Application of Generalized Linear Model for Correlated Health Outcomes of Children Under-five in Tanzania: A Case of Malaria, Anaemia and Fever

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Abstract

Malaria, anaemia, and fever are critical public health issues in Tanzania, affecting particularly children under-five years old. Despite ongoing efforts to lower child mortality, these diseases are still prevalent, contributing significantly to morbidity and mortality rates. This study investigated the patterns and common factors linked to childhood multimorbidity through the generalized linear model for correlated health outcomes. The study was based on two theoretical frameworks: the epidemiologic transition theory, and the social determinants of health theory. The analysis used data from three waves of the Tanzania Demographic and Health Survey and Malaria Indicator Survey conducted in 2007/08, 2011/12, and 2015/16. The findings revealed that the prevalence rates of malaria (9%–13%), anaemia (57%–70%), and fever (18%–22%) varied across the survey periods. Malaria risk increased with age, while anaemia and fever decreased as children aged. Children of mothers with no formal education had higher anaemia risks, and non-breastfed children were more likely to have fever. Other significant predictor factors included household size, maternal education, and employment status; which were consistently linked to the three health conditions across all survey years. The study recommends targeted health interventions, particularly in maternal education and breastfeeding promotion, to alleviate the burden of anaemia and fever. Strengthening malaria prevention strategies tailored to various age groups is also vital. Policy recommendations advocate for integrating maternal health education into community health programmes, promoting breastfeeding awareness, and enhancing access to child-focused healthcare services.

Keywords: *malaria, anaemia, fever, generalized, linear model*

1. Introduction

1.1 General Information

Childhood morbidity and mortality remain critical public health issues globally, especially in low- and middle-income countries, where diseases such as malaria, anaemia, and fever significantly impact children under-five years of age. These conditions are particularly prevalent in regions with limited healthcare access and preventive measures (Kejo et al., 2018; Milner et al., 2020; Ahinkorah, 2021). Despite global initiatives aimed at combating these illnesses through

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 ▪ *https://doi.org/10.56279/tjpsd.v32i2.263*

immunization, vector control, and enhanced healthcare services, they continue to contribute substantially to childhood mortality. The World Health Organization (WHO) reported 247m malaria cases and 619,000 deaths in 2021, primarily in sub-Saharan Africa (SSA) (WHO, 2022). Anaemia affects around 1.62bn people globally, with young children being particularly vulnerable (Gaston et al., 2021). Also, fever-related diseases account for over a third of all under-five deaths worldwide (Liu et al., 2016).

In SSA, the situation is dire, with one in thirteen children dying before their fifth birthday; a rate that is sixteen times higher than in high-income countries (Anteneh et al., 2017; Tesfa et al., 2021; WHO, 2020). This disparity underscores the ongoing inequalities in healthcare access, disease prevention, and treatment availability. A study in Rwanda revealed that children with moderate or severe anaemia had a fourfold increased risk of malaria infection, highlighting the interconnectedness of these diseases (Kateera et al., 2015). Research indicates that childhood morbidity is influenced by various factors, including maternal education, household wealth, maternal employment status, birth order, and a child's birth weight: all suggesting the necessity of multi-sectoral intervention approaches (Adedokun & Yaya, 2020).

In Tanzania, significant progress has been made in reducing child mortality; and in achieving Millennium Development Goal (MDG) 4 in 2015 (Afnan-Holmes et al., 2015). However, malaria, anaemia, and fever persist as the leading causes of under-five mortality (Lugangira et al., 2017). The ongoing prevalence of these diseases highlights the need for scaling up interventions to meet Sustainable Development Goals (SDGs) 2, 4, and 6; which aim to eliminate malnutrition, enhance education, and improve healthcare access by 2030 (Raszkowski & Bartniczak, 2019).

Previous studies (Mwaiswelo et al., 2021; Takele et al., 2019) have examined the relationship between diseases and various socioeconomic, demographic, environmental, and individual risk factors in SSA, and Tanzania in particular. However, many of these studies have limitations, often due to relying on logistic regression models that do not account for correlations between co-existing health conditions. Additionally, several studies—such as by Simbauranga et al. (2015) and Kassile et al. (2014)—utilize limited datasets with small sample sizes, which restricted their generalizability.

1.2 Theoretical Framework Underpinning the Study

The study employed the epidemiologic transition theory and the social determinants of health (SDH) theory to analyse the prevalence and co-morbidity of malaria, anaemia, and fever among children under-five in Tanzania. The epidemiologic transition theory, proposed by Omram (2001), identified four stages in the evolution of disease within societies. The **first stage**, known as *the age of pestilence and famine*, is characterised by high and fluctuating mortality rates, low and variable life expectancy (typically between 20 and 40 years), frequent epidemics, widespread famine, and poor sanitation, with infectious and parasitic diseases being the leading causes of death. The **second stage**, *the age of receding pandemics*, marks a decline in the frequency and severity of epidemics and pandemics, a gradual rise in life expectancy (to around 50 years), and improvements in sanitation, hygiene, and nutrition brought about by social and economic development, although infectious diseases persist at reduced levels. The **third stage**, referred to as *the age of degenerative and man-made diseases*, involves a continued decline in infectious diseases, and an increase in chronic and degenerative conditions such as heart disease, cancer, and stroke. Life expectancy rises above 60 years, while lifestyle-related factors—such as diet, smoking, and stress—become major contributors to mortality. The **final stage**, termed *the age of delayed degenerative diseases*, is characterised by the persistence of chronic diseases, which occur later in life due to advances in medical care. Life expectancy extends beyond 70 years, and improved health technologies and preventive medicine help delay morbidity and mortality.

