence of child anemia and the risk factors was hardly done in the country. In poor communities of Antananarivo, the prevalence of child anemia was 24.4%, and the determinants of anemia were younger child age, iron deficiency, and fecal calprotectin [9]. Consuming more wildlife may protect child hemoglobin concentration, so removing wildlife is likely to lead to a 29% increase in anemia [10]. In Madagascar 2021, regional disparity in child anemia is high from 27% in Haute Matsiatra to 62% in Atsimo Atsinanana [8]. Thus, the main hypothesis posited that the different socio-economic and environmental conditions are associated with the different scope of anemia prevalence in children in the regions.

This data on the prevalence of anemia in children in Madagascar calls for a more effective and immediate plan to ensure the safety of their health. However, in terms of interventions, targeting only children is unlikely to achieve the underlying reduction in childhood prevalence, as maternal health care, a factor that has a direct impact

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ISSN 1684 5374

on newborn health, must also be addressed to impactfully reduce childhood anemia prevalence [11, 12, 13, 14].

The availability of local information on prevalence and related risk factors could help decision-makers improve or strengthen interventions for the control of anemia. Using data from the latest DHS 2021 in Madagascar, this study aims to explore the prevalence and risk factors of anemia at the household, maternal, and childhood levels on a national basis and will conduct further analysis to observe the common risk factors in six provinces (Antananarivo, Fianarantsoa, Toamasina, Mahajanga, Toliara, and Antsiranana). The evidence and the corresponding results from our study will be used to improve the health and well-being of pregnant women and their children in Madagascar.

MATERIALS AND METHODS

Study Population

This study analyzed data obtained from the Madagascar Demographic and Health Survey 2021 (Madagascar DHS 2021) [8]. The Madagascar DHS 2021 was a nationally representative dataset, sampled by a stratified two-stage sampling approach, and included data from a total of 11,131 children aged 6 to 59 months. All women aged 15-49 years old living in the sampled households sample were eligible to be interviewed. In a subsample of the households, all children under 5 years old were weighed and measured to determine their nutritional status. In this subsample, all women aged 15-29 years and all children aged 6-59 months were eligible for anemia testing. For anemia testing, blood samples were collected from 5,108 children aged 6 to 59 months. Comprehensive information regarding the sampling structure and assessment methods is available in Madagascar DHS 2021 (National Institute of Statistics (INSTAT) and ICF, 2022).

Outcome Variables

Out of the 5,108 children in Madagascar DHS 2021 dataset, this secondary data analysis included a total of 5,048 children aged 6-59 months with Hb concentration measurements (n=1,800 aged 6 to 23 months and n=3,248 aged 24 to 59 months). The data of 60 children were excluded from the analysis due to either null values or inappropriate responses (for example, ‘don't know’ or ‘not a resident’). Blood samples were collected from a finger prick or a heel prick for children aged 6 to 12 months. The Hb analysis was conducted using the HemoCue 201+ system. Anemia was defined as a blood Hb level below 11.0 g/dL, based on WHO guidelines in 2011 [15], with Hb levels of 10.0 to 10.9 g/dL, 7.0 to 9.9 g/dL, and below 7.0 g/dL indicating mild, moderate, and severe anemia, respectively. This study adjusted the anemia cut-offs for altitude using formulae published by the Centers for Disease Control and Prevention (CDC) in 1998.

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ISSN 1684 5374

Predictor Variables

This study identified potential risk factors for anemia at the household, maternal, and child levels based on the conceptual framework of anemia developed by Namaste *et al.* [16]. A total of 30 candidate variables were selected as predictor variables (Table 1, Table S1).

At the household level, a total of six variables were identified: residence type, geographical zone, wealth quintile, the number of family members, drinking water sources, and type of sanitation facilities in use.

Maternal characteristics included 13 variables for identification: level of education, occupation type, attitude towards violence, exposure to any media (TV, newspaper, or radio) at least once a week, owning a mobile phone, place of the recent delivery, type of delivery assistance, putting the baby to the breast within 1 hour after birth, age, obesity level, short height, current pregnancy, and anemia status. Individual characteristics at child level included the following 12 variables for identification: sex, age, birth order, perceived birth size, stunting, wasting, current breastfeeding status, intake of iron supplements, vitamin A supplementation in the last 6 months, deworming within the last 6 months, symptoms of diarrhea within the last 2 weeks, and symptoms of fever within the last 2 weeks.

Statistical Analysis

Stata version 14 (StataCorp LP, College Station, TX, USA) was used for all statistical analyses. Data from the Madagascar DHS 2021 dataset was publicly available in Stata format from the DHS program (https://dhsprogram.com/Data/). The variables were extracted from the downloaded Madagascar DHS 2021 dataset, including household, maternal, and individual information for children with available hemoglobin (Hb) concentration measurements. Some variables were transformed for further analysis. The mothers' occupational status was classified into five groups, except for the ‘not working’ category. These groups included: (a) not working, (b) traditional (involving agricultural employment), (c) transitional (comprising household/domestic and service), (d) mixed (involving sales, skilled, and unskilled manual labor), and (e) modern (comprised of professional/technical, managerial, and clerical), with the classification method derived from Bongaarts, Blanc, & McCarthy [17]. To assess the mothers' attitudes toward domestic violence, they were asked about their opinions on whether a husband is justified in beating his wife in five different situations: (a) wife goes out without telling husband, (b) wife neglects the children, (c) wife argues with husband, (d) wife refuses to have sex with husband, and (e) wife burns the food. Mothers who answered 'no' to all five questions were considered to have an intolerant stance toward domestic violence (opposed to violence), while those who answered 'yes' to any of the questions were regarded as tolerant of domestic violence (not opposed to violence). The age groups of mothers

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ISSN 1684 5374

were classified as younger than 25, 25-34 (reference), 35-44, and 45 or older. The mothers' obesity status was determined based on their body mass index (BMI) as underweight (BMI < 18.5kg/m2), normal (18.5-24.9kg/m2) and overweight/obese (>=25.0 kg/m2). In addition, mothers were classified as stunted if their height was less than 150 cm. Lastly, maternal anemia was defined based on blood Hb levels, with pregnant women considered anemic if their Hb level was below 11.0 g/dL, and nonpregnant women considered anemic if their Hb level was below 12.0 g/dL. The household, maternal, and child characteristics were presented as categorical variables, analyzing the presence (yes or no) and severity (mild or moderate/severe) of anemia. Missing data was excluded in the data cleaning stage for the future analysis. To account for the original survey's sampling design and weights, complex survey analyses were applied in all statistical computations.

Chi-square tests were used to assess the comparability among the different levels of anemia. The analysis followed a two-step approach. Firstly, univariate logistic regression analysis was conducted using the selected variables for the outcome of anemia. Subsequently, variables with a p-value < 0.05 from the univariate regression were included in the multivariable logistic regression analysis. Risk factors for anemia were identified based on significant associations found in the multivariable analyses. Sub-group analysis was performed for six provinces. Common risk factors were defined as variables with p-value <0.05 in at least two provinces. A heatmap was provided to encapsulate the distribution of common risk factors (OR with 95% confidence interval [CI]) for the presence of child anemia across six provinces, using Microsoft Excel.

Ethical approval

The analysis of secondary data involved in this study was found to be exempt from the requirement for institutional review board approval.

RESULTS AND DISCUSSION

Prevalence of child anemia in Madagascar

Out of 5,048 children, the prevalence of anemia was 47%. Toliara province showed the highest proportion of children with anemia (56.3%), followed by Toamasina province (50.6%). Conversely, Antananarivo province, the capital, had the lowest child anemia rate (38.8%) (Figure 1(a)).

Anemia was more prevalent among children of underweight mothers (54.6%) compared to those of normal weight (45.2%) or overweight/obese mothers (41.6%). Also, children of mothers with moderate or severe anemia had a higher anemia occurrence (64.9%) compared to those of mildly anemic (56.3%) or non-anemic mothers (41.1%). Boys had a higher anemia presence (48.8%) compared to girls

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Volume 24 No. 9
September 2024
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ISSN 1684 5374

(44.4%). Anemia prevalence was higher among younger children (64% for ages 6 to 23 months) compared to older ones (36.8% for ages 24-59 months). (Figure 1(b)).

