1874-9445/23 *Send Orders for Reprints to reprints@benthamscience.net*

The Open Public Health Journal

Content list available at: https://openpublichealthjournal.com

RESEARCH ARTICLE

Modelling Factors Associated with Malnutrition and Anemia in Children under Five Years in Angola, Senegal, and Malawi by using a Joint Model

Chris Khulu[1,*], Shaun Ramroop[1] and Faustin Habyarimana[1]

[1]*School of Mathematics, Statistics and Computer Science, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, South Africa*

Abstract:

Background:

In Sub-Saharan Africa, malnutrition and anemia contribute a higher percentage to infant morbidity. Malnutrition is known as the dearth of proper nutrition in the human body and it is an important risk factor for the burden of diseases. The lack of hemoglobin and red cells in the human body is known as anemia, and it is divided into three groups. This paper aims to identify the determinants of anemia and malnutrition in Angola, Senegal and Malawi. The novelty of this study includes creating a sample that will be jointly modelled to identify determinants of anemia and malnutrition.

Methods:

This paper used 2016 information from Angola, Senegal and Malawi Demographic and Health Survey to conduct a secondary data analysis. To create a pool sample for the analysis, the Angola, Malawi and Senegal Demographic and Health Survey data were combined. The joint model under the generalized linear mixed model was employed to identify the determinants of malnourishment and anemia among children under five years in Angola, Senegal, and Malawi.

Results:

The analysis of the data was performed in SAS 9.4. The results of the covariance components indicated a positive correlation between nutritional status and anemia status. Joint generalized linear mixed model results revealed that children under five years residing with a mother that has attained a primary level of education are 2.995 times more likely to be malnourished when compared to children under five years residing with a mother that have attained a higher level of education. Children under five years residing in the rural setting of Angola, Senegal, and Malawi are 1.473 times more likely to be malnourished when compared to children under five years residing in the urban setting of Angola, Senegal and Malawi.

Conclusion:

Based on the joint generalized linear mixed model results, type of residence, sex of the child, age of the child, mother's level of education, birth interval and wealth index are the correlates of malnourishment and anemia in Angola, Senegal and Malawi. There is a greater need for partnership and collaboration among the studied countries to achieve the SGD target.

Keywords: Anemia, Malnourished, Chi-square test, Gamma measure, Joint model, Covariance.

Article History	Received: June 4, 2022	Revised: October 15, 2022	Accepted: November 8, 2022

1. INTRODUCTION

In Sub-Saharan Africa, malnutrition and anemia contribute a higher percentage to infant morbidity [1]. Malnutrition is known as the dearth of proper nutrition in the human body, and it is an important risk factor for the burden of diseases [2, 3]. World Health Organization (WHO) indicated that there is mild malnutrition, moderate malnutrition, and severe malnutrition.

The lack of hemoglobin and red cells in the human body is known as anemia, and it is divided into three groups [4 - 6]. Anemia is observed as the major public health concern globally for children [7]. The main cause of anemia in infancy, childhood, and pregnancy is iron deficiency [8].

In the current literature, a study conducted by Humbwavali *et al*. (2019) [9] in the sub-urban area of Angola showed that diarrhoea, death of an infant and primary caregiver not being a mother increase the chances of infant exposure to malnutrition. The study further revealed that joint exposures are likely to cause malnutrition in Angola.

* Address correspondence to this author at the School of Mathematics, Statistics and Computer Science, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, South Africa;
E-mail: chriskhulu@gmail.com

DOI: 10.2174/18749445-v15-e221220-2022-82, 2023, *16*, e187494452212164

Magalhaes *et al*. (2013) [10] in Northern Angola suggested that by employing the individual-level approach to map anemia at a small spatial scale that anemia is highly heterogeneous. The study further pronounced malnutrition as a significant contributor to the spatial variation in anemia risk. In addition, a study looking at iron deficiency anemia among 6-36 months infants from Northern Angola revealed that the age and gender of the infant are associated with iron deficiency anemia. Stunting was suggested to increase the odds of iron deficiency among 24-36 months [11].

A cross-sectional study by Sousa-Figueiredo *et al*. (2012) [12] of 1,237 school children in Angola was conducted to understand the distribution of malnutrition, and the results showed that malnutrition, malaria and anemia are related. A study in Southern Angola by Oliveira *et al*. (2015) [13] revealed that stunting is more frequent in older children, while anemia is more frequent in younger children.

There has been an improvement in child undernutrition in Senegal over the past decades. This is mainly the result of greater effort extended to political, and capacity-building sectors [14]. Nevertheless, child malnutrition remains a concern for children under five years in Senegal [15].

A cross-sectional study by Fiorentino *et al*. (2013) [16] in the Dakar area of Senegal showed that the prevalence of marginal Vitamin A, Zinc deficiency, and high transferring receptors was high in boys than girls, whereas height-for-age and retinol were significantly lower. In addition, the study also concluded that the lack of Zinc, iron and nutrients require targeted nutrition interventions.

