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Analysis of Malaria-Induced Anemia and Gender Differences among Children in Nigeria

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Walden University
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Abstract

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MS, Cabrini College, 2011

BS, University of Ibadan, 1995

Dissertation Submitted in Partial Fulfillment

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Public Health

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Abstract

Malaria is one of the leading causes of death among children under 5 years old in sub-Saharan Africa (SSA). Also, public health efforts on malaria prevention have been successful in many regions but remains an issue in SSA. Malaria-induced anemia (MA) is associated with health complications among children. The impact of several sociodemographic factors (age, gender, residential type, and parent's educational level) and malaria preventive/intervention measures such as mosquito net use and malaria medication use among children under 5 years old in Nigeria were assessed to inform malaria best practices and strategies, prioritize resource allocation, and support existing literature on malaria interventions. In this quantitative cross-sectional study guided by social-ecological model, 7,745 respondents who participated in the DHS 2015 survey were examined. Multinomial logistic regression was used to conduct inferential analysis to address the research questions. Children with malaria significantly (***p <0.001) had MA. The association between malaria medication use and MA was unstable due to small sample size. Gender was not significantly (p = 0.747) linked with MA. Children 0-36 months significantly (p = 0.04) had MA than those 37-59 months old. Parent's secondary education significantly (p = 0.03) predicted MA. Based on these findings, improving malaria intervention adherence such as use of mosquito net, age specific intervention measures and awareness via education should be included in the National Malaria Control Program (NMCP) vector control best practices. NMCP and their stakeholders should provide access to mosquito net use and malaria medication. More research is needed to fully understand the complexity of anemia in children less than 5 years old.

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Dedication

This dissertation is dedicated to an ex-governor of Lagos State, Nigeria, Late Alhaji Lateef Kayode Jakande, who extended free education to millions of Lagosian from which I benefited. To my children, Yiyinfoluwa, Atinuke, and Babatunde Bamgbose who understood that daddy had to study. And to ultimately Almighty God for His Grace through Jesus Christ.

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Chapter 1: Introduction to the Study

Introduction

Malaria is a preventable and curable disease. However, the burden and incidence of malaria is staggering. In 2015, 214 million new cases of malaria and 438,000 malaria deaths were reported worldwide (World Health Organization [WHO], 2015). By 2017, a total of 231 million malaria cases and 416,000 deaths were reported globally (WHO, 2019a). There was a slight decrease in 2018 with 228 million malaria cases reported globally (WHO, 2020). Of the 228 million cases, 405,000 fatality cases were reported (WHO, 2020). Children under the age of 5 were the mostly affected, accounting for 272,000 (67%) malaria deaths worldwide in the year 2018 alone (WHO, 2020). Sub-Saharan Africa is disproportionately affected with approximately 93% of the global malaria cases and 94% of malaria-related deaths (WHO, 2020).

Between 2000 and 2015, there was a decrease of malaria incidence by 42% globally and 37% in Africa, while death cases decreased by 66% and 60% respectively, due to the improvement of vector and insecticide control measures, such as insecticide-treated mosquito nets (ITNs) and indoor residual spraying (IRS) (WHO, 2015). Nonetheless, between 2015 to 2018, the incidence remained relatively the same (WHO, 2019b). Primarily, sub-Saharan Africa continues to struggle in implementing robust eradication approach to address the malaria issue (White, 2018; WHO, 2020). In contrast, malaria mortality rate declined 72% since 2000 in America, 65% in West Pacific Region, 64% in Eastern Mediterranean Region, and 49% in South-East Asia Region (WHO, 2015).

In 2015, European Regions reported zero indigenous cases of malaria (WHO, 2015). Also, in 2015, 33 countries had less than a thousand malaria cases and 16 countries reported zero indigenous cases in the 3 preceding years (WHO, 2015). None of these countries are in sub-Sahara Africa. By year 2015, 57 countries had achieved malaria cases reduction of a least 75% and 18 countries had 50-75% reduction in malaria cases (WHO, 2015). Similarly, none of these countries are in sub-Saharan Africa. Globally, 6 countries have the highest burden of malaria – Nigeria, Democratic Republic of the Congo, Uganda, Ivory Coast, Mozambique, and Niger. In 2015, Nigeria had about 25% of the total global malaria incidences reported (WHO, 2020). About 12% of the total global malaria incidence cases were in Democratic Republic of the Congo, 5% in Uganda, and approximately 4% each in Ivory Coast, Mozambique, and Niger (WHO, 2020).