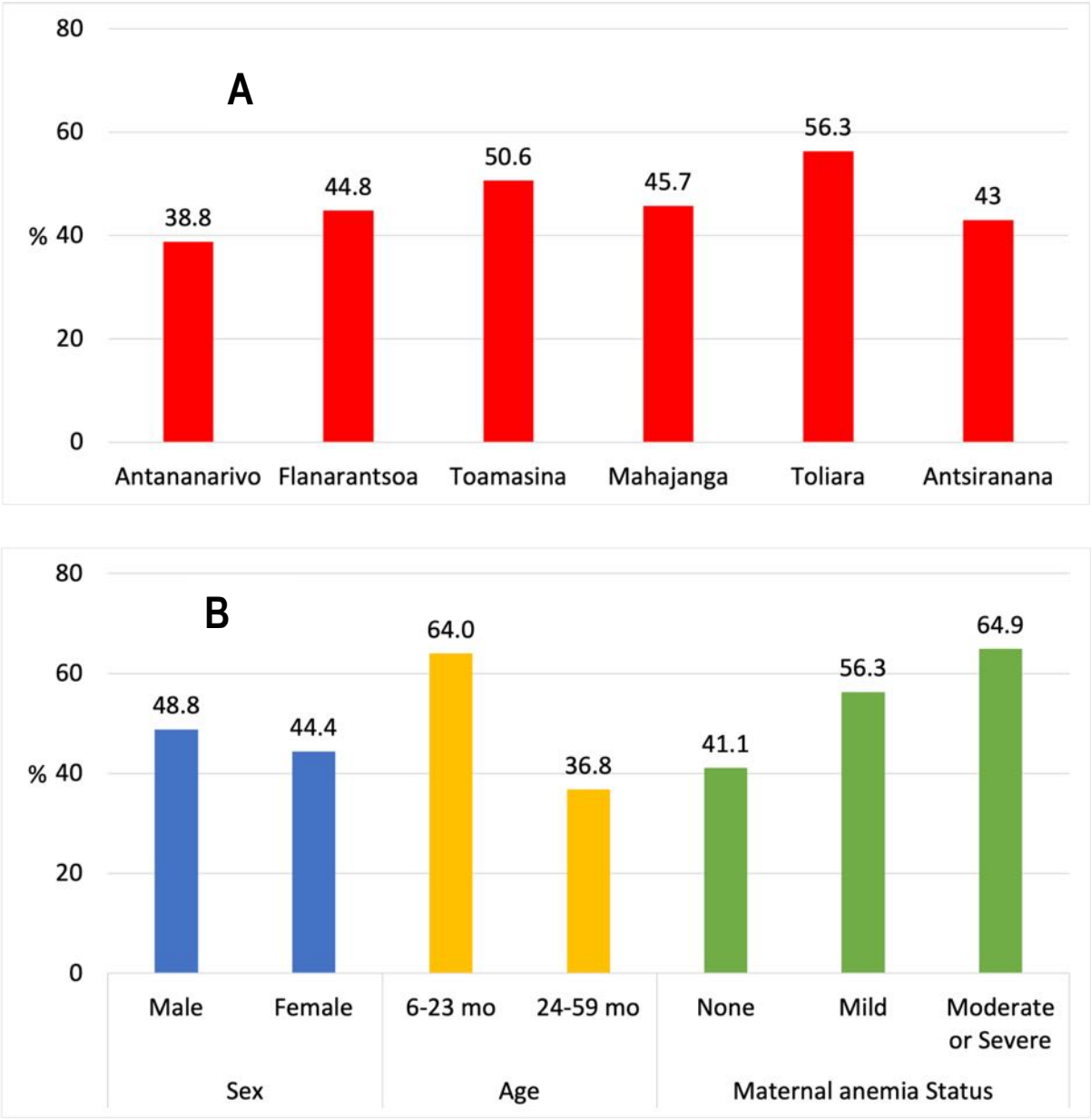

Figure 1: Prevalence of anemia among children aged 6-59 months (n=5,048) based on the Madagascar DHS 2021 data by (A) six provinces and (B) child sex, age, and maternal anemia status
Cut-offs for anemia were adjusted for altitude using formulae from the CDC (1998)

Household characteristics related to child anemia

At household level, residing in specific geographical zones was associated with a higher risk of child anemia. Among the six provinces in Madagascar, children living in Toamasina province (OR=1.49, 95% CI:1.12-1.99) and Toliara province (1.58,

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ISSN 1684 5374

1.13-2.20) had higher odds of developing anemia compared to those residing in Antananarivo province.

Maternal characteristics affecting child anemia

At the maternal level, education, age, nutritional status, and anemia status were identified as risk factors for child anemia. Lower odds of anemia were found in children with mothers having a secondary level of education compared to children with mothers having no formal education (0.77, 0.60-0.99). Children whose mothers' ages were younger than 25 had higher odds of having anemia compared to those whose mothers' ages were between 25 to 34 (1.22, 1.01-1.48). Similarly, the odds of anemia were higher for children whose mothers were underweight compared to those whose mothers had a normal weight (1.25, 1.01-1.53). Also, the odds of anemia were higher for children whose mothers had mild anemia (1.76, 1.44-2.15) or either moderate or severe anemia (2.44, 1.98-3.02) compared to children with non-anemic mothers.

Maternal education acts as a proxy for economic status and access to information about childcare. A previous study done by Ngwira A and LN Kazembe found that mothers who were unable to prepare nutritious food due to their low economic status, lack of nutritional knowledge, or lack of access to foods rich in iron and other micronutrients were more likely to have anemic children [18].

Similar to the results of the study conducted by Vinogradova *et al*. [2], this study confirmed a significant association between maternal and childhood anemia, indicating that maternal health and economic circumstances play a significant role in childhood anemia. Dietary choices of mothers have high influence on maternal health, which in turn affects the anemic status in children [2]. However, there is varying access to nutrient-rich foods, including essential micronutrients such as iron, due to the different social and economic circumstances that surround mothers. In this study, the researchers found that younger mothers were more likely to give birth to anemic children. This result can be attributed to several factors, the first of which is menstruation. This is supported by previous studies, such as Stanley *et al.* [19] and Beckert *et al.* [20] who found that menstrual blood loss during adolescence, pregnancy, and lactation increases iron requirements for the mother. This explains why the risk of anemia is lower in older mothers compared to younger mothers [21]. This is further supported by the fact that a major physiological impact of anemia results in both compensatory responses and acute or chronic consequences that involve poor growth, decreased activity, impaired cognitive performance, and behavior [22].

Based on these findings, it is important to prioritize areas with high prevalence of childhood anemia and strengthen antenatal services through iron and folic acid

supplementation, and various social behavior change communication activities to improve health and nutrition on the physiological risks of anemia with a priority of provinces with a high prevalence of anemia.

Maternal anemia, which has a strong causal link to childhood anemia, can lead to low birth weight, stillbirth, and adverse health outcomes for both the mother and child [23]. Therefore, maternal-focused education and healthcare can have a strong impact on reducing childhood anemia, and further research should be conducted to determine the exact causes and effect of the regional differences in the incidence of maternal anemia in Madagascar. Such investigations will help to address the maternal and child anemia challenges the country faces.

Individual factors influencing child anemia

At child level, female sex, younger age (6-23 months), high birth order, and symptoms of diarrhea and/or fever in the past two weeks were identified as risk factors for child anemia. Female children were less likely to have anemia than male children (0.85, 0.74-0.97). Children aged 24 to 59 months had lower odds of anemia than those aged 6 to 23 months (0.44, 0.36-0.55). Children who were born as the fifth or more had higher odds of anemia than those who were born as the first (1.52, 1.12-2.05). Lastly, children who experienced diarrhea symptoms within the last 2 weeks had 1.47 times higher odds of anemia (1.47, 1.15-1.88) compared to those without such experiences. Similarly, children who had fever symptoms within the last 2 weeks had 1.4 times higher odds of anemia (1.40, 1.12-1.74) compared to children without fever symptoms.

Regarding childhood age, a previous study by Mitchinson *et al.* [24] explained that the physiological changes in the prevalence of anemia in children begin at 11 months of age, suggesting that the most vulnerable period is between 6 and 11 months of age, as the high hemoglobin concentration at birth decreases after 6 months due to the depletion of iron stores. However, in this study, children aged 6-23 months had a higher prevalence of anemia than children aged 24-59 months. Therefore, to reduce the high prevalence of anemia in children under 2 years of age (children aged 6-23 months), a phased approach will be needed, including health information, promotion, and distribution of anemia management supplies through community health centers in high prevalence areas.

Variation in the main risk factors for child anemia in six provinces

The anemia rates varied across six regions in Madagascar. Two characteristics were common risk factors of child anemia in five provinces: maternal anemia status and child age. A positive association between maternal anemia and child anemia was found in Antsiranana (4.25, 1.84-9.82 for moderate/severe), Antananarivo (3.63, 1.84-7.17), Mahajanga (2.54, 1.44-4.47), Fianarantsoa (2.31, 1.58-3.38), and

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Volume 24 No. 9
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Toliara provinces (2.31, 1.66-3.23). Younger child age was also identified as another risk factor for child anemia. In Toliara (0.45, 0.26-0.78), Fianarantsoa (0.45, 0.34-0.61), Toamasina (0.43, 0.23-0.78), Antananarivo (0.37, 0.22-0.62), and Mahajanga provinces (0.26, 0.15-0.46), a negative association was found for children aged 24 months or older compared to those aged 6 to 23 months. Across the four provinces of Antananarivo, Fianarantsoa, Toamasina, and Toliara, a positive correlation was identified between mild maternal anemia and child anemia when compared to mothers without anemia. Additionally, a symptom of child fever within the last 2 weeks was a common risk factor in three provinces – Antsiranana (4.77, 1.37-16.61), Mahajanga (1.93, 1.05-3.54), and Toamasina (2.31, 1.20-4.45) – as it was identified positively associated with child anemia compared to those who responded as either having no symptoms or were unsure about their symptoms.