Tanzania is currently considered to be transitioning between the first and second stages of this epidemiologic evolution. However, despite improvements in healthcare reducing child mortality, malaria, anaemia, and fever remain significant health threats; reflecting ongoing healthcare access inequalities and environmental risks (WHO, 2022; Afnan-Holmes et al., 2015).

The SDH theory posits that health outcomes are influenced by socioeconomic, environmental, and behavioural factors rather than biological causes alone (Marmot & Wilkinson, 2005). Key components identified by the WHO (2021) include economic stability, education, healthcare access, social context, and neighbourhood environment. In Tanzania, children from low-income households and rural areas—and particularly those with less educated mothers—face higher risks of these diseases due to inadequate healthcare access and poor living conditions (Mwaiswelo et al., 2021; Adedokun & Yaya, 2020).

This study applies the two theories to explore how healthcare advancements and socioeconomic changes affect disease prevalence. It highlights the incomplete transition from infectious to non-communicable diseases, and emphasizes the need for targeted interventions. By integrating the SDH framework, the study identifies disparities in education, income, and healthcare access; providing insights for policy improvements aimed at addressing systemic inequalities in child healthcare delivery.

Finally, the study utilizes the generalized linear models (GLM) for a comprehensive analysis of correlated health outcomes, thereby enhancing the understanding of the interconnectedness of malaria, anaemia, and fever; and hence contributing to policy recommendations to reduce morbidity and mortality among children under-five in Tanzania.

2. Material and Methods

2.1 Data Sources

The study analysed data from three nationally representative surveys in Tanzania: the THMIS (2007/08 and 2011/12), and the TDHS-MIS (2015/16), conducted by the National Bureau of Statistics, with partners like the DHS Programme and WHO (2022). Using a multi-stage cluster sampling method for national representativeness, these surveys collected extensive information on women's socio-demographics, maternal and child health, and disease prevalence (DHS Programme, 2023). The sample sizes were 9,144, 10,496, and 13,376 households for the respective surveys. The analysis of the current study focused on children under-five with complete data on malaria, anaemia, and fever.

2.2 Extracted Data and Variables of Interest

2.2.1 Outcome Variables

The study examined three binary health outcomes in children: malaria, anaemia, and fever. Each condition was recorded as either present (1) or absent (0), based on caregiver reports or biomedical assessments during the surveys (October 2023). This approach aimed to provide a comprehensive understanding of childhood health issues related to these specific conditions.

2.2.2 Independent Variables

The independent variables were selected based on previous studies on childhood morbidity (Rashmi & Paul, 2022; Duah et al., 2021; Mwaiswelo et al., 2021). These variables are shown in Table 1.

Table 1: Independent Variables

Independent Variable	Categorization
Child's age (months)	0–11, 12–23, 24–35, 36–47, 48–59
Sex of the child	Male (0), Female (1)
Birth order	1–3 (0), 4–6 (1), 7+ (2)
Mother's education level	No formal education (0), Primary (1), Secondary/Higher (2)
Wealth index	Poor (0), Middle (1), Rich (2)
Place of residence	Urban (0), Rural (1)
Mother's employment status	Unemployed (0), Employed (1)
Preceding birth interval (months)	<24 (0), 24–47 (1), 48+ (2)
Number of children under-five in household	0–3 (0), 4–7 (1), 8+ (2)
Currently breastfeeding	No (0), Yes (1)
Household mosquito net ownership	No (0), Yes (1)
Child slept under bed net last night	No (0), Yes (1)

2.3 *Statistical Modelling and Data Analysis*

As mentioned, the study applied the Generalized Linear Model (GLM) to analyse the association between malaria, anaemia, and fever. The GLM framework is particularly useful for modelling correlated binary outcomes, and addressing dependencies among childhood diseases (McCullagh & Nelder, 2019).

2.3.1 Generalized Linear Model Specification

Each outcome variable Y_i (malaria, anemia, fever) was modelled using the Bernoulli distribution, a special case of the binomial distribution for binary response data:

$$Y_i \sim Bernoulli(\mu_i)$$

Where: μ_i represents the probability of a child experiencing a health outcome. The expected value of Y_i is given by:

$$E(Y_i) = \mu_i, \qquad 0 \leq \mu_i \leq 1$$

The relationship between the independent variables and outcome variables was expressed through a logit link function, ensuring the predicted probabilities remain between 0 and 1:

$$g(\mu_i) = \log\left(\frac{\mu_i}{1-\mu_i}\right) = \eta_i$$

Where:

$$\eta_i - \sum_{k=1}^{p} x_{ik}\beta_k$$

Here, x_{ik} represents the independent variables (child age, sex, maternal education, household wealth, etc.); and β_k are the estimated coefficients.

2.3.2 Correlated Health Outcomes Model

Since malaria, anaemia, and fever frequently co-exist, a Bivariate Bernoulli Model was applied to capture potential correlations. The likelihood functions for malaria (P_{i1}), anaemia (P_{i2}), and fever (P_{i3}) were specified as:

$$g_1(\mu_{i1}) = X_{i1}\beta_{i1} + Z_{i1}v_1$$
$$g_2(\mu_{i2}) = X_{i2}\beta_{i2} + Z_{i2}v_2$$
$$g_3(\mu_{i3}) = X_{i3}\beta_{i3} + Z_{i3}v_3$$

where:

$\beta_1, \beta_2, \beta_3$ are fixed effects
$v_1, v_2\ v_3$ are random effects
X_{i1}, X_{i2}, X_{i3}, are design matrices for fixed effects
Z_{i1}, Z_{i2}, Z_{i3} are design matrices for random effects.