Lack of healthcare access, limited awareness, scarce or unavailable intervention measures, lower socioeconomic status, and inadequate infrastructures are facilitators of high malaria burden in sub-Sahara Africa (Sumbele et al., 2016; Vorasan et al., 2015). The “high burden to high impact” (HBHI) approach is being adopted in 11 sub-Saharan Africa to jump-start the leveling of progress experienced between 2015 and 2017 after the achievements made between 2000 and 2015 against malaria. HBHI was started in 2018 and it was a country-led approach supported by WHO, the Role Back Malaria Partnership to end malaria, and other global partners. HBHI was implemented to use better analysis and strategic use of quality data to pinpoint where to deploy the most effective malaria control tools for maximum impact rather than the “one-size-fits all” approach to malaria (WHO, 2018d). The HBHI intervention promotes uptake of quality public health measures to prevent deaths arising from a disease that can be easily diagnosed, prevented, and cured with treatments, and eradicated (WHO, 2020). In this initial chapter, the background information on malaria disease, problem statement and purpose of the study, the research questions and hypotheses, theoretical framework, nature of the study, definitions, assumptions, scope of delimitations, limitations, and the significance of this study were discussed.

Background

These articles below contain meaningful, evidence-based information about the malaria epidemic, public health interventions, and epidemiologic assessment of anemia currently and previously used to advance the knowledge of malaria investigation. Sumbele et al. (2016) conducted a cross-sectional study to assess the association between different levels of anemia in 216 children that presented to the mount Cameroon area hospital between May and August 2014, a period reflecting the peak malaria transmission season in the area investigated (Sumbele et al., 2016). Clinical evaluations and questionnaires were administered to eligible participants enrolled in the study, and blood samples were collected for parasite status and full blood count evaluations (Sumbele et al., 2016). For the study, a multinomial logistic regression model analysis was used to evaluate the potential determinants of “Medium to Severe Anemia” and “Medium to Severe Malaria-Induced Anemia” after accounting for age, sex, socioeconomic status (SES), level of education, altitude, fever, and nutritional status as confounding variables (Sumbele et al., 2016). The Statistical Package for Social Sciences (SPSS) software version 20 was used to analyze the data. They found that anemia prevalence was highest among children ages 1–5 years old and that moderate to severe anemia with or without fever was not associated with malaria. Still, its occurrence was found to be significantly associated with fever (Sumbele et al., 2016). The authors suggested the need to focus on multiple geographical settings or locations to explore the impacts of malaria-triggered anemia further. My current study focused on the sub-Saharan African country of Nigeria: a region known to have the highest incidence and prevalence of malaria.

Kweku et al. (2017) investigated the impact of malaria and anemia control in children under 5 years of age after 10 years of the implementation of the long-lasting insecticide net (LLIN) in an intense, prolonged, and seasonal malaria transmission areas of Hohoe municipality in Ghana (Kweku et al., 2017). The cross-sectional study involved data collection from June to November 2006, 2010, and 2015, which ranged from 5,579 to 5,787 children (Kweku et al., 2017). The authors found that the significant positive trend in LLIN ownership accounted for a highly significant departure from the decreasing trend of anemia incidences. Anemia significantly increased between 2010 and 2015, accounting for a significant departure from the initially decreasing trend of anemia from 2006 (Kweku et al., 2017). Malaria parasitemia over the November surveys depicted a significant decline over the years of the study, with a significant decrease in anemia from 2006 to the 2010 period (Kweku et al., 2017). The authors concluded that the positive trend in the ownership and use of LLIN generally improved within 5 years after the implementation of a malaria control program but not as much 10 years after the implementation (Kweku et al., 2017). The trend described by Kweku et al. (2017)

provided information regarding the relationship between malaria in terms of its impacts on anemia incidence using a mosquito net use intervention program.

Saaka and Glover (2017) conducted a cross-sectional study aimed at the assessment of the prevalence of malaria, level of Insecticide Treated Nets (ITN) ownership and use, and factors that hinder its use in two communities of Buipe and Savelugu in the Northern region of Ghana. For the study, they enrolled 385 participants (219 females and 166 males) of 6 years old and above for the evaluation. They found a high prevalence of malaria awareness about the need for sleeping under ITNs for protection from a mosquito bite and explored the barriers of ITNs use among the selected target population (Saaka & Glover, 2017). The article provided key information about the challenges and barriers of ITN purpose and lack of adherence to its use even when there are increased awareness and knowledge of the need for ITN use.