In addition, a study by Alderman *et al*. (2008) [17] that employed a comparison of cohorts to assess the impact on the proportion of underweight in Senegal showed that the odds ratio of being underweight for children that received services provided by Senegal Enhancement project was 0.83 after controlling regional, village and households characteristics. The study concluded that health care and health-seeking behaviour aspects were improved in the treatment group relative to the control group.

The results of the study by Fiorentino *et al*. (2016) [18] showed that insufficient consumption of energy from protein, Zinc and Vitamin C are the contributors to Zinc deficiency. It was concluded in the study that to address nutritional deficiencies, the intervention of a feeding program is needed in urban primary schools in Senegal.

In Malawi, a case-control study by Calis *et al*. (2008) [19] of 381 pre-school children with severe anemia and 757 pre-school children without severe anemia in urban and rural settings in Malawi showed that there are multiple causes of severe anemia in Malawian pre-school children. The study also revealed the association between severe anemia and malaria.

A review study by Kalu and Etim (2018) [20] revealed that major factors related to malnutrition in Malawi include maternal factors and household socioeconomic standing. It was concluded in the study that the government of emergent nations and the global community should work together to remove these factors.

The study conducted on Pakistani children to understand the socioeconomic effect of malnutrition revealed that households with lower socioeconomic status had a higher prevalence of malnutrition [21]. In order to address the findings, it was proposed in the study that the government needs to enhance economic opportunities.

Household economic status and maternal factors were found to be the important contributors to children's nutritional status in the study conducted by Siddiqi *et al*. (2011) [22]. It was further revealed in the study that to improve the nutritional status of the child, the interventions must not only focus on the child but also newly mothers.

Furthermore, a study by Mamulwar *et al*. (2014) [23] revealed that improving the mother level of education improves the anthropometric parameters of the children. This indicates that the mother level of education remains the significant factor influencing children's nutritional standing.

Based on current report and literature, there is a greater intrusion required to address anemia and malnutrition to control the mortality rate of children under five years. Angola, Senegal, and Malawi are expected to reduce their current children under five years' mortality rate by at least fifty percent to meet the 2030 Sustainable Development Goal (SDG) target [6]. In 2016, the Angola, Senegal and Malawi mortality rate of children under five years was estimated to be 82.5 deaths per live births, 47.1 deaths per 1000 live births and 55.1 deaths per 1000 live births, respectively. The 2030 SDG target was set to be 25 deaths per 1000 live births.

The possibilities of association between anemia and malnutrition disease cannot be addressed by employing the separated model. The joint modelling is necessary to simultaneously model anemia and malnutrition to account for any overlaps between the two diseases. This type of modelling is superior because of its expansion in the capabilities of parameter estimation.

This paper aims to identify the determinants of anemia and malnutrition in Angola, Senegal and Malawi. These countries were selected based on their high children mortality rate, which indicates a greater need for immediate interventions. The above will result in the proposal of significant interventions that will support Angola, Senegal, and Malawi in achieving the SDG mortality rate plan. The significance of this paper underpins joint modelling of malnutrition and anemia and proposes strategies to minimize the mortality rate in Angola, Senegal, and Malawi.

The novelty of this study includes creating a sample that will be jointly modelled to identify determinants of anemia and malnutrition. There are fewer current kinds of literature that focus on modelling information from different countries jointly to address anemia and malnutrition, hence this study also aims to close that gap. Furthermore, malnutrition is influenced by many factors and fewer literatures that are focusing on the socioeconomic effect of malnutrition.

2. METHODS

2.1. Data Source

This paper used 2016 information from Angola, Senegal and Malawi Demographic and Health Survey to conduct secondary data analysis. This is cross-sectional data.

The Demographic and Health Survey of Angola was gathered in the period of October 2015 to March 2016 to understand household indicators, such as socioeconomic, health, *etc*. A sample of 16,109 households which had 14,379 women aged 15-49- and 5,684 men aged 15-54 was visited. The response rate for women and men was 96% and 94%, respectively. The Demographic and Health Survey of Malawi, which had a sample of 27,516 households, was collected in 2015 and 2016, where 26,564 households managed to provide the data. The system used to determine the sample population was stratification completed in two stages. In 2016 Demographic and Health Survey of Senegal, a sample of 4,437 households which had 8,865 women aged 15-49- and 3,527 men aged 15-59 households was able to provide the data.

To create a pool sample for the analysis, the Angola, Malawi and Senegal Demographic and Health Survey data were combined [2, 6, 24 - 26]. Table **1** in this paper shows the summary table of the pooled sample. A total of 7916 weighted samples were used in this study. The weighted sample was used to obtain insights that demonstrated the national level information and to account for complex sample design.

Table 1. Summary of a pooled sample by country.

	Children Age	Children Gender	Malnourished Children	Anemic Children
Angola	0-59	Male and Female	4676	1359
Senegal	0-59	Male and Female	2119	977
Malawi	0-59	Male and Female	4613	1373

2.2. Variable

2.2.1. Measurement of the Outcome Variable

The response variable (malnourished and anemia status) was obtained by using the weight-for-age (WAZ) and anemia level from the DHS data.