The variance-covariance structure was defined as:

$$V - \begin{bmatrix} \sum_{11} & \sum_{12} & \sum_{13} \\ \sum_{21} & \sum_{22} & \sum_{23} \\ \sum_{31} & \sum_{32} & \sum_{33} \end{bmatrix}$$

where $\sum_{11}, \sum_{22}$ and $\sum_{33}$ represent the variance components for malaria, anaemia, and fever, respectively; while $\sum_{12}, \sum_{13}$ and $\sum_{23}$ capture correlations between these conditions.

2.4 Goodness of Fit Assessment

To assess model fit, the -2Akaike Information Criterion (AIC) was used (Hirotsugu, 1973). AIC penalizes model complexity while maximizing fit, with lower values indicating better model performance:

$$AIC = \text{-2log}L + 2k$$

where:

L is the likelihood function,

k is the number of estimated parameters.

Models with the lowest AIC were considered optimal for predicting childhood morbidity outcomes.

3. Results and Discussion

3.1 Socio-Demographic Characteristics of Children Under-five

Table 2 presents the socio-demographic characteristics of the study population. The table shows that across all three survey periods, anaemia remained highly prevalent; affecting over 57% of children under-five. The highest prevalence was recorded in THMIS 2007/08 (69.7%), followed by TDHS-MIS 2015/16 (58.5%), and THMIS 2011/12 (57.4%). The proportion of children diagnosed with malaria varied between 9.3% and 12.5%, while fever affected between 18.6% and 22.4% of children in the three surveys.

Most children resided in rural areas (over 77% in all three surveys), with a significant proportion of their mothers having no formal education (over 35% across all surveys). The results also indicate that most mothers were engaged in employment, particularly in THMIS 2011/12 (88.4%), THMIS 2007/08 (81.3%), and TDHS-MIS 2015/16 (79.2%). Wealth distribution varied, with approximately 40–45% of households categorized as poor, 20–22% in the middle-income category, and 35–38% classified as wealthy.

These findings highlight persistent socio-economic disparities, which play a crucial role in influencing child health outcomes. Similar studies have shown that children from low-income households and those born to mothers with lower education levels face a higher risk of morbidity due to inadequate access to healthcare services and poor living conditions (Habyarimana & Ramroop, 2020; Parbey et al., 2019).

Table 2: Socio-demographic Characteristics of Children Under-five Years in Tanzania for THMISs 2007–08 & 2011–12 and TDHS-MIS 2015–16

Variable	Categories	2007/8	2011/12 n (%)	2015/16
Malaria	No	4856 (87.5)	5860 (90.3)	6909 (88.3)
	Yes	695 (12.5)	598 (9.3)	914 (11.7)
Anaemia	No	1680 (30.3)	2753 (42.6)	3247 (41.5)
	Yes	3871 (69.7)	3705 (57.4)	4576 (58.5)
Fever	No	4519 (81.4)	5011 (77.6)	6350 (81.2)
	Yes	1032 (18.6)	1447 (22.4)	1473 (18.8)
Preceding birth interval (in months)	<24	817 (14.7)	837 (13.0)	1243 (15.9)
	24–47	2678 (48.2)	2195 (34.0)	3264 (41.7)
	48+	2056 (37.1)	3426 (53.1)	3316 (42.4)
Birth order	1–3	2792 (50.3)	3299 (51.1)	4259 (54.5)
	4–6	1786 (32.2)	1998 (30.9)	2380 (30.4)
	7+	973 (17.5)	1161 (18.0)	1184 (15.1)
Sex of a child	Male	2809 (50.6)	3251 (50.3)	3934 (50.3)
	Female	2742 (49.4)	3207 (49.7)	3889 (49.7)
Child's age (in months)	≤ 11	706 (12.7)	789 (12.2)	985 (12.6)
	12–23	1405 (25.3)	1648 (25.5)	2049 (26.2)
	24–35	1205 (21.7)	1410 (21.8)	1702 (21.8)
	36–47	1104 (19.9)	1381 (21.4)	1552 (19.8)
	48–59	1131 (20.4)	1230 (19.1)	1535 (19.6)
Currently working for the mother	No	1038 (18.7)	746 (11.6)	1624 (20.8)
	Yes	4513 (81.3)	5712 (88.4)	6199 (79.2)
Education attainment of a mother	No formal education	2457 (44.3)	2560 (39.6)	2794 (35.7)
	Primary education	3064 (55.2)	3886 (60.2)	4273 (54.6)
	Higher/Sec. education	30 (0.5)	12 (0.2)	756 (9.7)
Type of place of residence	Urban	866 (15.6)	915 (14.2)	1749 (22.4)
	Rural	4685 (83.6)	5543 (85.8)	6074 (77.6)
Wealth Index	Poor	2248 (40.5)	2877 (44.6)	3449 (44.1)
	Middle	1156 (20.8)	1395 (21.6)	1533 (19.6)
	Rich	2147 (38.7)	2186 (33.8)	2841 (36.3)
Currently breastfeeding	No	2205 (39.7)	2776 (43.0)	3447 (65.1)
	Yes	3346 (60.3)	3682 (57.0)	4376 (34.9)
Number of children under 5 in the household	0–3	5093 (91.8)	5701 (88.3)	7169 (91.6)
	4–7	400 (7.2)	698 (10.8)	574 (7.3)
	8+	58 (1.0)	59 (0.9)	80 (1.0)
Have mosquito bed net for sleeping	No	1608 (29.0)	291 (4.5)	1659 (21.2)
	Yes	3943 (71.0)	6167 (95.5)	6164 (78.8)
Children under 5 Slept under bed net last night	No	2801 (50.5)	1043 (16.2)	2606 (33.3)
	Yes	2750 (49.5)	5415 (83.8)	5217 (66.7)

Source: Author's computation from THMIS 2007/08, THMIS 2011/12 and TDHS-MIS 2015/16

3.2 Factors Associated with Malaria, Anaemia and Fever in Children Under-five

The GLM results in Tables 3, 4, and 5 illustrate the risk factors associated with malaria, anaemia, and fever. The study identified common factors associated with all three conditions, including child's age, number of children under-five in a household, mother's employment status, breastfeeding status, wealth index, and maternal education.