The authors suggested that even though ITNs are sold at a heavily subsidized cost, the affordability for the people of Buipe and Savelugu was a major concern. They found that there was a high level of awareness and knowledge about the need to sleep under ITNs. Of those that participated in the study, 97.9% did not condemn the use of bed net; yet irritability, heat, and inability to sleep due to discomfort hindered the use. Thus, ITN ownership was low: 38% in Buipe and 27% in Savelugu. For these reasons, the authors suggested the need for exploring innovative materials for making ITN that is comfortable, and the insecticides should be one that is not harmful to the people, especially pregnant women, and the fetus, as perceived by the people.

Like the findings by Kweku et al. (2017), Saaka and Glover (2017), Sarpong et al. (2015), Sumbele et al. (2016), Vorasan et al. (2015), and many other researchers' work on malaria reviewed for this study, sub-Saharan African countries still suffer from an immense burden of malaria mortality and children under the age of 5 suffer the hardest hit. Thus, Sarpong et al. (2015) concluded that the burden of parasitemia, malaria, and anemia is a major public health problem among Ghana's school children in their study. At the time of the study, 32% of all outpatient department visits in Ghana were due to malaria and so was hospitalization of children under the age of 5 years which was 49%. Morbidity due to malaria cases was about 3 million with 4,000 deaths annually (Sarpong et al., 2015).

Although hookworm infections, nutritional infections, and haemoglobinopathies are some causes of anemia in children in Ghana, the major cause of anemia in children is malaria. Sarpong et al. (2015) "studied the indicators of malaria epidemiology and transmission among school children as a baseline assessment before IRS implementation in Ghana" (p. 1). IRS is a valuable malaria vector transmission control measure, but the exact efficacy data are not available for many settings. Their study was cross-sectional in nature and was conducted in two regions of Adansi South District of the Ashanti Region and Wa West District of the Upper West Region of Ghana on children between the ages of 2 and 14 years old. Study cohort were Early Childhood Development Centers and primary school pupils selected through simple random sampling from a physical randomization device. They enrolled 1,649 pupils for the study. For the association between parasitemia and personal characteristics, they found that there was no evidence of an association between the housing type and parasitemia (Sarpong et al., 2015); however, there was declining risk for parasitemia with increasing age (*OR* 0.91, 95% CI 0.87–0.95, $p < 0.001$) and the National Health Insurance Scheme (NHIS) enrollment (*OR* 0.75, 95% CI 0.60–0.94, $p = 0.01$). The mean haemoglobin concentration was significantly lower ($p < 0.001$) in participants with parasitemia compared to those without. The authors concluded that the burden of malaria and anemia is a significant public health problem among school children in Ghana, and more investigations of the intervention measures to stem the tide are warranted (Sarpong et al., 2015).

Vorasan et al. (2015) suggested that most research on malaria were cross-sectional or cohort studies of 1 to 2 years, they conducted a retrospective cohort study to examine the long-term impact of malaria infection on school performance among children aged 6-17 years in a school of a subdistrict of Ratchaburi Province malaria-endemic area in Thailand. The authors used the student *t*-test and ANOVA to analyze the mean difference of school performance scores between groups, and logistic regression was used for the predictive factors of school performance such as multiple uncomplicated malaria attacks and childhood malaria infection (Vorasan et al., 2015). Those children enrolled to the study were classified into malaria and nonmalaria groups using their history of malaria infection. A total of 457 participants were enrolled. The assessment of school performance was by the class teachers' graded scores in Thai Language and Mathematics subjects. The authors found that the study participants' parents were mostly uneducated (60% of the fathers and 70% of the mothers), 67% of the participants were from low-income families, and a third of the children had low emotional intelligence.

Although, childhood malaria infection may affect cognitive functioning and lead to impairment of memory and compromised language functioning; however, they concluded that an association between childhood malaria infection and school performance was not statistically significant. The finding suggested that in low malaria endemic area, the educational consequence after uncomplicated malaria may be less and may not be long termed (Vorasan et al., 2015).