In general, a child is observed to be mild malnutrition when the WAZ is greater than -2.0, severely malnutrition when the WAZ is less than -3 and moderate malnutrition when the WAZ is between -3.0 and -2.0. These three groups are severe anemia which relates to hemoglobin concentration that is less than 7.0 g/dl; moderate anemia relates to hemoglobin concentration in the interval 7.0-9.9 g/dl and mild anemia which is associated with hemoglobin concentration in the interval 10.0-10.9 g/dl.

For the purpose of this study, a child is categorised as malnourished when the WAZ is less than -3.0 and nourished when the WAZ is greater than -3.0. In contrast, a child is categorized as anemic when the hemoglobin level of the child is less than 9.9 g per dL and a child is classified as not anemic when the hemoglobin of the child is greater than 9.9 g per dL.

2.2.2. Measurement of Explanatory Variables

Socio-economic, environmental and health basics of living are known to be the underlying factors of malnutrition and anemia status. In this study, we used the framework that is explained [27, 28] to select the independent variables. This is the conceptual framework for the analysis of anemia and malnutrition risks. Type of residence (Rural or Urban) is the community-level variable in this study. Whereas, household size (0-5, 6-10, 11-15 or > 15), mother's level of education (Primary, Secondary or Higher), birth interval (<24, 24-47 or > 47), wealth index (Poor, Middle or Rich), sex of household head (Male or Female) and marital status (unmarried, divorced, married) are the Household-level variables. Household economic status in this study was measured by using the assets owned, ownership of living stock and infrastructure. Briefly, the Principal Component Analysis (PCA) was conducted in SPSS to create an asset index which was then used to define the household wealth status. The paper by C. Khulu & S. Ramroop [6] explained the full statistical method. Individual level variables are childbirth order (2-3, 4-5 or > 5), child's age in months (< 12, 12-23, 24-35, 36-47 or 48-59) and sex of child (Male or Female).

2.2.3. Ethical Approval

This study was conducted under the ethical standards of the Helsinki declaration. The ethical clearance is approved by the University of Gondar Institutional Review Board (IRB). Country specific DHS protocols were reviewed and approved by the Health Science Research Committee and the ICF IRB ensured that the survey complies with the U.S Department of Health and Human Services regulation for the protection of human subjects. A written request was submitted to the DHS programme and permission was granted for the use of the data.

2.3. Statistical Analyses

2.3.1. Test of Association

The gamma measure and chi-square test were used to evaluate the relationship between the independent variable and the dependent variable. When the independent variable was ordinal, the gamma measure was utilised. Whereas, when the independent variable was nominal, the chi-square was used to test the association [29].

The definitions of the above test of association methods and the results are detailed in the previously published studies by the authors [2, 6]

2.3.2. Model Overview

Let Y_{ij} be a binary random variable and take the values of 1 or 0 that denote the i^{th} outcome (i = 1, 2) of the j^{th} (j = 1, 2, . . ., 16708) subject, with i = 1 for nutritional status and i = 2 for anemia status.

The two binary outcomes formulate a bivariate binary response vector $Y = (Y^{1j}/Y^{2j})$. If the two outcomes (nutritional status and anemia status) are independent, then the generalized linear mixed model is given below

$$g_1(\mu_{1j}) = B_1X_{1j} + Z_{1j}\gamma_{1j} + \varepsilon_{1j}$$
$$g_2(\mu_{2j}) = B_2X_{2j} + Z_{2j}\gamma_{2j} + \varepsilon_{2j} \quad (1)$$

Where ε_{1j}~N (0, σ^2_1), ε_{2j}~N (0, σ^2_2), γ_{1j}~N (0, G_1), γ_{2j}~N (0, G_2), B_1 and B_2 are the vectors of fixed effects, γ_1 and γ_2 are the vectors of the random effects, X_{1j}, X_{2j}, Z_{1j} and Z_{2j} are the designs matrices for the fixed effects and random effects respectively.

To consider the relationship between nutritional status and anemia status, one could use the following bivariate linear mixed model.

$$Y_j = BX_j + Z_j\gamma_j + \varepsilon_j \quad (2)$$

With ε_i ~ N (0, Σ_i), γ_i ~ N (0, G_i) where $X_j = \begin{pmatrix} X_{1j} & 0 \\ 0 & X_{2j} \end{pmatrix}$, $Z_j = \begin{pmatrix} Z_{1j} & 0 \\ 0 & Z_{2j} \end{pmatrix}$, $B = \begin{pmatrix} b_1 \\ b_2 \end{pmatrix}$ and $\gamma = \begin{pmatrix} \gamma_1 \\ \gamma_2 \end{pmatrix}$.

The covariance matrix of measurement errors is defined by $\Sigma = \begin{pmatrix} \sigma^2{}_1 & 0 \\ 0 & \sigma^2 \end{pmatrix}$.