Table 3: Results of Generalized Linear Models showing risk factors associated with Malaria for THMIS 2007_08, THMIS 2011_12 and TDHS–MIS 2015_16

Variables	Malaria THMIS 2007_08			Malaria THMIS 2011_12			Malaria TDHS_MIS 2015_16		
	OR (95% C.I)	P-value	Overall P	OR (95% C.I)	P-value	Overall P	OR (95% C.I	P-value	Overall P
Sex of a Child			0.36			0.555			0
Male(Ref)									
Female	1.08(0.92,1.27)	0.365		0.94(0.79,1.12)	0.502		0.90(0.78,1.04)	0.159	
Age of a child in months			0			0			0.001
0–11	0.64(0.45,0.91)**	0.013		0.55(0.37,0.82)***	0.003		0.59(0.44,0.81)***	0.001	
12–23(Ref)									
24–35	1.34(1.04,1.73)**	0.023		1.43(1.09,1.86)***	0		1.20(0.96,1.49)	0.102	
36–47	1.21(0.94,1.56)	0.144		1.52(1.17,1.97)***	0		1.37(1.11,1.71)***	0.004	
48–59	1.49(1.17,1.92)***	0.001		1.94(1.49,2.51)***	0		1.41(1.13,1.75)***	0.002	
Number of U5C in the HH			0.002			0			0
0–3(Ref)									
4–7	1.66(1.30,2.22)***	0		1.69(1.34,2.13)***	0		1.43(1.14,1.79)**	0.002	
>=8	1.22(0.64,2.37)	0.554		1.43(0.69,2.96)	0.338		1.60(0.98,2.61)*	0.058	
Place of residence			0.001			0			0
Urban	0.62(0.44,0.88)***	0.007		0.46(0.29,0.73)***	0.001		0.65(0.48,0.89)***	0.007	
Rural (Ref)									
Mother education			0.078			0.539			0
No education	0.84(0.71,0.99)**	0.044		1.06(0.89,1.27)	0.511		1.54(1.33,1.78)***	0	
Primary education (Ref)									
Higher/Sec. education	0.53(0.07,3.99)	0.536		2.82(0.35,22.81)	0.33		0.29(0.15,0.58)***	0	

Variables	Malaria THMIS 2007_08			Malaria THMIS 2011_12			Malaria TDHS_MIS 2015_16		
	OR (95% C.I)	**P-value**	**Overall P**	**OR (95% C.I)**	**P-value**	**Overall P**	**OR (95% C.I**	**P-value**	**Overall P**
Mother working			0			0			0.254
No	0.41(0.31,0.55)***	0		0.40(0.26,0.62)***	0		0.58(0.47,0.73)***	0	
Yes(Ref)									
Currently breast feeding			0			0.37			0
No	1.31(1.09,1.57)***	0.004		0.88(0.73,1.06)	0.183		1.04(0.89,1.22)	0.596	
Yes(Ref)									
Wealth Index			0			0			0
Poor									
Middle	0.71(0.58,O.86)***	0.001		0.68(0.55,0.84)***	0		0.63(0.52,0.75)***	0	
Rich	0.29(0.23,0.37)***	0		0.39(0.30,0.51)***	0		0.18(0.14,0.24)***	0	
Have mosquito net for sleeping			0.561			0.128			0.109
No	1.05(0.84,1.32)	0.682		1.55(0.89,2.66)	0.116		0.42(0.32,0.56)***	0	
Yes(Ref)									
U5C slept under mosquito bed net			0.205			0			0
No	0.88(0.71,1.09)	0.261		0.48(0.35,0.68)***	0		0.83(0.67,1.04)	0.102	
Yes(Ref)									
AIC	3910			3747			4930		

Source: Author'scomputationfromTHMIS2007/08,THMIS2011/12andTDHS-MIS2015/16

Table 4: Results of Generalized Linear Models of Risk Factors Associated with Anaemia for THMIS 2007_08, THMIS 2011_12 and TDHS–MIS 2015_16

Variables	Anaemia THMIS 2007_08			Anaemia THMIS 2011_12			Anaemia TDHS_MIS 2015_16		
	OR (95% C.I)	P-value	Overall P	OR (95% C.I)	P-value	Overall P	OR (95% C.I	P-value	Overall P
Sex of a Child			0.034			0			0
Male (Ref)									
Female	0.88(0.79,0.99)**	.037		0.80(0.72,0.89)***	0		0.83(0.76,0.92)***	0	
Age of a child in months		.	0			0			0
0–11	1.64(1.27,2.12)***	0		1.15(0.95,1.41)	0.162		1.31(1.09,0.92)***	0.004	
12–23 (Ref)									
24–35	0.56(0.46,0.68)***	0		0.49(0.41,0.58)***	0		0.50(0.43,1.57)***	0	
36–47	0.36(0.30,0.43)***	0		0.32(0.28,0.38)***	0		0.30(0.26,0.58)***	0	
48–59	0.28(0.24,0.34)***	0		0.25(0.22,0.29)***	0		0.26(0.22,0.34)***	0	
Number of U5C in the HH			0			0.477			0
0–3 (Ref)									
4–7	1.58(1.24,2.03)***	0		1.14(0.97,1.36)	0.118		1.39(1.15,1.68)***	0.001	
>=8	2.11(1.07,4.17)**	0.03		0.82(0.48,1.39)	0.457		2.62(1.50,4.58)***	0.001	
Place of residence			0.128			0.497			0.329
Urban	1.13(0.95,1.36)	0.172		0.93(0.78,1.10)	0.383		0.95(0.83,1.08)	0.425	
Rural (Ref)									
Education attainment of a mother			0			0			0
No education	1.32(1.16,1.49)***	0		1.22(1.09,1.37)***	0		1.35(1.22,1.51)***	0	
Primary education (Ref)									
Higher/Secondary education	1.45(0.59,3.51)	0.413		0.39(0.12,1.31)*	0.126		0.93(0.78,1.11)	0.423	