Ghana has made significant progress with providing access to ITNs to its citizens; however, ITNs use remains suboptimal in some regions of the country and malaria continues to be a major public health problem. Ahorlu et al. (2019) conducted a qualitative research study using a similar secondary dataset used in this current study but for the country of interest, the Ghana Demographic and Health Survey dataset. Ahorlu et al. (2019) did their study to provide in-depth information on the barriers and facilitators of ITN use among those with access. The authors enrolled 174 study participants (43% male and 57% female). NVivo 12 (QSR International software was used to thematize the data. The key themes identified were heat and discomfort, malaria knowledge obliviousness, lack of motivation for ITN use, and reaction to the insecticide were the primary barriers to ITN use and adoption.

In contrast, they found that malaria-related ill-health or loss of a loved one to malaria was the most potent motivator for consistent ITN use. The concept of prevention measures of malaria rather than its treatment was a positive facilitator of economic growth (Ahorlu et al., 2019). The study informed the effective use of ITNs in reducing or eradicating malaria in sub-Saharan Africa and enhancing malaria awareness.

Problem Statement

Globally, malaria remains a life-threatening yet preventable and treatable health problem (Sumbele et al., 2016). While the number of malaria cases and associated deaths have declined in the developed countries through the years, the morbidity and mortality associated with the disease remain high in Cameroon, Chad, Ghana, Niger, Nigeria, and other sub-Saharan African countries (Njunda et al., 2016; Vorasan et al., 2015). About 41% of Cameroonians suffer an episode of malaria each year, with a mortality rate of 30 to 35%; on the other hand, childhood malaria mortality is 67% in Cameroon (Mbako et al., 2017). In Chad, the disease affects about 95% of the population and is the leading cause of morbidity and mortality, resulting in approximately one in every four deaths reported in the hospitals (Devi, 2018). According to Hassan et al. (2018), about 40% of patients presenting for treatment in Chad suffer from malaria. It is also the leading cause of death in Chad with 29.3% mortality in adults and 30% mortality in children less than 5 years old (Hassan et al., 2018). In Niger, malaria is also the leading cause of morbidity and mortality in children under the age of 5 years, totaling more than 3 million, which is approximately one-fifth of Niger's population (Guillebaud et al., 2013). Nigeria accounted for a quarter of the world's malaria cases and reported the highest estimated increase in cases in 2017 when compared with 2016 (WHO, 2018a).

Biological plausibility has proven and documented how malaria influences anemia condition is that individuals who have malaria via mosquito bite are infected with the parasite, *Plasmodium*, and the anemia condition occurs when the malaria is left untreated (Cohee & Laufer, 2018). Upon infection, the *plasmodium* parasite attacks the red blood cell causing the individual to have malaria-Induced anemia and fever if the malaria is not treated (Cohee & Laufer, 2018). A fever is a common medical sign experienced when a person's body temperature rises above the normal range of 36–37° Centigrade (98–100° Fahrenheit). In a household survey study between 2015 and 2017 by Cohee and Laufer (2018) of 16 high-burden malaria prevalence African countries, the prevalence of anemia among the study participants was 61% for children aged under 5 years. Of the children that tested positive for malaria, the prevalence of anemia was 79% (WHO, 2018a). Additionally, Cohee and Laufer (2018) suggested that malaria infection is associated with anemia and decreased educational attainment based on their analysis. They also concluded that effective antimalaria drugs lowered the prevalence of malaria and anemia substantially and improved cognitive functioning (Cohee & Laufer, 2018).

Globally, 273 million children and 529 million women are affected by anemia from any cause, which corresponds to 8.8% of all years lived with disability (Pasricha et al., 2018). It is highest in sub-Saharan Africa, representing approximately 62.3% of all cases globally (Pasricha et al., 2018). The prevalence of anemia in children younger than 5 years old is higher than in other age groups (Cohee & Laufer, 2018; Pasricha et al., 2018). The estimated prevalence of anemia worldwide between 1993 and 2011 decreased only by 4% in both pregnant women and preschool children, 33% to 29%, and 47% to 43%, respectively (Pasricha et al., 2018). The failure to substantially reduce the burden of malaria and anemia in West Africa and sub-Saharan Africa, as a whole, may primarily be due to economic hardships, infrastructure reform, and public health barriers (Pasricha et al., 2018; Sumbele et al., 2016). Hence, the need for further investigation on malaria and malaria-Induced anemia's preventive measures, control, and treatment is needed, especially among children younger than 5 years old who bear the most burden (Sumbele et al., 2016).