Province-specific risk factors were as follows. In Fianarantsoa province, maternal primary education (0.61, 0.42-0.87) and secondary education (0.40, 0.23-0.69) were protecting factors from child anemia compared to informal education. In Mahajanga province, a positive association was observed in the fourth wealth quintile (1.81, 1.08-3.04) compared to the lowest. A significant negative association was found in breastfed (0.22, 0.06-0.72), and currently breastfeeding (0.28, 0.08-0.98). In Antsiranana province, places of recent child delivery such as health facilities (2.14, 1.20-3.84) and child iron supplementation (4.30, 1.09-16.90) were positively associated with child anemia. In Antananarivo province, a significant positive association was found with exposure to any media at least once a week (1.56, 1.16-2.09). In Toamasina province, female children were less likely to be anemic compared to male (0.63, 0.41-0.96).

Although the wealth quintile was not found to be a significant factor in our study, Toamasina and Toliara provinces had a significant prevalence of child anemia. The prevalence of childhood anemia was notably higher in the northern and southern regions compared to the central Antananarivo province. Northern and Southern regions, mainly rural areas, had been reported to have poor road infrastructure compared to the central area of the capital. Of the total 31,640 kilometers of roads, approximately 64% were in poor condition, and only 10% of the roads were kept in practicable condition throughout the year, making logistics and accessibility much more challenging in these regions [25].

Although various explanations can be found for the regional differences in the prevalence and severity of childhood anemia, our results suggest that these differences are driven by dietary patterns based on the shared living environment of mothers and newborns, consistent with previous studies by Gao *et al*. [26] Since mothers and children typically share similar living environments during the first 12 months of life, they tend to have similar dietary patterns and a quality of life.

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Therefore, these findings show that maternal health and nutrition interventions are an essential part of reducing childhood anemia, along with changes in dietary patterns of a shared living environment.

Characteristics	Antananarivo OR (95%CI) (n=1,128)	Antsiranana OR (95%CI) (n=327)	Fianarantsoa OR (95% CI) (n=1,176)	Mahajanga OR (95%CI) (n=715)	Toamasina OR (95%CI) (n=611)	Toliara OR (95% CI) (n=1,091)
Poorer wealth quintile (Ref. Lowest)	N/S	N/S	0.89 (0.59, 1.33)	1.28 (0.81, 2.01)	0.52 (0.25, 1.10)	N/S
Middle wealth quintile (Ref. Lowest)	N/S	N/S	0.92 (0.57, 1.50)	0.93 (0.57, 1.53)	0.75 (0.36, 1.57)	N/S
Richer wealth quintile (Ref. Lowest)	N/S	N/S	1.34 (0.70, 2.59)	1.81 (1.08, 3.04)	0.62 (0.27, 1.40)	N/S
Richest wealth quintile (Ref. Lowest)	N/S	N/S	1.08 (0.42, 2.77)	0.72 (0.38, 1.34)	0.67 (0.27, 1.67)	N/S
Improved drinking water source (Ref. Unimproved source)	N/S	N/S	0.78 (0.52, 1.16)	N/S	0.91 (0.56, 1.46)	N/S
Unimproved toilet facility (Ref. Open defecation)	N/S	0.62 (0.21, 1.84)	0.91 (0.62, 1.34)	N/S	N/S	N/S
Improved toilet facility (Ref. Open defecation)	N/S	1.55 (0.71, 3.37)	0.98 (0.57, 1.69)	N/S	N/S	N/S
Mother's primary education level (Ref. No education)	N/S	N/S	0.61 (0.42, 0.87)	N/S	N/S	N/S
Mother's secondary education level (Ref. No education)	N/S	N/S	0.40 (0.23, 0.69)	N/S	N/S	N/S
Mother's higher education level (Ref. No education)	N/S	N/S	0.60 (0.20, 1.79)	N/S	N/S	N/S
Mother's traditional occupation (Ref. Not working)	N/S	N/S	0.89 (0.59, 1.34)	N/S	N/S	N/S
Mother's transitional occupation (Ref. Not working)	N/S	N/S	0.30 (0.09, 1.02)	N/S	N/S	N/S
Mother's mixed occupation (Ref. Not working)	N/S	N/S	0.97 (0.62, 1.51)	N/S	N/S	N/S
Mother's modern occupation (Ref. Not working)	N/S	N/S	0.69 (0.30, 1.60)	N/S	N/S	N/S
Mother's obesity level_Normal (Ref. underweight)	N/S	N/S	0.79 (0.53, 1.19)	N/S	N/S	N/S
Mother's obesity level_Overweight or obese (Ref. underweight)	N/S	N/S	0.53 (0.26, 1.09)	N/S	N/S	N/S
Mother's age_Less than 25 years old (Ref. 25-34 years old)	1.09 (0.73, 1.61)	N/S	1.45 (1.09, 1.95)	N/S	N/S	N/S
Mother's age_35-44 years old (Ref. 25-34 years old)	1.03 (0.63, 1.66)	N/S	0.89 (0.61, 1.30)	N/S	N/S	N/S
Mother's age_45 years old or older (Ref. 25-34 years old)	5.6 (1.59, 19.64)	N/S	0.83 (0.34, 2.07)	N/S	N/S	N/S
Mother's mild anemia status (Ref. None)	2.19 (1.31, 3.68)	1.31 (0.54, 3.17)	1.72 (1.13, 2.61)	0.90 (0.56, 1.47)	1.83 (1.11, 3.01)	2.15 (1.38, 3.36)
Mother's moderate or severe anemia status (Ref. None)	3.63 (1.84, 7.17)	4.25 (1.84, 9.82)	2.31 (1.58, 3.38)	2.54 (1.44, 4.47)	1.28 (0.61, 2.70)	2.32 (1.66, 3.23)
Mother's attitude towards violence_Opposed to violence (Ref. No)	N/S	1.85 (1.03, 3.33)	1.36 (1.00, 1.86)	N/S	N/S	N/S
Currently pregnant (Ref. No or unsure)	N/S	N/S	N/S	0.63 (0.28, 1.38)	N/S	N/S
Delivery assistance from professionals (Ref. Non professionals)	N/S	N/S	0.88 (0.56, 1.38)	N/S	0.77 (0.49, 1.23)	N/S
Exposure to any media (TV, Newspaper, Radio) at least once a week (Ref. No)	1.56 (1.16, 2.10)	N/S	0.81 (0.56, 1.18)	N/S	0.67 (0.39, 1.15)	N/S
Own a mobile phone (Ref. No)	N/S	N/S	1.18 (0.78, 1.91)	N/S	N/S	N/S
Place of the recent delivery_Health facilities (Ref. Home or others)	N/S	2.15 (1.20, 3.84)	0.91 (0.63, 1.31)	N/S	N/S	N/S
Put the baby to the breast within 1 hour after birth (Ref. No)	0.93 (0.67, 1.29)	N/S	N/S	N/S	N/S	N/S
Child's sex_Female (Ref. Male)	N/S	N/S	N/S	N/S	0.63 (0.41, 0.96)	N/S
Child's age_24 Months or older (Ref. 6-23 Months)	0.37 (0.22, 0.62)	N/S	0.45 (0.34, 0.61)	0.26 (0.15, 0.46)	0.43 (0.23, 0.78)	0.45 (0.26, 0.78)
Child's perceived birth size_Smaller (Ref. Average)	N/S	N/S	N/S	N/S	N/S	1.44 (0.94, 2.21)
Child's perceived birth size_Larger (Ref. Average)	N/S	N/S	N/S	N/S	N/S	1.39 (0.97, 2.00)
Child's vitamin A supplement in last 6 months (Ref. No)	N/S	N/S	0.94 (0.70, 1.28)	N/S	N/S	N/S
Child's iron supplement (Ref. No)	N/S	4.30 (1.09, 16.90)	N/S	N/S	N/S	N/S
Child's deworming medicine in last 6 months (Ref. No)	0.92 (0.66, 1.26)	N/S	0.89 (0.62, 1.27)	N/S	1.07 (0.74, 1.55)	0.76 (0.57, 1.00)
Symptom of fever within last 2 weeks (Ref. No or don't know)	N/S	4.77 (1.37, 16.61)	N/S	1.93 (1.05, 3.54)	2.31 (1.20, 4.45)	1.78 (1.05, 3.00)
Symptom of diarrhea within last 2 weeks (Ref. No or don't know)	1.34 (0.80, 2.23)	N/S	2.11 (1.26, 3.55)	1.32 (0.57, 3.06)	N/S	1.46 (0.88, 2.42)
Ever breastfed, not currently (Ref. Never breastfed)	1.12 (0.24, 5.26)	N/S	N/S	0.22 (0.06, 0.72)	0.82 (0.36, 1.85)	1.15 (0.54, 2.47)
Currently breastfed (Ref. Never breastfed)	2.19 (0.44, 10.84)	N/S	N/S	0.28 (0.08, 0.98)	1.57 (0.54, 4.57)	1.39 (0.59, 3.27)
Child's stunting (Ref. No, normal)	N/S	N/S	N/S	N/S	1.5 (0.97, 2.31)	N/S

OR	
	< 0.50
	0.50-0.99
	1.00-1.49
	1.50-1.99
	2.00-2.49
	2.50-2.99
	3.00-3.49
	≥ 3.50
	Not significant at multivariate regression
N/S	Not significant at bivariate regression

Figure 2: Heat map visualizing the distribution of common risk factors for the presence of child anemia across six provinces based on data from Madagascar Demographic and Health Survey 2021

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SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Study limitations

There are several limitations in their study, including the absence of investigations into some factors affecting anemia that were not covered in previous research. These factors include the lack of research on other micronutrients, the absence of food security assessments, and the lack of investigations into the quality of maternal diets associated with maternal anemia. Additionally, the study only examined child-related diets up to 2 years old but found no significant association with child anemia. Finally, the limited sample size in each region is a constraint in this study as it prevents an in-depth analysis of important anemia-related risk factors.