Variables	Anaemia THMIS 2007_08			Anaemia THMIS 2011_12			Anaemia TDHS_MIS 2015_16		
	OR (95% C.I)	**P-value**	**Overall P**	**OR (95% C.I)**	**P-value**	**Overall P**	**OR (95% C.I**	**P-value**	**Overall P**
Mother working			0.344			0.001			0
No	0.93(0.79,1.09)	0.353		1.33(1.13,1.58)***	0.001		1.39(1.23,1.57)***	0	
Yes (Ref)									
Currently breastfeeding			0.334			0.008			0.001
No	1.11(0.98,1.27)	0.112		0.88(0.79,0.99)**	0.041		0.89(0.79,0.99)**	0.028	
Yes (Ref)									
Wealth Index			0.173			0.34			0.018
Poor (Ref)									
Middle	0.99(0.86,1.18)	0.995		0.96(0.84,1.09)	0.477		1.02(0.89,1.16)	0.821	
Rich	1.10(0.94,1.28)	0.187		1.09(0.95,1.25)	0.247		0.83(0.73,0.95)***	0.006	
AIC	6439.580			8266.150			9834.951		

Source: Author's computation from THMIS 2007/08, THMIS 2011/12 and TDHS-MIS 2015/16

Table 5: Results of Generalized Linear Models of Factors Associated with Fever for THMIS 2007_08, THMIS 2011_12 and TDHS 2015_16

Variables	Fever THMIS 2007_08			Fever THMIS 2011_12			Fever TDHS_MIS 2015_16		
	OR (95% C.I)	P-value	Overall P	OR (95% C.I)	P-value	Overall P	OR (95% C.I	P-value	Overall P
Sex of a Child			0.925			0.759			0.659
Male (Ref)									
Female	1.00(0.87,1.15)	0.964		0.98(0.86,1.10)	0.695		0.98(0.87,1.10)	0.685	
Age of a child in months			0			0			0
0–11	1.28(1.03,1.59)**	0.024		1.15(0.95,1.39)	0.162		1.06(0.88,1.28)	0.568	
12–23 (Ref)									
24–35	0.72(0.58,0.88)***	0		0.59(0.49,0.71)***	0		0.86(0.72,1.01)*	0.073	
36–47	0.49(0.39,0.61)***	0		0.49(0.42,0.60)***	0		0.62(0.52,0.75)***	0	
48–59	0.34(0.27,0.44)***	0		0.32(0.26,0.39)***	0		0.51(0.42,0.62)***	0	
Number of children under five in the HH			0.241			0.923			0.032
0–3 (Ref)									
4–7	0.88(0.67,1.16)	0.364		1.03(0.85,1.25)	0.788		0.97(0.78,1.21)	.0778	
>=8	2.39(1.35,4.22)***	0.003		0.86(0.43,1.70)	0.653		0.26(0.11,0.61)***	0.002	
Place of residence			0.021			0.102			0.267
Urban	1.31(1.06,1.60)***	0.011		1.01(0.96,1.42)	0.13		1.06(0.90,1.25)	0.463	
Rural (Ref)									
Education attainment of a mother			0.327			0.79			0.329
No education	1.07(0.93,1.24)	0.367		1.01(0.89,1.15)	0.869		1.12(0.99,1.27)*	0.083	
Primary education (Ref)									
Higher/Secondary education	0.67(0.23,1.98)	0.472		0.41(0.36,1.23))	0.675		1.08(0.88,1.34)	0.448	

Variables	Fever THMIS 2007_08			Fever THMIS 2011_12			Fever TDHS_MIS 2015_16		
	OR (95% C.I)	**P-value**	**Overall P**	**OR (95% C.I)**	**P-value**	**Overall P**	**OR (95% C.I**	**P-value**	**Overall P**
Currently working of a mother			0.364			0.031			0.656
No	0.92(0.77,1.11)	0.403		0.80(0.66,0.98)***	0.034		1.02(0.89,1.18)	0.744	
Yes (Ref)									
Currently breastfeeding			0			0			0.015
No	1.30(1.09,1.53)***	0.002		1.38(1.20,1.59)***	0		1.14(1.00,1.31)**	0.049	
Yes (Ref)									
Wealth Index			0.532			0.713			0.125
Poor (Ref)									
Middle	1.20(0.99,1.44)*	0.052		0.97(0.83,1.14)	0.77		0.96(0.82,1.13)	0.696	
Rich	1.06(0.88,1.27)	0.527		1.05(0.89,1.23)	0.587		1.15(0.98,1,36)	0.104	
Anemia Level			0.305			0.001			0.007
No	0.91(0.77,1.08)	0.293		0.81(0.71,0.93)***	0.002		0.84(0.74,0.95)***	0.007	
Yes (Ref)									
Malaria			0			0			0
No									
Yes	3.09(2.56,3.73)***	0		3.39(2.82,4.09)***	0		2.81(2.38,3.31)***	0	
AIC	5088			6550			7343		

Source: Author's computation from THMIS 2007/08, THMIS 2011/12 and TDHS–MIS 2015/16

3.2.1 Factors Associated with Malaria

Table 3 presents the factors influencing malaria prevalence. The results indicate that child's age, household size, residence and socioeconomic status, and mother's employment status are the factors associated with malaria for children under-five. First, infants aged 0–11 months were significantly less likely to contract malaria compared to older children aged 12–23 months. However, the risk of malaria increased progressively with age, peaking among children aged 48–59 months; who were 49% (THMIS 2007/08), 94% (THMIS 2011/12), and 41% (TDHS-MIS 2015/16) more likely to contract malaria. This aligns with findings from previous studies indicating that older children are more exposed to malaria due to increased mobility and greater outdoor activity, which lead to higher exposure to mosquito bites (Anjorin et al., 2023; Emina et al., 2021).