The covariance matrix of the random effects is the matrix $G = \begin{pmatrix} G_1 & G_{12} \\ G_{21} & G_2 \end{pmatrix}$.

In this study, matrix G was used as the covariance matrices of the joint model where G_1 and G_2 are the variance components of nutritional status and anemia status, respectively. G_{12} and G_{21} are the correlation components between nutritional status and anemia status.

Through conditional independence assumption, one can obtain the likelihood function of the joint responses [30]. In this study, a maximum likelihood approach was employed to obtain estimates of the parameters. As the integrals do not have a closed form, we used an approximation based on Gaussian quadrature, as found to be consistent and asymptotically normally distributed.

The multivariate joint model has an advantage over separate models. This advantage includes better control of type I error rates in multiple tests, the gain in the parameter estimates efficiency, and the ability to answer intrinsically multivariate questions [31].

There are different model selection methods (AIC, BIC and likelihood ratio test) that can be applied to GLMM (this is known as a goodness of fit test). The AIC and BIC are the common techniques employed when selecting the best model for the data. This test is conducted when comparing two or more models [32]. In this study, the authors are not aiming at comparing two or more models; hence model selection was based on the data structure and literatures [25, 31, 33, 34].

Furthermore, the validation of the fitted model can be completed by checking that linear systematic components of the model are correctly specified, the correct link function is used and whether the data contain outliers. Based on the literature, the joint model through the generalized linear model is confirmed as a best-fit model as it considers the correlation between the response variable [25, 31, 33, 34].

Equation 3 is the joint generalized linear mixed model of the nutritional status and anemia status of each under five-year children:

$$\begin{pmatrix} Nutrition \\ Anemia \end{pmatrix} = \begin{pmatrix} b_{10} + b_{11}residence + b_{12}age + \cdots + b_{16}wealth \\ b_{20} + b_{21}residence + b_{22}age + \cdots + b_{26}wealth \end{pmatrix} + \begin{pmatrix} \gamma_1 country \\ \gamma_2 country \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \quad (3)$$

3. RESULTS

The analysis of the data was performed using SAS 9.4 PROC GLIMMIX procedure. Concerning the diagnostics of the fitted model, the authors examined the normality of the random effect using the Shapiro-Wilks test at a 5% level of significance. The Shapiro- Wilks test yields a *P-Value* of 0.591, and this indicated a non-significant deviation from normality. The cross-tabulation results of the data, which explains the demographics of the pooled sample, can be found on the previously published paper of the authors [2, 6]. These two papers evaluated the risk factors of malnutrition and anemia separately. Furthermore, the objectives, tactics and statistical methods that were employed are not similar to those of this study. Likewise, the explanatory variables are different.

In this study, the authors considered different covariance structures (autoregressive AR (1), variance component (VC), compound symmetry (CS), heterogeneous compound symmetry (CSH) and unstructured (UN)), but only unstructured covariance variance was found to be suitable for the analysis based on convergence criteria. The analysis to check for possible interaction effects was also conducted, but none was found to be significant.

To confirm the need for the random intercept in the model, the COVTEST statement in SAS was used. The results of this test are shown in Table **2**. The results indicated that the covariance parameter was highly significant, and thereof confirmed the necessity of including the random country effect in the model. Table **3** findings revealed that there is a significant positive correlation between nutritional status and anemia status (est. = 0.471, *P-Value* = 0.024). A positive correlation indicates that nutrition and anemia change in the same direction.

Table 2. Test covariance parameters.

Label	DF	-2 Log likelihood	Y^2	*P-Value*
No G-side effects	1	7768	33.86	<0.0001

Table 3. Variance components.

Label	Estimate	SE	*P-Value*
Nutrition status	0.546	0.135	0.000
Anemia status	1.832	0.249	0.045
Correlation	0.471	0.115	0.024

Table 4. Parameter estimates and odds ratios.

	Malnutrition			Anemic		
Covariates	Estimates	OR	*P-Value*	Estimate	OR	*P-Value*
Intercept	3.500	-	0.000	2.378	-	0.000
Resident	-	-	-	-	-	-
Ref:Urban	-	-	-	-	-	-
Rural	0.387	1.473	0.000	0.561	1.752	0.000
Child's age	-	-	-	-	-	-
Ref:< 12	-	-	-	-	-	-
12-23	0.012	1.012	0.945	0.994	2.702	0.000
24-35	0.017	1.017	0.914	0.884	2.421	0.000
36-47	-0.045	0.956	0.766	0.948	2.581	0.000
48-59	-0.068	0.934	0.654	0.781	2.184	0.000
Sex of child	-	-	-	-	-	-
Ref:Male	-	-	-	-	-	-
Female	0.093	1.097	0.193	0.266	1.304	0.000
Mother level of education	-	-	-	-	-	-
Ref:Higher	-	-	-	-	-	-
Primary	1.097	2.995	0.047	1.888	6.606	0.000
Secondary	0.217	1.242	0.032	0.442	1.556	0.002
Birth interval	-	-	-	-	-	-
Ref: >47 months	-	-	-	-	-	-
<24	-0.403	0.668	0.001	0.208	1.231	0.278
24-47	-0.330	0.719	0.000	0.398	1.489	0.001
Wealth index	-	-	-	-	-	-
Ref:Rich	-	-	-	-	-	-
Poor	0.880	2.411	0.000	0.258	1.294	0.084
Middle	0.204	1.226	0.000	-0.089	0.915	0.533

Table **4** displays the parameter estimates and the odds ratios of nutrition and anemia. Factors such as birth interval, mother's level of education, wealth index and type of residence are found to be statistically significant in influencing nutritional status in this study.