The DHS data does not provide data regarding the quality of health center care in rural areas, which is closely related to maternal and child anemia and can help prevent potential physical risk factors in children. Additionally, while there may be differences among African countries, the team acknowledges that there is a missed opportunity in this study for analyzing the relationship between mother's exposure to violence, depression, and nutrition with anemia, as these aspects were not examined despite being covered in previous studies.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Half of the under-five children are anemic in Madagascar, and the prevalence varied across six regions. Child younger age and maternal anemia were major common risk factors in all six provinces. Common determinants of child anemia in Madagascar are older age, and positively associated with maternal anemia, younger age, underweight, low education, and child's fever or diarrhea episode in the past two weeks and high birth order. To address child anemia, it is encouraged that government figures support national and regional nutrition programs for mothers with anemia, poor health, and low socio-economic status and young children. Additionally, further research is needed to explore pathways through which child anemia is related to maternal anemia and variation by regional location is recommended.

ACKNOWLEDGMENTS

We acknowledge the Demographic Health Survey (DHS) for providing data publicly.

Conflicts of interest

The authors have no conflicts of interest

Data Share Statement

Data described in the manuscript, code book, and analytic code are publicly available

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SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Credit Authorship contribution statement

The authors' responsibilities were as follows: Y.H.K. and Y.S.K. designed the current study; Y.J.C conducted data analysis; Y.S.K., C.H.K., and E.S. wrote the manuscript; Y.H.K. had primary responsibility for final content. All authors read and approved the final manuscript.

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SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: Characteristics at household, maternal, and child levels among children aged 6-59 months (n=5,048) in the Madagascar DHS 2021

Characteristic	Any anemia (N=2438) (weighted %)	P value	None (N=2669) (weighted %)	Mild (N=1358) (weighted %)	Moderate or Severe (N=1080) (weighted %)	P value
Household level						
Residence						
Urban	45.6	0.71	54.4	22.8	22.9	0.24
Rura	46.7		53.3	26.4	20.3	
Geographical zone						
Antananarivo Province	38.8	<0.001	61.2	22.3	16.5	<0.001
Fianarantsoa Provinc	44.8		55.2	24.5	20.3	
Toamasina Province	50.6		49.4	28.7	21.9	
Mahajanga Province	45.7		54.3	27.1	18.5	
Toliara Province	56.3		43.7	29.0	27.3	
Antsiranana Province	43.0		57.0	25.2	17.8	
Wealth quintile						
Lowest	53.2	<0.001	46.9	27.4	25.7	<0.001
Second	47.0		53.0	27.0	20.0	
Middle	42.0		58.0	24.8	17.2	
Fourth	45.9		54.1	25.6	20.3	
Highest	42.4		57.6	23.7	18.7	
Number of Family Members						
1-4	46.1	0.23	53.9	25.3	20.7	0.55
5-6	45.2		54.8	25.2	20.0	
7 or more	48.8		51.2	27.4	21.4	
Drinking water quality						
Unimproved source	48.7	0.03	51.3	26.9	21.8	0.049
Improved source	43.6		56.4	24.5	19.1	
Sanitation facility						
Open defecation	51.5	<0.001	48.6	26.7	24.8	<0.001

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Unimproved sanitation	41.6		58.4	23.4	18.2	
Improved sanitation	46.3		51.2	27.8	18.5	
Mother level						
Mother - Sociological factors						
Mother's Education level						
No education	53.6	<0.001	46.4	28.7	24.8	<0.001
Primary	46.3		53.7	26.2	20.0	
Secondary	42.6		57.4	23.5	19.1	
Higher	37.7		62.3	23.1	14.6	
Mother's Occupation						
Not working	50.9	0.14	49.1	26.0	25.0	0.22
Traditional (agricultural)	46.7		54.3	25.1	20.6	
Transitional (household/domestic work, service)	44.4		55.6	27.9	16.5	
Mixed (sales, manual labor)	47.5		52.5	27.5	19.9	
Modern (professional, technical, managerial, clerical)	38.7		61.3	21.9	16.8	
Mother's attitude towards violence						
Not opposed to violence	43.3	0.003	56.7	25.0	18.3	0.006
Opposed to violence	48.6		51.4	26.4	22.2	
Exposure to any media at least once a week						
No	48.3	0.01	51.7	26.7	21.6	0.03
Yes	43.0		57.0	24.2	18.8	
Own a mobile phone						
No	47.5	0.11	52.5	26.3	21.2	0.26
Yes	43.9		56.1	24.6	19.3	
Mother- Delivery-related factors						
Place of the recent delivery						
Home or others	47.7	0.09	52.3	26.6	21.1	0.23
Health facility	44.7		55.3	24.7	20.0	

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Type of delivery assistance						
Non-professionals	50.9	0.005	49.1	29.3	21.6	0.01
Professionals	45.2		54.8	24.8	20.4	
Put the baby to the breast < 1 hr after births						
No	43.6	0.001	56.5	34.7	19.8	0.003
Yes	49.2		50.8	27.8	21.4	
Mother - Biological factors						
Age						
<25 y	49.2	0.13	50.8	26.1	23.1	0.20
25-34 y	45.1		54.9	23.4	19.7	
35-44 y	44.7		55.3	26.2	18.5	
>=45 y	48.2		51.8	27.8	20.4	
Nutritional status						
Underweight	54.6	<0.001	45.4	26.9	27.7	<0.001
Normal	45.2		54.8	25.4	19.9	
Overweight/Obesity	41.6		58.4	27.4	14.2	
Height						
>=150	46.6	0.96	53.5	26.1	20.4	0.95
<150cm	46.5		53.4	25.8	20.8	
Currently pregnant						
No or unsure	46.9	0.13	53.1	25.7	21.2	0.02
Yes	42.3		57.8	27.8	14.5	
Anemia Status						
None	41.1	<0.001	58.9	24.9	16.2	<0.001
Mild	56.3		43.7	29.8	26.5	
Moderate or severe	64.9		35.2	26.8	38.1	
Child level						
Sex						
Male	48.8	0.006	51.3	25.9	22.8	0.003
Female	44.4		55.6	25.8	18.6	
Age						
6-23 mo	64.0	<0.001	36.1	31.7	32.2	<0.001
24-59 mo	36.8		63.2	22.6	14.2	
Birth order						
1st	43.0	0.008	57.0	23.2	19.8	0.03
2nd-4th	46.5		53.5	25.9	20.6	
>=5th	50.5		49.5	28.7	21.7	

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Perceived birth size						
Smaller	49.8	0.08	50.2	26.1	23.7	0.10
Average	44.8		55.2	25.2	19.5	
Larger	46.7		53.4	26.4	20.2	
Child- Nutritional factors						
Stunting						
No	45.5	0.14	54.5	26.3	19.1	0.02
Yes	48.3		51.7	25.1	23.2	
Wasting						
No	46.3	0.28	53.7	26.1	20.2	0.03
Yes	49.6		50.4	23.0	26.6	
Currently breastfeeding						
Never breastfed	38.0	<0.001	58.7	17.6	23.7	<0.001
Ever, not currently	41.3		62.0	23.1	14.9	
Currently breastfeeding	62.0		38.0	31.5	30.5	
Iron supplement						
No	46.6	0.99	53.4	25.9	20.7	0.96
Yes	46.5		53.5	26.8	19.8	
Vitamin A supplement in last 6 mo						
No	48.1	0.02	52.0	26.6	21.5	0.11
Yes	44.1		55.9	24.7	19.4	
Deworming in last 6 mo						
No	51.3	<0.001	48.7	26.9	24.4	<0.001
Yes	41.8		58.2	24.8	16.9	
Child - Comorbidities						
Diarrhea within last 2 weeks						
No	44.8	<0.001	55.2	25.3	19.5	<0.001
Yes	62.2		37.9	31.0	31.2	
Fever within last 2 weeks						
No	45.1	<0.001	55.0	25.5	19.5	<0.001
Yes	56.5		43.5	28.0	28.5	

Abbreviation: Madagascar DHS 2021, Madagascar Demographic and Health Survey of 2021

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SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2: Univariate and multivariate analysis of risk factors for anemia in children aged 6-59 months (n=5,048) in the Madagascar DHS 2021