Secondly, household size was another factor associated with contracting malaria. There was the likelihood of malaria increasing significantly among children in households with more than four children. Also, as per Table 3, households with 4–7 children were 66% (THMIS 2007/08), 69% (THMIS 2011/12), and 43% (TDHS-MIS 2015/16) more likely to have children diagnosed with malaria. Larger households often experience higher transmission risks due to overcrowding, inadequate bed net coverage, and increased exposure to mosquitos (Habyarimana & Ramroop, 2020; Ugwu & Zewotir, 2018).

Thirdly, residence and socioeconomic status was yet another factor. Children from urban areas were significantly less likely to contract malaria than those in rural settings, with odds reductions of 38% (THMIS 2007/08), 54% (THMIS 2011/12), and 35% (TDHS-MIS 2015/16). Similarly, children from wealthier households had a significantly lower risk of contracting malaria due to better access to preventive measures such as treated bed nets and healthcare services (Habyarimana et al., 2017).

Lastly, mother's employment status was directly related to children catching malaria. The risk was higher among children whose mothers were employed, with non-working mothers' children 59% (THMIS 2007/08), 60% (THMIS 2011/12), and 42% (TDHS-MIS 2015/16) less likely to contract malaria. This could be due to limited parental supervision and poorer childcare practices among working mothers, leading to increased exposure to malaria vectors (Bisht, 2021).

3.2.2 Factors Associated with Anaemia

Table 4 highlights the factors associated with anaemia among children under-five. The key findings show that these include sex of the child, child's age, and maternal education. Also, female children were significantly less likely to be anaemic compared to male children, with 12% (THMIS 2007/08), 20% (THMIS 2011/12), and 17% (TDHS-MIS 2015/16) lower odds. Similar trends have been observed in studies from Ethiopia and Kenya, where boys exhibited higher anaemia prevalence, potentially due to differences in iron metabolism and dietary intake (Mohammed et al., 2019; Ngesa & Mwambi, 2014).

Moreover, anaemia prevalence decreased as children aged, with the highest risk being among infants under 12 months. This is consistent with findings from earlier research showing that young children are more susceptible to iron deficiency due to rapid growth and inadequate complementary feeding (Kemmer et al., 2003; Zhao et al., 2012).

Additionally, anaemia prevalence was significantly higher in children whose mothers had no formal education, with an increased risk of 32% (THMIS 2007/08), 22% (THMIS 2011/12), and 35% (TDHS-MIS 2015/16). Several studies suggest that maternal education influences dietary practices, healthcare-seeking behaviour, and overall child nutrition; thereby reinforcing the importance of education in reducing childhood anaemia (Provan, 1999; Zhao et al., 2012).

3.2.3 Factors Associated with Fever

Table 5 presents the determinants of fever among children under-five. The results indicate that child's age, breastfeeding status, and malaria as risk factors. Similar to the case of malaria and anaemia, the risk of fever declined with age. Children aged 48–59 months were 66% (THMIS 2007/08), 68% (THMIS 2011/12), and 49% (TDHS-MIS 2015/16) less likely to experience fever than those aged 12–23 months. This aligns with previous studies showing that older children have stronger immune systems; hence they are less susceptible to infections (Adedokun & Yaya, 2020).

Moreover, children who were not breastfed were at a significantly higher risk of fever, with 30% (THMIS 2007/08), 38% (THMIS 2011/12), and 14% (TDHS-MIS 2015/16) increased likelihood of experiencing fever. This finding is in line with earlier research indicating that breastfeeding provides essential antibodies and immune support, thereby reducing infection risks (Takele et al., 2019; Kumi-Kyereme & Amo-Adjei, 2016).

Furthermore, fever was highly correlated with malaria, with children diagnosed with malaria being over three times more likely to develop fever. This highlights malaria's significant role in contributing to febrile.

4. Conclusion and Recommendations

4.1 Conclusion

The study underscores the pressing issue of multi-morbidity among children aged under-five in Tanzania, revealing significant health risks from malaria, anaemia, and fever; particularly in rural and low-income households. The analysis of the data from three national surveys (THMIS 2007/08, THMIS 2011/12, TDHS-MIS 2015/16) identifies child's age as a key determinant, with older children facing higher malaria risks but lower anaemia and fever risks. Other factors influencing disease prevalence include household size, residence, maternal education, employment status, and breastfeeding practices. Notably, children from larger households, rural areas, and mothers lacking formal education are at greater risk of morbidity. The study employs a Generalized Linear Model to effectively correlate health outcomes and estimate risk factors associated with childhood multi-morbidity. The findings highlight the urgent need for targeted interventions that address socio-economic disparities, enhance maternal education, and improve preventive healthcare services to mitigate childhood morbidity and mortality in Tanzania.

4.2 Policy Recommendations

The study outlines a comprehensive set of policy recommendations aimed at reducing the incidence of malaria, anaemia, and fever among children under-five, in Tanzania. First, targeted health interventions should be undertaken for high-risk groups, particularly children from rural and low-income households. Community-based healthcare initiatives that promote malaria prevention through the distribution of treated bed nets, indoor residual spraying, and improved access to diagnostics and treatment: all these should be advocated. Additionally, national immunization programmes should be expanded to include iron-folic acid supplementation and deworming campaigns to combat anaemia.