Steady improvements in combating malaria disease have produced substantial and enormous progress in many countries. However, the progress in sub-Saharan Africa is still substantially problematic (Sumbele et al., 2016). Substantial progress was made between 2000 and 2015 in malaria cases reduction (Mbako et al., 2016), but the 2019 WHO malaria report indicated that there was a significant decline in the malaria case reduction progress between 2015 and 2017 (WHO, 2019b). Also, between 2010 and 2015, the incidence rate of malaria declined globally from 72 to 59 cases per 1000 population at risk (an 18% reduction over that period). Between 2015 and 2017, the malaria case prevalence was still 59 per 1000 population at risk for the previous 3 years (WHO, 2018a). As such, the WHO emphasized the need for continued promotion of the "Zero malaria starts with me" program (WHO, 2019b). The "Zero malaria starts with me" program is a grassroots campaign aimed at increasing malaria-driven awareness among target populations, public health agencies, and public authorities. The aim is to promote information sharing about the disease, its risk factors, and preventative measures through the sharing of relevant resources and malaria preventative approaches to empower communities and individuals in taking ownership in the prevention, control, and reduction of malaria disease (WHO, 2019a).

Malaria kills roughly 435,000 people each year, most of the deaths are reported in Africa and among children under the age of 5 years old (von Seidlein et al., 2019; White, 2018), a public health crisis that must be halted. Nigeria accounted for 25% of all the cases of malaria disease in sub-Saharan Africa (WHO, 2018b). Cameroon, Chad, and Niger have similar malarial burden as Nigeria and are among the 11 countries with the biggest malaria problems and complications (WHO, 2019). If the current trend continues, the *WHO Global Technical Strategy for Malaria* 2016-2030's plan intended to reduce malaria incidence, and its associated deaths, by 40% would not be met (Rosenthal et al., 2019). Despite the advances made to reduce the cases of malaria, the current stalling of the progress is of public health and epidemiological concerns (Rosenthal et al., 2019). As malaria remains a major killer of children in Cameroon, Chad, Ghana, Niger, Nigeria, and other sub-Saharan Africa countries, continued evaluations of the control measures must be conducted regularly (Rosenthal et al., 2019; von Seidlein, 2019; WHO, 2019a). Therefore, to prevent the loss of a child every 2 minutes in sub-Saharan Africa, public health efforts must stride to eradicate or substantially reduce malaria cases in the region (Sumbele et al., 2016).

Malaria is a major cause of anemia and a common reason for blood transfusion in children (von Seidlein, 2019). While malaria is one of the factors that contribute to the public health problem of anemia, other factors such as blood loss by bleeding, decreased or faulty red blood cell production, and destruction of red blood cells via acute bacterial and viral infections can cause anemia as well (von Seidlein, 2019). Sumbele et al. (2016) emphasized that anemia causes significant morbidity and mortality, but only seem like a moderate or severe public health problem. Malaria-Induced anemia is only partially defined in its severe form, and the main clinical presentations of severe malaria-Induced anemia are those caused by *Plasmodium falciparum* (Schaber, 2018; von Seidlein, 2019). However, Sumbele et al. (2016) suggested, from their research, that not all severe anemia is associated with malaria. As a result, assessing the influence of sociodemographic and nutritional indices on the prevalence of malaria and how it may relate to anemia in Nigeria will provide valuable information to health authorities and public health agencies of Nigeria - thereby promoting meaningful measures for the eradication of malaria and the prevention of anemia acquired through malaria. The findings from this study may suggest preventive measures of malaria in Nigeria and may project to other sub-Saharan African countries with similar demographics as Nigeria, such as Cameroon, Chad, Ghana, and Niger.

According to Sumbele et al. (2016), in the context of the decline in the prevalence of malaria in Cameroon, the moderate prevalence of malaria-Induced anemia and the low occurrence of moderate to severe malaria-Induced anemia observed in hospitals was a contributing factor to the public health problem. They found that malaria may not be associated anemia, whether in cases of moderate to severe anemia or moderate of severe malaria-Induced anemia (Sumbele et al., 2016). Inherently, the study duration timeline and the number of participants were limited. Therefore, Sumbele et al. (2016) suggested that the contribution of malaria to the public health problem of anemia should be interpreted further and with caution. As such, they recommended that more studies in different ecological settings and a larger population to be done to assess the association between malaria and anemia (Sumbele et al., 2016). The information is vital for the planning and delivery of a comprehensive intervention approach to address the public health problems of malaria and anemia. The findings from this study should provide information to policy makers to reassess current preventive measures in Nigeria or any African country with similar interest and with similar topography as Nigeria to eradicate malaria burden. Other sub-Saharan African countries with a high incidence and prevalence of malaria and anemia should also benefit from the results of this study.