Characteristic	OR (95% CI) [a], univariate analysis	OR (95% CI) [a], multivariate analysis (N=4,955)
Household level		
Residence (Ref. Urban)	1.00	
Rural	1.04 (0.83-1.32)	
Geographical zone (Ref. Antananarivo Province)	1.00	1.00
Fianarantsoa Province	1.28 (1.00-1.63) *	1.03 (0.78-1.37)
Toamasina Province	1.62 (1.23-2.12) **	1.49 (1.12-1.99) **
Mahajanga Province	1.33 (1.00-1.76) *	1.10 (0.81-1.48)
Toliara Province	2.04 (1.57-2.65) ***	1.58 (1.13-2.20) **
Antsiranana Province	1.19 (0.65-2.18)	1.03 (0.54-1.98)
Wealth quintile (Ref. Lowest)	1.00	1.00
Second	0.78 (0.64-0.96) *	0.91 (0.73-1.13)
Middle	0.64 (0.52-0.79) ***	0.91 (0.71-1.16)
Fourth	0.75 (0.59-0.95) *	1.17 (0.87-1.56)
Highest	0.65 (0.50-0.85) **	1.06 (0.73-1.53)
Number of Family Members (Ref. 1-4)	1.00	
5-6	0.96 (0.83-1.12)	
7 or more	1.12 (0.94-1.33)	
Drinking water quality (Ref. unimproved source)	1.00	1.00
Improved source (n=2,053)	0.81 (0.68-0.98) *	0.85 (0.68-1.06)
Sanitation facility (Ref. open defecation)	1.00	1.00
Unimproved sanitation	0.67 (0.55-0.81) ***	0.85 (0.67-1.09)
Improved sanitation	0.81 (0.67-0.99) *	1.20 (0.94-1.53)
Mother level		
Mother - Sociological factors		
Education level (Ref. no education)	1.00	1.00

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Primary	0.75 (0.62-0.90) **	0.90 (0.73-1.10)
Secondary	0.64 (0.53-0.79) ***	0.77 (0.60-0.99) *
Higher	0.52 (0.34-0.80) **	0.64 (0.34-1.23)
Occupation (Ref. not working)	1.00	1.00
Traditional (agricultural)	0.81 (0.66-1.00)	0.87 (0.69-1.08)
Transitional (household/domestic work, service)	0.77 (0.48-1.24)	1.07 (0.66-1.72)
Mixed (sales, manual labor)	0.87 (0.70-1.09)	1.01 (0.81-1.27)
Modern (professional, technical, managerial, clerical)	0.61 (0.41-0.90) *	0.88 (0.55-1.41)
Attitude towards violence (Ref. not opposed to violence)	1.00	1.00
Opposed to violence (n=3,139)	1.24 (1.08-1.43) **	1.13 (0.96-1.32)
Exposure to any media at least once a week (Ref: No)	1.00	1.00
Yes	0.81 (0.68-0.95) *	1.03 (0.86-1.24)
Own a mobile phone (Ref. no)	1.00	
Yes	0.86 (0.72-1.03)	
Mother - Delivery-related factors		
Place of the recent delivery (Ref. home or others)	1.00	
Health facility	0.89 (0.77-1.02)	
Type of delivery assistance (Ref. non-professionals)	1.00	1.00
Professionals	0.80 (0.68-0.93) **	0.93 (0.78-1.12)
Put the baby to the breast < 1hr after birth (Ref. no)	1.00	1.00
Yes	1.25 (1.10-1.43) **	0.96 (0.83-1.12)
Mother - Biological factors		
Age (Ref. 25-34 y)	1.00	1.00
<25 y	1.18 (1.02-1.36) *	1.22 (1.01-1.48) *
35-44 y	0.98 (0.82-1.19)	0.84 (0.68-1.04)
=>45 y	1.13 (0.72-1.77)	0.89 (0.53-1.48)

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Obesity level (Ref. normal)	1.00	1.00
Underweight	1.46 (1.21-1.75) ***	1.25 (1.01-1.53) *
Overweight/Obesity	0.86 (0.67-1.12)	1.01 (0.78-1.32)
Height (Ref. >= 150 cm)	1.00	
<150cm	1.00 (0.85-1.16)	
Currently pregnant (Ref. no or unsure)	1.00	
Yes	0.83 (0.65-1.05)	
Anemia Status (Ref. none)	1.00	1.00
Mild	1.85 (1.53-2.23) ***	1.76 (1.44-2.15) ***
Moderate or severe	2.65 (2.16-3.25) ***	2.44 (1.98-3.02) ***
Child level		
Sex (Ref. male)	1.00	1.00
Female	0.84 (0.74-0.95) **	0.85 (0.74-0.97) *
Age (Ref. 6-23 months)	1.00	1.00
24-59 months	0.33 (0.28-0.38) ***	0.44 (0.36-0.55) ***
Birth order (Ref. 1st)	1.00	1.00
2nd-4th	1.15 (0.98-1.35)	1.22 (0.99-1.50)
>=5th	1.35 (1.12-1.63) **	1.52 (1.12-2.05) **
Perceived birth size (Ref. average)	1.00	1.00
Smaller	1.22 (1.03-1.46) *	1.11 (0.92-1.33)
Larger	1.08 (0.92-1.26)	1.02 (0.87-1.19)
Child - Nutritional factors		
Stunting (Ref. no)	1.00	
Yes	1.12 (0.96-1.30)	
Wasting (Ref. no)	1.00	
Yes	1.14 (0.90-1.46)	
Currently breastfeeding (Ref. never)	1.00	1.00
Ever, not currently	0.87 (0.57-1.32)	0.94 (0.58-1.51)
Currently breastfeeding	2.32 (1.51-3.56) ***	1.38 (0.82-2.31)
Iron supplement (Ref. no)	1.00	
Yes	1.00 (0.63-1.58)	

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SCHOLARLY, PEER REVIEWED
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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Vitamin A supplement in last 6 mo (Ref. no)	1.00	1.00
Yes	0.85 (0.74-0.98) *	1.02 (0.87-1.19)
Deworming in last 6 mo (Ref. no)	1.00	1.00
Yes	0.68 (0.60-0.78) ***	0.99 (0.84-1.16)
Child - Comorbidities		
Diarrhea within last 2 weeks (Ref. no)	1.00	1.00
Yes	2.02 (1.62-2.52) ***	1.47 (1.15-1.88) **
Fever within last 2 weeks (Ref. no)	1.00	1.00
Yes	1.58 (1.28-1.97) ***	1.40 (1.12-1.74) **

Abbreviation: Madagascar DHS 2021, Madagascar Demographic and Health Survey of 2021 a Survey design and sampling weights of the Madagascar DHS 2021 were accounted for in all logistic regression models

*0.01≤P<0.05; **0.001≤P<0.01; ***P<0.001

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Volume 24 No. 9
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Supplement Tables

Table S1: Characteristics at household, maternal, and child levels that were not included for logistic regression analysis models among children aged 6-59 months in the Madagascar DHS 2021

Characteristic	Any anemia (weighted %)	P value	None (weighted %)	Mild (weighted %)	Moderate or Severe (weighted %)	P value
Household level						
Cooking fuel (n=5048)						
Non-Efficient=0 (n=5004)	2379 (47)	0.43	2625 (54)	1324 (26)	1055 (21)	0.52
Efficient=1 (n=44)	20 (53)		24 (47)	14 (35)	6 (18)	
Safe disposal of Child's stool (feces)(n=2790)						
No (n=1801)	1023 (56)	0.12	778 (44)	520 (28)	503 (28)	0.23
Yes (n=989)	515 (52)		474 (48)	272 (27)	243 (25)	
Mother level						
Mother's decision-making score (n=4095)						
low (n=1276)	598 (45)	0.63	678 (55)	330 (24)	268 (21)	0.42
high (n=2819)	1326 (46)		1493 (54)	755 (27)	571 (20)	
Women's empowerment (empower)(n=4095)						
low (n=872)	402 (45)	0.60	470 (55)	224 (25)	178 (20)	0.68
High (n=3223)	1522 (46)		1701 (54)	861 (26)	661 (20)	
Number of antenatal clinic visits during last pregnancy (n=3726)						
0-3 (n=1513)	825 (51)	0.19	688 (49)	449 (28)	376 (23)	0.38
4 or more (n=2213)	1061 (49)		1152 (52)	599 (27)	462 (22)	
Iron mother (m45) (N=3737)						
No (n=1000)	554 (52)	0.14	446 (48)	302 (29)	252 (24)	0.31
Yes (n=2737)	1338 (49)		1399 (51)	749 (27)	589 (22)	

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ISSN 1684 5374

Mother's Smoking (n=5048)						
No (n=5010)	2376 (46)	0.07	2634 (54)	1324 (26)	1052 (21)	0.23
Yes (n=38)	23 (62)		15 (38)	14 (34)	9 (28)	
Child level						
Postnatal check-up on child within two days after delivery (n=3737)						
No or Don't know (n=1956)	1033 (51)	0.27	923 (49)	581 (29)	452 (22)	0.38
Yes (n=1781)	859(49)		922 (52)	470 (26)	389 (22)	
Iron-rich food (n=2789)						
No (n=1796)	986 (54)	0.39	810 (46)	512 (28)	474 (26)	0.32
Yes (n=993)	551 (56)		442 (44)	280 (27)	271 (29)	
Minimum dietary diversity (diversity) (n=1800)						
No (n=1368)	896 (64)	0.71	472 (36)	449 (32)	447 (32)	0.90
Yes (5 out of 8) (n=432)	265 (63)		167 (37)	135 (31)	130 (32)	
Minimum meal frequency (n=1800)						
No (n=681)	440 (63)	0.77	241 (37)	216 (30)	224 (34)	0.49
Yes (n=1119)	721 (64)		398 (36)	368 (33)	353 (31)	
Minimum acceptable diet (n=1800)						
No (n=1473)	965 (64)	0.39	508 (36)	484 (32)	481 (32)	0.73
Yes (n=327)	196 (62)		131 (39)	100 (30)	96 (31)	