Children under five years residing in the rural setting of Angola, Senegal, and Malawi are 1.473 times more likely to be malnourished when compared to children under five years residing in the urban setting of Angola, Senegal and Malawi.

It can be observed from the results that as the age of the child increases, the odds of being malnourished reduce. This finding indicates that children under five years from Angola, Senegal, and Malawi need to be protected from malnourished exposure at an early stage of their lives. This result further shows that when children transition from breastfeeding to solid food, there are opportunities for developing parents how to ensure that transition is smooth and has no effect on children.

Child’s gender was found to be significantly associated with the nutrition status of the child. A female under five years in Angola, Senegal, and Malawi is more likely to be malnourished (1.097 times) when compared to a male under five year’s children.

In addition, the results showed that improving the mother's level of education reduces the chance of children under five years who are malnourished. Children under five years residing with a mother that has attained a primary level of education are 2.995 times more likely to be malnourished when compared to children under five years residing with a mother that have attained a tertiary level of education.

Household wealth status was found to significantly affect the nutrition status of the under five-year children. The odds of being malnourished reduce as household wealth improves. Children under five years in Angola, Senegal, and Malawi residing in a poor household are 2.411 times more likely to be malnourished when compared to children under five years residing in a rich household.

In the same table, factors such as child's age, child's gender, type of residence and mother's level of education are statistically significant in influencing anemia status.

Children under five years residing in the rural setting of Angola, Senegal, and Malawi are 1.572 times more likely to be anemic when compared to children under five years residing in the urban setting of Angola, Senegal and Malawi.

In addition, the child's gender was found to be significantly defining anemia status. A female child from Angola, Senegal and Malawi was found to be 1.304 times more likely to be anemic when compared to a male child counterpart.

Whereas, children under five years residing with a mother who has attained a primary level of education are 6.606 times more likely to be affected by anemia when compared to children under five years residing with a mother who has attained a tertiary level of education.

In contrast, children under five years in Angola, Senegal, and Malawi residing in a poor household are 1.294 times more likely to be anemic when compared to children under five years residing in a rich household.

4. DISCUSSION

In this study, a joint model under a generalized linear mixed model was employed to obtain the determinants of malnourished and anemia among children under five years in Angola,

Senegal and Malawi. The 2016 Demographic Health Survey (DHS) data from Angola, Senegal, and Malawi were combined to create a pooled sample. This method was used in other literature [2, 6, 25 - 27].

The results of the joint generalized linear mixed model were obtained from SAS 9.4 software. The results of the covariance components revealed that there is a significant positive correlation between nutritional status and anemia status.

The results further revealed that type of residence, mother's level of education, birth interval and wealth index are statistically signify cant in influencing nutritional status. Whereas type of residence, the child's age, the child's gender and the mother's level of education are statistically significant in influencing anemia status.

A child from a rural setting is found to be more likely to be malnourished and anemic when compared to a child from an urban setting. This result agrees with the findings of the study [2, 6]. This finding indicates that there is a gap in the health resources available to rural and urban areas. The department of health and the policymakers of healthcare in Angola, Senegal and Malawi need to enforce mobile health services in rural areas. The fore mentioned is one of many interventions to close the gap.

In contrast, a child residing with a mother that has attained a primary level of education is found to be more likely to be malnourished and anemic when compared to a child residing with a mother that has a higher level of education. Similar results were found in the study [24, 36, 37].

The education system and structure policymakers in Angola, Senegal, and Malawi need to propose strategic interventions on the education system. Among many interventions is the introduction of an educational program that will cover all age groups since most of the households in Angola, Senegal and Malawi are occupied by the older generation that did not have an opportunity to attain schooling [38]. These strategic interventions need to reach the rural setting of Angola, Senegal, and Malawi. In the study conducted in China, it was confirmed that health education focusing on feeding practices is very necessary for ensuring good management of nutrition intake [39].

Another factor that is found to be significantly associated with malnourishment and anemia is household wealth status. Many studies conducted in developing countries have found this factor to be a common factor among many factors that highly contribute to the under-five children mortality rate [30, 37, 40]. A child from a poor household in Angola, Senegal, and Malawi is more likely to be malnourished and anemic when compared with a child from a rich household.