Secondly, maternal education and awareness should be enhanced to underscore the critical role of maternal education in improving child health outcomes; and call for increased access to formal education for girls and young mothers. Community outreach initiatives should educate mothers on breastfeeding, nutrition, and hygiene to reduce anaemia and fever-related illnesses. Educational campaigns should also employ behavioural change communication strategies to raise awareness about disease prevention and early treatment-seeking behaviour.

Thirdly, child nutrition and breastfeeding practices should be emphasized. Public health policies should advocate for exclusive breastfeeding for the first six months, and continued breastfeeding for at least two years, as these practices can reduce susceptibility to infections. The government should enhance nutrition-sensitive social protection programmes, including food fortification and nutrition support for vulnerable households, while integrating nutrition-focused interventions into maternal and child healthcare services.

Fourthly, household overcrowding and family planning should be addressed. The study indicates that larger households face higher risks of malaria and anaemia; hence, scaling up family planning programmes and reproductive health education is essential. This includes expanding access to affordable contraceptive services and maternal health clinics to empower families in making informed decisions about child-spacing.

Lastly, there is a need to mount socioeconomic empowerment programmes for women. The study found that children of working mothers had higher odds of contracting malaria, indicating a need for social support systems like subsidized daycare and flexible working hours. Strengthening economic empowerment initiatives—such as microfinance and skills development programmes—would enhance household income and healthcare access. Employers are urged to adopt family-friendly policies—including paid maternity leave and childcare services—to improve maternal well-being and child health outcomes.

Overall, these recommendations aim to create a holistic approach to improving child health in Tanzania by addressing health interventions, education, nutrition, family planning, and women empowerment.

References

Adedokun, S. T. & Yaya, S. (2020). Childhood morbidity and its determinants: Evidence from 31 countries in sub-Saharan Africa. *BMJ Global Health*, 5(10): e003109.

Afnan-Holmes, H., Magoma, M., John, T., Levira, F., Msemo, G., Armstrong, C. E., Martínez-Álvarez, M., Kerber, K., Kihinga, C. & Makuwani, A. (2015). Tanzania's countdown to 2015: An analysis of two decades of progress and gaps for reproductive, maternal, newborn, and child health, to inform priorities for post-2015. *The Lancet Global Health*, 3(7): e396-e409.

Ahinkorah, B. O. (2021). Maternal age at first childbirth and under-five morbidity in sub-Saharan Africa: Analysis of cross-sectional data of 32 countries. *Archives of Public Health*, 79(1): 151. https://doi.org/10.1186/s13690-021-00674-5.

Anjorin, S., Okolie, E. & Yaya, S. (2023). Malaria profile and socioeconomic predictors among under-five children: An analysis of 11 sub-Saharan African countries. *Malaria Journal*, 22(1): 1–11.

Anteneh, Z. A., Andargie, K. & Tarekegn, M. (2017). Prevalence and determinants of acute diarrhoea among children younger than five years old in Jabithennan District, Northwest Ethiopia, 2014. *BMC Public Health*, 17(1): 1–8.

Bisht, M. (2021). Behavioural problems of children among working and non-working mothers. *International Journal of Advances in Nursing Management*, 395–399.

Duah, H. O., Amankwa, C. E., Adomako, I., Owusu, B. & Agbadi, P. (2021). Comorbid patterns of anaemia and diarrhoea among children aged under 5 years in Ghana: A multivariate complex sample logistic regression analysis and spatial mapping visualisation. *International Health*, 13(6): 562–572.

Emina, J. B. O., Doctor, H. V. & Yé, Y. (2021). Profiling malaria infection among under-five children in the Democratic Republic of Congo. *PLOS ONE*, 16(5): e0250550. https://doi.org/10.1371/journal.pone.0250550.

Gaston, R. T., Ramroop, S. & Habyarimana, F. (2021). Joint modelling of malaria and anaemia in children less than five years of age in Malawi. *Heliyon*, 7(5): e06899.

Habyarimana, F. & Ramroop, S. (2020). Prevalence and risk factors associated with malaria among children aged six months to 14 years old in Rwanda: Evidence from 2017 Rwanda Malaria Indicator Survey. *International Journal of Environmental Research and Public Health*, 17(21): Article 21. https://doi.org/10.3390/ijerph17217975.

Habyarimana, F., Zewotir, T. & Ramroop, S. (2017). Structured additive quantile regression for assessing the determinants of childhood anaemia in Rwanda. *International Journal of Environmental Research and Public Health*, 14(6): 652.

Hirotsugu, A. (1973). Information Theory and an extension of the Maximum Likelihood Principle. 2*nd International Symposium on Information Theory,* 1973.

Kassile, T., Lokina, R., Mujinja, P. & Mmbando, B. P. (2014). Determinants of delay in care seeking among children under-five with fever in Dodoma Region, Central Tanzania: A cross-sectional study. *Malaria Journal*, 13(1): 348. https://doi. org/ 10. 1186/1475-2875-13-348.

Kateera, F., Ingabire, C. M., Hakizimana, E., Kalinda, P., Mens, P. F., Grobusch, M. P., Mutesa, L. & van Vugt, M. (2015). Malaria, anaemia and under-nutrition: Three frequently co-existing conditions among preschool children in rural Rwanda. *Malaria Journal*, 14: 1–11.

Kejo, D., Petrucka, P. M., Martin, H., Kimanya, M. E. & Mosha, T. C. (2018). Prevalence and predictors of anaemia among children under 5 years of age in Arusha District, Tanzania. *Pediatric Health, Medicine and Therapeutics*, 9: 9. https://doi.org/10. 2147/ PHMT.S148515.