Abbreviation: Madagascar DHS 2021, Madagascar Demographic and Health Survey of 2021

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table S2: Univariate logistic regression analysis of risk factors anemia in children aged 6-59 months at Antananarivo province in the Madagascar DHS 2021

Characteristics	Odds Ratio[a]	P-Value	95% Conf. Interval	
Household Level				
Area (Ref. Urban)	**1.00**			
Rural	1.09	0.62	0.77	1.55
Wealth Quintile (Ref. Lowest)	**1.00**			
Poorer	1.22	0.54	0.65	2.29
Middle	0.86	0.64	0.46	1.61
Richer	1.16	0.65	0.61	2.18
Richest	1.42	0.29	0.74	2.72
Number of family members (Ref. One to four)	**1.00**			
Five or six	0.76	0.11	0.54	1.07
Seven or more	1.01	0.95	0.68	1.51
Drinking water source (Ref. Unimproved)	**1.00**			
Improved	1.01	0.95	0.67	1.53
Toilet facility (Ref. Open defecation)	**1.00**			
Unimproved toilet facility	0.66	0.10	0.40	1.08
Improved toilet facility	0.94	0.81	0.55	1.58
Maternal Level				
Education level (Ref. No education)	**1.00**			
Primary level	1.08	0.80	0.58	2.01
Secondary level	1.07	0.83	0.55	2.08
Higher level	0.84	0.72	0.32	2.21
Occupation (Ref. Not working)	**1.00**			
Traditional occupation	0.73	0.23	0.43	1.23
Transitional occupation	0.96	0.93	0.43	2.16
Mixed occupation	0.81	0.37	0.50	1.30
Modern occupation	0.56	0.13	0.27	1.19
Obesity level (Ref. Normal)	**1.00**			
Underweight	1.29	0.13	0.93	1.81
Overweight or obese	1.22	0.48	0.71	2.08
Anemia status (Ref. None)	**1.00**			

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
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ISSN 1684 5374

Mild	1.90	0.003	1.25	2.87
Moderate or severe	3.29	<0.001	1.86	5.82
Mother's attitude towards violence (Ref. No)	**1.00**			
Opposed to violence	0.93	0.61	0.71	1.23
Currently pregnant (Ref. No or unsure)	**1.00**			
Yes	0.68	0.12	0.41	1.11
Type of delivery assistance (Ref. Nonprofessionals)	**1.00**			
Professionals	1.29	0.21	0.86	1.93
Exposure to any media (TV, Newspaper, Radio) at least once a week (Ref. No)	**1.00**			
Yes	1.35	0.04	1.01	1.81
Own a mobile phone (Ref. No)	**1.00**			
Yes	1.15	0.56	0.73	1.81
Place of the recent delivery (Ref. Home or others)	**1.00**			
Health facilities	1.28	0.10	0.96	1.71
Put the baby to the breast within 1 hour after birth (Ref. No)	**1.00**			
Yes	1.39	0.05	1.01	1.93
Mother's stunting (Ref. Normal)	**1.00**			
Yes, stunting	0.94	0.68	0.71	1.25
Child Level				
Sex (Ref. Male)	**1.00**			
Female	0.91	0.53	0.69	1.21
Age (Ref. 6-23 Months)	**1.00**			
24 Months or older	0.24	<0.001	0.18	0.31
Vitamin A supplement in the last 6 months (Ref. No)	**1.00**			
Yes	0.95	0.72	0.71	1.27
Iron supplement (Ref. No)	**1.00**			
Yes	0.73	0.39	0.35	1.51
Deworming medicine in the last 6 months (Ref. No)	**1.00**	0.001	0.44	0.80
Yes	0.59			

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SCHOLARLY, PEER REVIEWED
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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Symptoms of fever within the last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	0.83	0.36	0.56	1.24
Symptoms of diarrhea within the last 2 weeks (Ref. No or don't know)	**1.00**	0.01	1.21	3.18
Yes	1.96			
Currently Breastfed (Ref. Never breastfed)	**1.00**			
Ever, not currently	1.01	0.99	0.31	3.29
Currently breastfeeding	3.83	0.03	1.16	12.61
Stunting (Ref. No, normal)	**1.00**			
Yes	1.00	0.98	0.71	1.43
Wasting (Ref. No, normal)	**1.00**	0.83	0.52	2.25
Yes	1.08			
Birth order (Ref. 1st)	**1.00**			
2nd to 4th	1.06	0.78	0.72	1.55
5th or more	1.37	0.24	0.81	2.32
Birth size (Ref. Average)	**1.00**			
Smaller	1.37	0.12	0.92	2.04
Larger	1.18	0.25	0.89	1.57

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SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table S3: Univariate logistic regression analysis of risk factors anemia in children aged 6-59 months at Fianarantosoa province in the Madagascar DHS 2021

Characteristics	Odds Ratio[a]	P-Value	95% Conf. Interval	
Household Level				
Area (Ref. Urban)	**1.00**			
Rural	1.14	0.48	0.79	1.64
Wealth Quintile (Ref. Lowest)	**1.00**			
Poorer	0.65	0.01	0.46	0.91
Middle	0.48	<0.001	0.34	0.68
Richer	0.59	0.04	0.36	0.97
Richest	0.34	<0.001	0.21	0.56
Number of family members (Ref. One to four)	**1.00**			
Five or six	0.96	0.80	0.68	1.35
Seven or more	0.91	0.55	0.65	1.26
Drinking water source (Ref. Unimproved)	**1.00**			
Improved	0.62	0.01	0.44	0.87
Toilet facility (Ref. Open defecation)	**1.00**			
Unimproved toilet facility	0.62	0.01	0.44	0.87
Improved toilet facility	0.53	0.01	0.33	0.83
Maternal Level	**1.00**			
Education level (Ref. No education)	**1.00**			
Primary level	0.60	0.002	0.43	0.83
Secondary level	0.36	<0.001	0.23	0.55
Higher level	0.48	0.047	0.23	0.99
Occupation (Ref. Not working)	**1.00**			
Traditional occupation	0.70	0.05	0.49	1.01
Transitional occupation	0.19	0.003	0.06	0.55
Mixed occupation	0.65	0.05	0.43	1.00
Modern occupation	0.32	0.002	0.15	0.65
Obesity level (Ref. Normal)	**1.00**			
Underweight	1.51	0.04	1.02	2.23
Overweight or obese	0.43	0.002	0.26	0.73
Anemia status (Ref. None)	**1.00**			

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Mild	1.92	0.001	1.31	2.80
Moderate or severe	2.94	<0.001	2.06	4.21
Mother's attitude towards violence (Ref. No)	**1.00**			
Opposed to violence	1.60	0.001	1.22	2.10
Currently pregnant (Ref. No or unsure)	**1.00**			
Yes	0.98	0.94	0.61	1.58
Type of delivery assistance (Ref. Nonprofessionals)	**1.00**			
Professionals	0.65	0.03	0.44	0.96
Exposure to any media (TV, Newspaper, Radio) at least once a week (Ref. No)	**1.00**			
Yes	0.60	<0.001	0.47	0.77
Own a mobile phone (Ref. No)	**1.00**			
Yes	0.67	0.02	0.48	0.93
Place of the recent delivery (Ref. Home or others)	**1.00**			
Health facilities	0.68	0.01	0.50	0.92
Put the baby to the breast within 1 hour after birth (Ref. No)	**1.00**			
Yes	1.28	0.07	0.98	1.68
Mother's stunting (Ref. Normal)	**1.00**			
Yes, stunting	0.90	0.48	0.68	1.20
Child Level				
Sex (Ref. Male)	**1.00**			
Female	0.94	0.61	0.73	1.20
Age (Ref. 6-23 Months)	**1.00**			
24 Months or older	0.42	<0.001	0.33	0.55
Vitamin A supplement in last 6 months (Ref. No)	**1.00**			
Yes	0.68	0.004	0.52	0.88
Iron supplement (Ref. No)	**1.00**			
Yes	0.59	0.51	0.12	2.91
Deworming medicine in last 6 months (Ref. No)	**1.00**			
Yes	0.61	0.002	0.45	0.83