Purpose of the Study

The purpose of this current study is to assess the association between malaria and malaria-induced anemia among children who have malaria and those who do not have malaria in the sub-Saharan African country of Nigeria. To do this, I investigated the link between malaria medication use and malaria-Induced anemia status (anemia versus no anemia) among children with positive malaria. Assessing if gender, residence type (rural or urban), parent's educational level, and Mosquito net use may be associated with malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria was investigated. Last, the association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia was also explored. Evidence-based assessments showed that mosquito-driven malaria damages red blood cells and reduces red blood cell count during infection in children and adults, thereby causing anemia if malaria was not treated timely (Sumbele et al., 2016).

Research Questions and Hypotheses

The research questions for the current study intended to investigate the association between malaria and malaria-induced anemia, and the methods used to control the transmission of malaria parasites (especially Plasmodium *falciparum* in sub-Saharan Africa) in a large population setting so that broad base conclusions could be made. The following research questions drove the study:

Research Question 1 (RQ1): Is there an association between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and Mosquito net use?

$H_0$1: There is no relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

H_a1: There is a relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

Research Question 2 (RQ2): Is there an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use?

$H_0$2: There is no association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

H_a2: There is an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

Research Question 3 (RQ3): Is there an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and Mosquito net use?

H_03: There is no association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

H_a3: There is an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

Research Question 4 (RQ4): Is there an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria?

H_04: There is no association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria.

H_a4: There is an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria.

Theoretical Framework for the Study

The social ecological model (SEM) is a theoretical framework used for understanding the multiple levels of a social system, interactions between people, and the environment within the system (Swick, & Williams, 2006). The theory frames the ecological perspectives as the interaction variables and the interdependence of the variables within and across all levels of a health problem (Swick, & Williams, 2006). People's interactions with their physical and sociocultural environments are considered when using this theory. SEM was introduced after the First World War to bridge the gap between behavioral theories on small settings and the anthropological theories (Swick & Williams, 2006). Later, the model was introduced as a conceptual model in the 1970s and as a theory in the 1980s by Urie Bronfenbrenner (Swick, & Williams, 2006). The SEM was used to explain the associations between the independent variables (malaria status for RQ1, accepted malaria medication use for RQ2, malaria-induced anemia status for RQ3, and residence type, parent’s educational level, malaria medication use, and mosquito net use for RQ4 and the dependent variables). The dependent variable for RQ1, RQ2, and RQ4 is malaria-induced anemia. Gender is the depended variable for RQ3. Furthermore, SEM was used to explain the interaction between the selected confounders (age, gender, mosquito net use, parents' educational level, and residence type) as with the dependent and independent variables.

SEM is widely used in epidemiological or public health research-informed studies and is guided by several health promotion measures, policies, and practices (Glanz et al., 2008). The model is extensively employed in health promotion interventions because it could be used to explain individual-level interactions with physical and sociocultural environments (Glanz et al., 2008). Irrespective of disease outcomes, social, environmental, and economic factors contribute immensely to the burden of disease distribution (Glanz et al., 2008) and SEM can be used to address these factors. The SEM, when applied properly in any study, helps in assessing individual behavioral change within specific social, physical environmental, and economic settings (Golden et al., 2015). As such, it has been established that social and physical environment strongly influence individual and population health/health condition and other health determinants, coined as social determinants of health (Golden et al., 2015). The factors under this current investigation (age, accepted malaria treatment medicine, gender, mosquito net use, parents' educational level, and residence type) are part of the social determinants of health.

Nature of the Study

The study design is cross-sectional because the secondary database for this study was collected through a survey-based questionnaire approach. For the purposed ethical concerns regarding participants' protection, the secondary data source only provided de-identified data. The secondary data is currently available/accessible and was downloaded from the Demographic and Health Surveys (DHS) website after their permission was granted. The most current DHS program dataset was downloaded for this study. Before the DHS dataset was downloaded, I obtained the dataset access permission by applying for full Institutional Review Board (IRB) approval from Walden University. With the IRB approval and the completion of DHS's request to use their dataset, I was permitted to download the latest version of the DHS dataset from the open-source DHS website and stored the dataset in my password-protected computer.