Kemmer, T. M., Bovill, M. E., Kongsomboon, W., Hansch, S. J., Geisler, K. L., Cheney, C., Shell-Duncan, B. K. & Drewnowski, A. (2003). Iron deficiency is unacceptably high in refugee children from Burma. *The Journal of Nutrition*, 133(12): 4143–4149. https://doi.org/10.1093/jn/133.12.4143.

Kumi-Kyereme, A. & Amo-Adjei, J. (2016). Household wealth, residential status and the incidence of diarrhoea among children under-five years in Ghana. *Journal of Epidemiology and Global Health*, 6(3): 131–140.

Liu, L., Oza, S., Hogan, D., Chu, Y., Perin, J., Zhu, J., Lawn, J. E., Cousens, S., Mathers, C. & Black, R. E. (2016). Global, regional, and national causes of under-5 mortality in 2000–15: An updated systematic analysis with implications for the Sustainable Development Goals. *The Lancet*, 388(10063): 3027–3035.

Lugangira, K., Kazaura, M. & Kalokola, F. (2017). Morbidity and mortality of children aged 2–59 months admitted in the Tanzania Lake Zone's public hospitals: A cross-sectional study. *BMC Research Notes*, 10(1): 502. https://doi.org/10.1186/s13104-017-2818-z.

Marmot, M. & Wilkinson, R. (2005). *Social determinants of health*. OUP Oxford.

McCullagh, P. (2019). *Generalized linear models*. Routledge.

Milner, E. M., Kariger, P., Pickering, A. J., Stewart, C. P., Byrd, K., Lin, A., Rao, G., Achando, B., Dentz, H. N. & Null, C. (2020). Association between malaria infection and early childhood development mediated by anaemia in Rural Kenya. *International Journal of Environmental Research and Public Health*, 17(3): 902.

Mohammed, S. H., Habtewold, T. D. & Esmaillzadeh, A. (2019). Household, maternal, and child related determinants of haemoglobin levels of Ethiopian children: Hierarchical regression analysis. *BMC Pediatrics*, 19(1): 1–10.

Mwaiswelo, R. O., Mmbando, B. P., Chacky, F., Molteni, F., Mohamed, A., Lazaro, S., Mkalla, S. F., Samuel, B. & Ngasala, B. (2021). Malaria infection and anaemia status in under-five children from Southern Tanzania where seasonal malaria chemoprevention is being implemented. *PloS One*, 16(12): e0260785.

Ngesa, O. & Mwambi, H. (2014). Prevalence and risk factors of anaemia among children aged between 6 months and 14 years in Kenya. *PLoS One*, 9(11): e113756.

Omram, A. R. (2001). The epidemiologic transition: A theory of the epidemiology of population change. *Bulletin of the World Health Organization*, 79(2): 161–170.

Parbey, P. A., Tarkang, E., Manu, E., Amu, H., Ayanore, M. A., Aku, F. Y., Ziema, S. A., Bosoka, S. A., Adjuik, M. & Kweku, M. (2019). Risk factors of anaemia among children under-five years in the Hohoe Municipality, Ghana: A case control study. *Anemia*, 2019: e2139717. https://doi.org/10.1155/2019/2139717.

Provan, D. (1999). Mechanisms and management of iron deficiency anaemia. *British Journal of Haematology*, 105, *Suppl.* 1: 19–26.

Rashmi, R. & Paul, R. (2022). Determinants of multimorbidity of infectious diseases among under-five children in Bangladesh: Role of community context. *BMC Pediatrics*, 22(1): 1–13.

Raszkowski, A. & Bartniczak, B. (2019). On the road to sustainability: Implementation of the 2030 Agenda sustainable development goals (SDG) in Poland. *Sustainability*, 11(2): 366.

Simbauranga, R. H., Kamugisha, E., Hokororo, A., Kidenya, B. R. & Makani, J. (2015). Prevalence and factors associated with severe anaemia amongst under-five children hospitalized at Bugando Medical Centre, Tanzania. *BMC Hematology*, 15(1): 1–9.

Takele, K., Zewotir, T. & Ndanguza, D. (2019). Risk factors of morbidity among children under age five in Ethiopia. *BMC Public Health*, 19(1): 942. https://doi.org/ 10.1186/ s12889-019-7273-4.

Tesfa, D., Tiruneh, S. A., Azanaw, M. M., Gebremariam, A. D., Engdaw, M. T., Kefale, B., Abebe, B. & Dessalegn, T. (2021). Time to death and its determinants among under-five children in sub-Saharan Africa using the recent (2010–2018) demographic and health survey data: Country-based shared frailty analyses. *BMC Paediatrics*, 21(1): 515. https://doi.org/10.1186/s12887-021-02950-3.

Ugwu, C. L. J. & Zewotir, T. T. (2018). Using Mixed Effects Logistic Regression Models for complex survey data on malaria rapid diagnostic test results. *Malaria Journal*, 17(1): 453. https://doi.org/10.1186/s12936-018-2604-y.

World Health Organisation (WHO). (2020). *Children: Improving survival and well-being*. https://www.who.int/news-room/fact-sheets/detail/children-reducing-mortality.

WHO. (2021, June 9). *Infant and young child feeding*. https://www.who.int/news-room/fact-sheets/detail/infant-and-young-child-feeding.

WHO. (2022, January 28). *Child mortality (under* 5 *years)*. https://www.who.int/news-room/fact-sheets/detail/levels-and-trends-in-child-under-5-mortality-in-2020.

Zhao, A., Zhang, Y., Peng, Y., Li, J., Yang, T., Liu, Z., Lv, Y. & Wang, P. (2012). Prevalence of anaemia and its risk factors among children 6–36 months old in Burma. *The American Journal of Tropical Medicine and Hygiene*, 87(2): 306–311. https://doi. org/10.4269/ajtmh.2012.11-0660.