Studies conducted in developing countries further revealed that improving household wealth status and the mother's level of education reduces the child's risk of being exposed to malnourished and anemia [24, 35, 36, 41, 42]. This, in general, indicates that the government and policymakers of developing countries need to put more effort and resources to improve all the programs that are targeting poor and not educated communes.

CONCLUSION

This study aimed to jointly identify key determinants of nutritional status and anemia status. The results of the joint generalized linear mixed model were obtained from SAS 9.4 Software. The results of variance components revealed a positive correlation between nutrition status and anemia status.

The results further revealed that the type of residence, sex of the child, age of the child, mother's level of education, birth interval and wealth index are the correlates of malnourishment and anemia in Angola, Senegal and Malawi. These variables are also identified in other studies conducted in Africa or developing countries [24 - 31, 37, 40 - 43].

It can be concluded from this study that female children between the age of 24-59 months from rural communities with the mother having attained primary or secondary education and residing in poor or middle households are associated with malnourished and anemia problems.

Therefore, for Angola, Senegal, and Malawi to achieve the SGD target, the government and policymakers of these countries need to improve strategic programs that will address the issues inducing childhood mortality. Such programs include parental education, financial education, children's dietary focus program and mobile health facilities.

There is a greater need for partnership and collaboration among the studied countries to achieve the SGD target. The African continent has limited resources; hence the idea of collaboration will accelerate the implementation of the recommended interventions.

Limitations of this study include modelling common factors across Angola, Senegal, and Malawi DHS data. These excluded factors have been found by other literature to be associated with malnourishment and anemic. These variables include dietary variables, episodes of diarrhoea, *etc*.

Future studies should focus on incorporating additional common variables and DHS data from other African countries. This would add to the knowledge of factors contributing to childhood mortality and broaden the landscape of countries that can collaborate. It is, therefore, suggested that a similar study should be carried out in more than three countries.

LIST OF ABBREVIATIONS

WHO	=	World Health Organization
WAZ	=	Weight-for-age

VC	=	Variance Component
CS	=	Compound Symmetry

AUTHORS' CONTRIBUTIONS

Mr C Khulu: Wrote the draft of the paper and analysed the data.

Dr F Habyarimana: Reviewed the analysis and provided more insight.

Prof S Ramroop: Verified the sound, methodology and analysis of the paper.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The ethical clearance is approved by the University of Gondar Institutional Review Board (IRB). Country specific DHS protocols were reviewed and approved by the Health Science Research Committee and the ICF IRB.

HUMAN AND ANIMAL RIGHTS

No animals were used for studies that are the basis of this research. All the humans were used in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013 (http://ethics.iit.edu/ecodes/node/3931).

CONSENT FOR PUBLICATION

The written informed consent form was taken from the participants.

STANDARDS OF REPORTING

STROBE guidelines were followed.

FUNDING

None.

AVAILABILITY OF DATA AND MATERIALS

The dataset analysed during this study is not publicly available, but data is available from the corresponding author on reasonable request [C.K]. Additionally, further information about the data and conditions for access is available upon registration and request to DHS program-http://dhsprogram.com.

CONFLICT OF INTEREST

The authors declare they have no competing interests.

ACKNOWLEDGEMENTS

The author would like to thank all the relevant parts that contributed to the collection of the data from Angola, Malawi, and Senegal.

REFERENCES

[1] Ehrhardt S, Burchard GD, Mantel C, *et al.* Malaria, anemia, and malnutrition in African children de ning intervention priorities. Paediatr Int Child Health 2020; 33: 108-14.

[2] Khulu C, Ramroop S. Determinants of malnutrition in under five children in Angola, Malawi and Senegal. Open Public Health J 2020; 13(1): 55-61. [http://dx.doi.org/10.2174/1874944502013010055]

[3] Thorne C J, Roberts L M. Anaemia and malnutrition in children aged 059 months on the Bijags Archipelago, Guinea-Bissau, West Africa: A cross-sectional, population-based study. JID 2013; 2-20.

[4] Appiah CA, Mensah FO, Hayford FEA, Awuuh VA, Kpewou DE. Predictors of undernutrition and anemia among children aged 624 months in a low-resourced setting of Ghana: A baseline survey. J Health Res 2020; 2020: 1-11.

[5] Warrier RP, Dole MG, Warder J, Suskind RM. The Anemia of Malnutrition. Mal-nourished Child 1990; 19: 61-72.