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Symptom of fever within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	1.44	0.06	0.98	2.11
Symptom of diarrhea within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	2.65	<0.001	1.68	4.18
Currently Breastfeeding (Ref. Never breastfed)	**1.00**			
Ever, not currently	1.07	0.89	0.44	2.60
Currently breastfeeding	2.34	0.08	0.91	6.03
Stunting (Ref. No, normal)	**1.00**			
Yes	1.14	0.36	0.86	1.52
Wasting (Ref. No, normal)	**1.00**			
Yes	1.02	0.96	0.56	1.85
Birth order (Ref. 1st)	**1.00**			
2nd to 4th	1.04	0.83	0.75	1.43
5th or more	0.98	0.93	0.69	1.40
Birth size (Ref. Average)	**1.00**			
Smaller	1.04	0.78	0.80	1.36
Larger	0.87	0.38	0.62	1.20

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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Table S4: Univariate logistic regression analysis of risk factors anemia in children aged 6-59 months at Toamasina province in the Madagascar DHS 2021

Characteristics	Odds Ratio[a]	P-Value	95% Conf. Interval	
Household Level				
Area (Ref. Urban)	**1.00**			
Rural	1.08	0.74	0.67	1.77
Wealth Quintile (Ref. Lowest)	**1.00**			
Poorer	0.41	0.01	0.23	0.76
Middle	0.47	0.03	0.24	0.92
Richer	0.38	0.01	0.19	0.75
Richest	0.28	<0.001	0.14	0.55
Number of family members (Ref. One to four)	**1.00**			
Five or six	0.93	0.67	0.66	1.31
Seven or more	1.03	0.89	0.66	1.62
Drinking water source (Ref. Unimproved)	**1.00**			
Improved	0.69	0.04	0.49	0.98
Toilet facility (Ref. Open defecation)	**1.00**			
Unimproved toilet facility	0.59	0.17	0.27	1.27
Improved toilet facility	0.54	0.09	0.26	1.10
Maternal Level				
Education level (Ref. No education)	**1.00**			
Primary level	0.82	0.48	0.48	1.43
Secondary level	0.81	0.48	0.45	1.46
Higher level	0.53	0.14	0.23	1.24
Occupation (Ref. Not working)	**1.00**			
Traditional occupation	0.76	0.38	0.41	1.42
Transitional occupation	0.74	0.57	0.26	2.13
Mixed occupation	1.04	0.90	0.54	2.04
Modern occupation	1.10	0.86	0.38	3.16
Obesity level (Ref. Normal)	**1.00**			
Underweight	1.07	0.83	0.60	1.88
Overweight or obese	0.75	0.25	0.46	1.22
Anemia status (Ref. None)	**1.00**			

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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Mild	2.13	0.002	1.32	3.44
Moderate or severe	1.51	0.25	0.75	3.06
Mother's attitude towards violence (Ref. No)	**1.00**			
Opposed to violence	1.09	0.64	0.76	1.56
Currently pregnant (Ref. No or unsure)	**1.00**			
Yes	1.34	0.51	0.55	3.28
Type of delivery assistance (Ref. Nonprofessionals)				
Professionals	0.67	0.048	0.446	0.99
Exposure to any media (TV, Newspaper, Radio) at least once a week (Ref. No)	**1.00**			
Yes	0.65	0.049	0.42	0.99
Own a mobile phone (Ref. No)	**1.00**			
Yes	0.69	0.05	0.47	1.01
Place of the recent delivery (Ref. Home or others)	**1.00**			
Health facilities	0.82	0.15	0.63	1.08
Put the baby to the breast within 1 hour after birth (Ref. No)	**1.00**			
Yes	1.32	0.11	0.94	1.85
Mother's stunting (Ref. Normal)	**1.00**			
Yes, stunting	1.19	0.34	0.83	1.69
Child Level				
Sex (Ref. Male)	**1.00**			
Female	0.60	0.01	0.42	0.86
Age (Ref. 6-23 Months)	**1.00**			
24 Months or older	0.31	<0.001	0.22	0.44
Vitamin A supplement in last 6 months (Ref. No)	**1.00**			
Yes	0.75	0.12	0.52	1.08
Iron supplement (Ref. No)	**1.00**			
Yes	0.42	0.18	0.12	1.48
Deworming medicine in last 6 months (Ref. No)	**1.00**			
Yes	0.67	0.02	0.49	0.92

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
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Symptom of fever within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	1.73	0.07	0.95	3.16
Symptom of diarrhea within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	2.96	<0.001	1.64	5.35
Currently Breastfeeding (Ref. Never breastfed)	**1.00**			
Ever, not currently	1.19	0.63	0.58	2.44
Currently breastfeeding	3.55	0.001	1.71	7.37
Stunting (Ref. No, normal)	**1.00**			
Yes	1.48	0.03	1.04	2.11
Wasting (Ref. No, normal)	**1.00**			
Yes	1.36	0.38	0.68	2.70
Birth order (Ref. 1st)	**1.00**			
2nd to 4th	1.27	0.17	0.90	1.80
5th or more	1.51	0.09	0.93	2.43
Birth size (Ref. Average)	**1.00**			
Smaller	0.92	0.75	0.57	1.51
Larger	0.79	0.23	0.53	1.17

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SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table S5: Univariate logistic regression analysis of risk factors anemia in children aged 6-59 months at Mahajanga province in the Madagascar DHS 2021

Characteristics	Odds Ratio[a]	P-Value	95% Conf. Interval	
Household Level				
Area (Ref. Urban)	**1.00**			
Rural	0.85	0.50	0.53	1.36
Wealth Quintile (Ref. Lowest)	**1.00**			
Poorer	1.33	0.15	0.90	1.98
Middle	0.96	0.88	0.60	1.55
Richer	1.64	0.04	1.01	2.65
Richest	0.67	0.18	0.37	1.21
Number of family members (Ref. One to four)	**1.00**			
Five or six	1.31	0.20	0.87	1.98
Seven or more	1.32	0.24	0.83	2.09
Drinking water source (Ref. Unimproved)	**1.00**			
Improved	0.92	0.66	0.62	1.35
Toilet facility (Ref. Open defecation)	**1.00**			
Unimproved toilet facility	1.01	0.97	0.52	1.98
Improved toilet facility	1.38	0.14	0.89	2.14
Maternal Level				
Education level (Ref. No education)	**1.00**			
Primary level	1.07	0.79	0.64	1.79
Secondary level	0.99	0.97	0.56	1.75
Higher level	0.61	0.53	0.13	2.93
Occupation (Ref. Not working)	**1.00**			
Traditional occupation	0.92	0.69	0.62	1.37
Transitional occupation	1.10	0.90	0.24	4.98
Mixed occupation	0.78	0.33	0.48	1.29
Modern occupation	0.68	0.47	0.24	1.96
Obesity level (Ref. Normal)	**1.00**			
Underweight	1.25	0.43	0.72	2.17
Overweight or obese	0.69	0.22	0.38	1.26
Anemia status (Ref. None)	**1.00**			

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SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Mild	1.00	0.99	0.62	1.63
Moderate or severe	2.31	0.004	1.31	4.08
Mother's attitude towards violence (Ref. No)	**1.00**			
Opposed to violence	0.83	0.40	0.54	1.28
Currently pregnant (Ref. No or unsure)	**1.00**			
Yes	0.51	0.04	0.27	0.95
Type of delivery assistance (Ref. Nonprofessionals)	**1.00**			
Professionals	0.74	0.10	0.51	1.06
Exposure to any media (TV, Newspaper, Radio) at least once a week (Ref. No)	**1.00**			
Yes	1.02	0.91	0.67	1.57
Own a mobile phone (Ref. No)	**1.00**			
Yes	1.15	0.44	0.80	1.66
Place of the recent delivery (Ref. Home or others)	**1.00**			
Health facilities	1.01	0.98	0.63	1.62
Put the baby to the breast within 1 hour after birth (Ref. No)	**1.00**			
Yes	1.11	0.60	0.75	1.64
Mother's stunting (Ref. Normal)	**1.00**			
Yes, stunting	1.57	0.13	0.88	2.82
Child Level				
Sex (Ref. Male)	**1.00**			
Female	1.01	0.94	0.71	1.46
Age (Ref. 6-23 Months)	**1.00**			
24 Months or older	0.21	<0.001	0.14	0.31
Vitamin A supplement in last 6 months (Ref. No)	**1.00**			
Yes	1.12	0.60	0.74	1.69
Iron supplement (Ref. No)	**1.00**			
Yes	1.07	0.92	0.29	3.99
Deworming medicine in last 6 months (Ref. No)	**1.00**			
Yes	1.05	0.82	0.68	1.64

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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Symptom of fever within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	2.31	0.003	1.34	4.00
Symptom of diarrhea within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	2.31	0.01	1.20	4.44
Currently Breastfeeding (Ref. Never breastfed)	**1.00**			
Ever, not currently	0.11	0.001	0.03	0.42
Currently breastfeeding	0.40	0.19	0.10	1.58
Stunting (Ref. No, normal)	**1.00**			
Yes	1.37	0.15	0.89	2.11
Wasting (Ref. No, normal)	**1.00**			
Yes	0.86	0.59	0.49	1.51
Birth order (Ref. 1st)	**1.00**			
2nd to 4th	1.13	0.52	0.78	1.62
5th or more	1.33	0.14	0.91	1.94
Birth size (Ref. Average)	**1.00**			
Smaller	1.28	0.30	0.81	2.02
Larger	0.99	0.96	0.72	1.37