[6] Khulu C, Ramroop S. Key determinants of anemia among youngsters under five years in Senegal, Malawi, and Angola. Int J Environ Res Public Health 2020; 17(22): 8538. [http://dx.doi.org/10.3390/ijerph17228538] [PMID: 33217900]

[7] Enawgaw B, Workineh Y, Tadesse S, Mekuria E, Addisu A, Genetu M. Prevalence of anemia and associated factors among hospitalized children attending the University of Gondar Hospital, Northwest Ethiopia. EJIFCC 2019; 30(1): 35-47. [PMID: 30881273]

[8] Olivares M, Walter T, Hertrampf E, Pizarro F. Anaemia and iron deficiency disease in children. Br Med Bull 1999; 55(3): 534-43. [http://dx.doi.org/10.1258/0007142991902600] [PMID: 10746344]

[9] Humbwavali JB, Giugliani C, Nunes LN, Dalcastagnê SV, Duncan BB. Malnutrition and its associated factors: a cross-sectional study with children under 2 years in a suburban area in Angola. BMC Public Health 2019; 19(1): 220. [http://dx.doi.org/10.1186/s12889-019-6543-5] [PMID: 30791903]

[10] Role of malnutrition and parasite infections in the spatial variation in childrens anaemia risk in northern Angola. Geospatial Health 2013; 7: 341-54.

[11] Fançony C, Soares Â, Lavinha J, Barros H, Brito M. Iron deficiency anaemia among 6-to-36-month children from northern Angola. BMC Pediatr 2020; 20(1): 298. [http://dx.doi.org/10.1186/s12887-020-02185-8] [PMID: 32552666]

[12] Sousa-Figueiredo JC, Gamboa D, Pedro JM, *et al.* Epidemiology of malaria, schistosomiasis, geohelminths, anemia and malnutrition in the context of a demographic surveillance system in northern Angola. PLoS One 2012; 7(4): e33189-9. [http://dx.doi.org/10.1371/journal.pone.0033189] [PMID: 22493664]

[13] Oliveira D, Ferreira FS, Atouguia J, Fortes F, Guerra A, Centeno-Lima S. Infection by intestinal parasites, stunting and anemia in school-aged children from Southern Angola. PLoS One 2015; 10(9): e0137327. [http://dx.doi.org/10.1371/journal.pone.0137327] [PMID: 26371758]

[14] Brar S, Akseer N, Sall M, *et al.* Drivers of stunting reduction in Senegal: A country case study. Am J Clin Nutr 2020; 112(Suppl. 2): 860S-74S. [http://dx.doi.org/10.1093/ajcn/nqaa151] [PMID: 32778881]

[15] Ruel-Bergeron J. The Case for Investment in Nutrition in Senegal. Analysis and Perspective: 15 Years of Experience in the Development of Nutrition Policy in Senegal. World Bank, Washington, DC; CLM, Dakar, Senegal. License: Creative Commons Attribution CC BY 3.0 IGO. 2020.

[16] Fiorentino M, Bastard G, Sembène M, *et al.* Anthropometric and micronutrient status of school-children in an urban West Africa setting: A cross-sectional study in Dakar (Senegal). PLoS One 2013; 8(12): e84328-8. [http://dx.doi.org/10.1371/journal.pone.0084328] [PMID: 24391938]

[17] Alderman H, Ndiaye B, Linnemayr S, *et al.* Effectiveness of a community-based intervention to improve nutrition in young children in Senegal: A difference in difference analysis. Public Health Nutr 2009; 12(5): 667-73. [http://dx.doi.org/10.1017/S1368980008002619] [PMID: 18559130]

[18] Fiorentino M, Landais E, Bastard G, Carriquiry A, Wieringa F, Berger J. Nutrient intake is insufficient among senegalese urban school children and adolescents: Results from two 24 h recalls in state primary schools in Dakar. Nutrients 2016; 8(10): 650. [http://dx.doi.org/10.3390/nu8100650] [PMID: 27775598]

[19] Calis JHJ, Phiri KS, Faragher EB, *et al.* Severe Anemia in Malawian Children. Engl J Med 2008; 358: 888-99.

[20] Kalu RE, Etim KD. Factors associated with malnutrition among under five children in developing countries: A review. Glob J Pure Appl Math 2018; 24: 69-74.

[21] Ahmad D, Afzal M, Imtiaz A. Effect of socioeconomic factors on malnutrition among children in Pakistan. Future Business Journal

2020; 6(1): 30.
[http://dx.doi.org/10.1186/s43093-020-00032-x]

[22] Siddiqi MNA, Haque MN, Goni MA. Malnutrition of under-five children: Evidence from Bangladesh. Asian J Med Sci 2011; 2(2): 113-9.
[http://dx.doi.org/10.3126/ajms.v2i2.3662]

[23] Mamulwar M, Rathod HK, Jethani S, *et al.* Nutritional status of under-five children in urban slums of Pune. Int J Med Public Health 2014; 4(3): 247-52.
[http://dx.doi.org/10.4103/2230-8598.137710]

[24] Takele K, Zewotir T, Ndanguza D. Understanding correlates of child stunting in Ethiopia using generalized linear mixed models. BMC Public Health 2019; 19(1): 626.
[http://dx.doi.org/10.1186/s12889-019-6984-x] [PMID: 31118013]

[25] Subramanian SV, Perkins JM, Özaltin E, Davey Smith G. Weight of nations: a socioeconomic analysis of women in low- to middle-income countries. Am J Clin Nutr 2011; 93(2): 413-21.
[http://dx.doi.org/10.3945/ajcn.110.004820] [PMID: 21068343]

[26] Neuman M, Kawachi I, Gortmaker S, Subramanian SV. Urban-rural differences in BMI in low- and middle-income countries: the role of socioeconomic status. Am J Clin Nutr 2013; 97(2): 428-36.
[http://dx.doi.org/10.3945/ajcn.112.045997] [PMID: 23283503]

[27] Kawo KN, Asfaw ZG, Yohannes N. Multilevel analysis of determinants of anemia preva-lence among children aged 659 months in Ethiopia: Classical and bayesian approaches. Hindawi 2018; 2018: 1-13.

[28] Habyarimana F, Zewotir T, Ramroop S. A proportional odds model with complex sampling design to identify key determinants of malnutrition of children under ve years in Rwanda. MCSER 2014; 5: 1642-8.

[29] Talukder A. Factors associated with malnutrition among under ve children: Illustration using Bangladesh Demographic and Health Survey, 2014 data. MDPI 2017; 4: 1-8.

[30] Fang D, Sun R, Wilson JR. Joint modeling of correlated binary outcomes: The case of contraceptive use and HIV knowledge in Bangladesh. PLoS One 2018; 13(1): e0190917.
[http://dx.doi.org/10.1371/journal.pone.0190917] [PMID: 29351328]

[31] Habyarimana F, Ramroop S, Zewotir T. Joint modelling of poverty of households and malnutrition of children under five years from Demographic and Health Survey data. Case of Rwanda 2016; 8: 108-14.

[32] Moeti A. Factors A_ecting the Health Status of the People of Lesotho, Master of Science in Applied Statistics. Pietermaritzburg: School of Statistics and Actuarial Science, University of KwaZulu-Natal 2007.

[33] Gebregziabher M, Zhao Y, Dismuke CE, Axon N, Hunt KJ, Egede LE. Joint modeling of multiple longitudinal cost outcomes using multivariate generalized linear mixed models. Health Serv Outcomes Res Methodol 2013; 13(1): 39-57.
[http://dx.doi.org/10.1007/s10742-012-0103-0] [PMID: 30555270]

[34] Zhong Y, Hu B, Hall G B, Hoque F, Xu W, Gao X. A generalized linear mixed model approach to assess Emerald Ash Borer Diffusion. Int J Geogr Inf Syst 2020; 9: 1-17.
[http://dx.doi.org/10.3390/ijgi9070414]

[35] Kuziga F, Adoke Y, Wanyenze RK. Prevalence and factors associated with anaemia among children aged 6 to 59 months in Namutumba district, Uganda: A cross sectional study. BMC Pediatr 2017; 17(1): 25.
[http://dx.doi.org/10.1186/s12887-017-0782-3] [PMID: 28100200]

[36] Sop SMK, Mananga MJ, Tetanye E, Gouado I. Risk factors of anemia among young children in rural Cameron. Int J Curr Microbiol Appl Sci 2015; 4: 925-35.

[37] World Health Organization and World Bank Group. World Health Statistics. Washington, DC 2015.

[38] Poda GG, Hsu CY, Chao JCJ. Factors associated with malnutrition among children <5 years old in Burkina Faso: evidence from the Demographic and Health Surveys IV 2010. Int J Qual Health Care 2017; 29(7): 901-8.
[http://dx.doi.org/10.1093/intqhc/mzx129] [PMID: 29045661]

[39] Yang W, Li X, Li Y, *et al.* Anemia, malnutrition and their correlations with socio-demographic characteristics and feeding practices among infants aged 0–18 months in rural areas of Shaanxi province in northwestern China: A cross-sectional study. BMC Public Health 2012; 12(1): 1127.
[http://dx.doi.org/10.1186/1471-2458-12-1127] [PMID: 23273099]

[40] Abuka T, Jembere D, Tsegaw D. Determinants for acute malnutrition among under-five children at public health facilities in Gedeo Zone, Ethiopia: A case-control study. Pediatr Ther 2017; 7(2): 317-28.
[http://dx.doi.org/10.4172/2161-0665.1000317]

[41] Gebreegziabiher G, Etana B, Niggusie D. Determinants of anemia among children aged 6-59 months living in Kilte Awulaelo Woreda, Northern Ethiopia. Anemia 2014; 2014: 1-9.
[http://dx.doi.org/10.1155/2014/245870] [PMID: 25302116]

[42] Kejo D, Petrucka P, Martin H, Kimanya M, Mosha T. Prevalence and predictors of anemia among children under 5 years of age in Arusha District, Tanzania. Pediatric Health Med Ther 2018; 9: 9-15.
[http://dx.doi.org/10.2147/PHMT.S148515] [PMID: 29443328]

[43] Teji Roba K, O'Connor TP, Belachew T, O'Brien NM. Anemia and undernutrition among children aged 6–23 months in two agroecological zones of rural Ethiopia. Pediatric Health Med Ther 2016; 7: 131-40.
[http://dx.doi.org/10.2147/PHMT.S109574] [PMID: 29388596]