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 9
September 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table S6: Univariate logistic regression analysis of risk factors anemia in children aged 6-59 months at Toliara province in the Madagascar DHS 2021

Characteristics	Odds Ratio[a]	P-Value	95% Conf. Interval	
Household Level				
Area (Ref. Urban)	**1.00**			
Rural	1.05	0.91	0.44	2.52
Wealth Quintile (Ref. Lowest)	**1.00**			
Poorer	1.00	0.99	0.70	1.43
Middle	0.79	0.29	0.51	1.22
Richer	1.01	0.98	0.66	1.54
Richest	0.82	0.66	0.34	2.01
Number of family members (Ref. One to four)	**1.00**			
Five or six	0.86	0.40	0.59	1.24
Seven or more	0.90	0.55	0.63	1.29
Drinking water source (Ref. Unimproved)	**1.00**			
Improved	1.21	0.30	0.84	1.75
Toilet facility (Ref. Open defecation)	**1.00**			
Unimproved toilet facility	0.85	0.36	0.59	1.21
Improved toilet facility	1.28	0.52	0.59	2.78
Maternal Level				
Education level (Ref. No education)	**1.00**			
Primary level	0.92	0.65	0.65	1.31
Secondary level	0.77	0.19	0.52	1.14
Higher level	0.78	0.70	0.22	2.81
Occupation (Ref. Not working)	**1.00**			
Traditional occupation	0.98	0.93	0.66	1.46
Transitional occupation	0.78	0.63	0.27	2.20
Mixed occupation	1.21	0.33	0.82	1.78
Modern occupation	0.85	0.70	0.38	1.93
Obesity level (Ref. Normal)	**1.00**			
Underweight	1.36	0.07	0.98	1.89
Overweight or obese	0.80	0.43	0.46	1.40
Anemia status (Ref. None)	**1.00**			

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Volume 24 No. 9
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Mild	2.03	0.001	1.37	3.01
Moderate or severe	2.22	<0.001	1.60	3.07
Mother's attitude towards violence (Ref. No)	**1.00**			
Opposed to violence	1.01	0.97	0.71	1.42
Currently pregnant (Ref. No or unsure)	**1.00**			
Yes	0.71	0.14	0.45	1.12
Type of delivery assistance (Ref. Non professionals)	**1.00**			
Professionals	1.01	0.95	0.75	1.36
Exposure to any media (TV, Newspaper, Radio) at least once a week (Ref. No)	**1.00**			
Yes	0.98	0.95	0.46	2.06
Own a mobile phone (Ref. No)	**1.00**			
Yes	0.79	0.19	0.56	1.12
Place of the recent delivery (Ref. Home or others)	**1.00**			
Health facilities	0.78	0.09	0.59	1.04
Put the baby to the breast within 1 hour after birth (Ref. No)	**1.00**			
Yes	1.28	0.06	0.99	1.65
Mother's stunting (Ref. Normal)	**1.00**			
Yes, stunting	1.09	0.64	0.76	1.56
Child Level				
Sex (Ref. Male)	**1.00**			
Female	0.84	0.19	0.65	1.09
Age (Ref. 6-23 Months)	**1.00**			
24 Months or older	0.38	0.01	0.29	0.51
Vitamin A supplement in last 6 months (Ref. No)	**1.00**			
Yes	1.02	0.91	0.77	1.34
Iron supplement (Ref. No)	**1.00**			
Yes	1.83	0.28	0.60	5.56
Deworming medicine in last 6 months (Ref. No)	**1.00**			
Yes	0.70	0.01	0.54	0.92

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Symptom of fever within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	1.86	0.02	1.09	3.19
Symptom of diarrhea within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	1.77	0.01	1.14	2.74
Currently Breastfeeding (Ref. Never breastfed)	**1.00**			
Ever, not currently	0.96	0.93	0.42	2.23
Currently breastfeeding	2.36	0.04	1.06	5.29
Stunting (Ref. No, normal)	**1.00**			
Yes	1.09	0.61	0.78	1.54
Wasting (Ref. No, normal)	**1.00**			
Yes	1.40	0.10	0.93	2.09
Birth order (Ref. 1st)	**1.00**			
2nd to 4th	1.03	0.86	0.72	1.48
5th or more	1.10	0.61	0.75	1.62
Birth size (Ref. Average)	**1.00**			
Smaller	1.55	0.03	1.04	2.32
Larger	1.32	0.08	0.97	1.79

Abbreviation: Madagascar DHS 2021, Madagascar Demographic and Health Survey of 2021 a Survey design and sampling weights of the Madagascar DHS 2021 were accounted for in all logistic regression models

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ISSN 1684 5374

Table S7: Univariate logistic regression analysis of risk factors anemia in children aged 6-59 months at Antsiranana province in the Madagascar DHS 2021

Characteristics	Odds Ratio[a]	P-Value	95% Conf. Interval	
Household Level				
Area (Ref. Urban)	**1.00**			
Rural	0.53	0.17	0.21	1.33
Wealth Quintile (Ref. Lowest)	**1.00**			
Poorer	1.03	0.96	0.34	3.09
Middle	1.79	0.47	0.36	8.84
Richer	2.52	0.26	0.50	12.62
Richest	2.21	0.34	0.43	11.33
Number of family members (Ref. One to four)	**1.00**			
Five or six	1.29	0.37	0.74	2.23
Seven or more	1.69	0.16	0.80	3.56
Drinking water source (Ref. Unimproved)	**1.00**			
Improved	0.81	0.68	0.29	2.27
Toilet facility (Ref. Open defecation)	**1.00**			
Unimproved toilet facility	0.71	0.56	0.22	2.32
Improved toilet facility	2.36	0.048	1.01	5.51
Maternal Level				
Education level (Ref. No education)	**1.00**			
Primary level	1.87	0.12	0.85	4.16
Secondary level	1.73	0.25	0.67	4.46
Higher level	1.57	0.63	0.24	10.41
Occupation (Ref. Not working)	**1.00**			
Traditional occupation	0.76	0.48	0.36	1.63
Transitional occupation	2.89	0.19	0.58	14.36
Mixed occupation	1.04	0.93	0.46	2.36
Modern occupation	2.12	0.42	0.33	13.74
Obesity level (Ref. Normal)	**1.00**			
Underweight	2.70	0.05	1.00	7.28
Overweight or obese	1.39	0.39	0.66	2.93
Anemia status (Ref. None)	**1.00**			

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Mild	1.36	0.51	0.54	3.40
Moderate or severe	4.71	0.002	1.84	12.04
Mother's attitude towards violence (Ref. No)	**1.00**			
Opposed to violence	2.24	0.01	1.20	4.21
Currently pregnant (Ref. No or unsure)	**1.00**			
Yes	1.00	0.99	0.39	2.13
Type of delivery assistance (Ref. Nonprofessionals)	**1.00**			
Professionals	0.69	0.51	0.22	2.13
Exposure to any media (TV, Newspaper, Radio) at least once a week (Ref. No)	**1.00**			
Yes	1.14	0.63	0.66	1.97
Own a mobile phone (Ref. No)	**1.00**			
Yes	1.32	0.25	0.82	2.13
Place of the recent delivery (Ref. Home or others)	**1.00**			
Health facilities	2.16	0.02	1.15	4.04
Put the baby to the breast within 1 hour after birth (Ref. No)	**1.00**			
Yes	1.23	0.42	0.74	2.06
Mother's stunting (Ref. Normal)	**1.00**			
Yes, stunting	1.03	0.94	0.48	2.21
Child Level				
Sex (Ref. Male)	**1.00**			
Female	0.68	0.15	0.40	1.16
Age (Ref. 6-23 Months)	**1.00**			
24 Months or older	0.66	0.14	0.37	1.15
Vitamin A supplement in last 6 months (Ref. No)	**1.00**			
Yes	1.45	0.16	0.86	2.44
Iron supplement (Ref. No)	**1.00**			
Yes	5.04	0.02	1.29	19.76
Deworming medicine in last 6 months (Ref. No)	**1.00**			
Yes	1.45	0.15	0.88	2.42

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Symptom of fever within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	4.14	0.01	1.36	12.64
Symptom of diarrhea within last 2 weeks (Ref. No or don't know)	**1.00**			
Yes	1.87	0.17	0.76	4.61
Currently Breastfeeding (Ref. Never breastfed)	**1.00**			
Ever, not currently	0.16	0.06	0.03	1.07
Currently breastfeeding	0.20	0.12	0.03	1.58
Stunting (Ref. No, normal)	**1.00**			
Yes	1.46	0.09	0.94	2.27
Wasting (Ref. No, normal)	**1.00**			
Yes	0.55	0.11	0.26	1.16
Birth order (Ref. 1st)	**1.00**			
2nd to 4th	1.55	0.17	0.83	2.92
5th or more	1.48	0.33	0.67	3.27
Birth size (Ref. Average)	**1.00**			
Smaller	0.85	0.69	0.38	1.92
Larger	1.94	0.13	0.82	4.57

Abbreviation: Madagascar DHS 2021, Madagascar Demographic and Health Survey of 2021 a Survey design and sampling weights of the Madagascar DHS 2021 were accounted for in all logistic regression models

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