Before downloading the survey data from the DHS program, it was necessary to acquire an authorization letter which was sent to me via an email that explained the boundaries of the use of the dataset. For example, the dataset cannot be used for another purpose other than the purpose for which it was requested, no efforts should be made to identify any household or individual respondent interviewed in the survey, and that the dataset must be treated as confidential. DHS dataset users are required to submit an electronic copy of any reports or publications resulting from using their data files.

The datasets are downloaded as zipped files to be unzipped for analysis. Also, the folder contained a codebook (word document) that provided useful information on country-specific variables, and differences in the standard Recode Manual of the dataset, which was also downloaded from the website. All the variables collected for my country of interest, Nigeria, were included in the dataset and the required variables for the current study was extracted from the dataset and used for my analysis. DHS completes these health care organizations sponsored data collection in many countries around the world, especially in sub-Saharan African countries. DHS is the custodian of the data.

The target population in this current study is children younger than 5 years old, regardless of gender. In cases there are more than one child in a family less than 5 years old, all the children were included in the study. Malaria status is the independent variable for the first research question (RQ1) in this study. Malaria is categorized as a nominal variable. The two malaria groups are children with malaria (diagnosed with malaria) and those without malaria (no malaria diagnosis). The comparative groups for RQ1 were grouped into two categories based on their malaria status. Malaria-induced anemia is the dependent variable for RQ1, RQ2, and RQ4, and it is also a nominal variable – whether the child is diagnosed with anemia. Gender is the dependent variable for RQ3 and was a nominal variable of whether the child is a boy or girl.

Whether the child has accepted a malaria treatment medication before at least once is the independent variable for the second research question (RQ2). It is a nominal variable. Of all the children, only those that tested positive for malaria would be analyzed in RQ2. I identified children that had anemia and those that did not have anemia from those children that have malaria based on the measurement of their red blood cell count as recorded in the survey. Parents' educational level and mosquito net use are the confounding variables for RQ1, RQ2, and RQ3. They were also used as independent variables for RQ4 of this study. Parents' educational level was grouped into three categories as an ordinal variable. The three groups are "primary education," "secondary education," and "higher." The mosquito net use ("Did anyone sleep under this mosquito net last night?") was grouped into a two-level nominal categorical variable, "yes" or "no." Another independent variable for RQ4 is residence type. The resident type variable is a categorical nominal variable of those children that leaved in the rural area and those that leaved in the urban area on the day interviewed. Age and gender are the confounding variables for RQ4. The age variable is presented as a continuous variable in the dataset. This variable was grouped into two categories of those children that are less than 36 months old and those between 36 months old inclusively and less than 60 months old. Gender was categorized into two groups as a nominal level of measurement variable. The two groups that were used to represent gender differences are if the child were a male or a female.

For Chapter 4 analysis, G*power software was used to calculate the minimum sample size required for this study. The 1.3 effect size was selected for my power estimation. For the inferential analysis, the predetermined values used to determine whether to reject or fail to reject the null hypothesis are alpha [α] (Type I error/false positive) value of 5% (0.05) and confidence level (CI) of 95% (0.95). Multiple logistic regression was used for the inferential statistical analysis using the version 27 SPSS software. Also, SPSS was used for descriptive analysis.

Definitions

Terms used in the study that have multiple meanings are as follows:

Age: This is the age of the child on the day of the interview.

Anemia: The hemoglobin result from blood test. A condition due to lack of enough healthy red blood cells to carry adequate oxygen throughout the body's tissues (Greenhouse et al., 2019).

Gender: Is the child a boy or girl? A role based on sex at birth. Both male and female children met the inclusion criteria of this study and were included in the study population.

Malaria: Hemoglobin level from blood sample collected from patient at the time of the survey. Malaria is a serious or fatal disease caused by a parasite commonly transmitted by certain types of mosquito which feeds on human hosts (Greenhouse et al., 2019). People who get malaria are typically very sick with high fevers, shaking chills, and flu-like illness (Greenhouse et al., 2019).

Malaria-Induced Anemia: This is when the red blood cell ruptures from the infection of malaria parasites that enters the body through infective mosquito bites. Thus, causing, reduction in the amount of red blood cells in the body (Scheu et al., 2019).

Malaria Knowledge: The ability to understand that malaria parasites can be transmitted through mosquito bites. May also include how malaria disease is acquired, how it is spread, the ability to recognize the risks, the benefits of protection, and knowledge of available preventive efforts.

Malaria Status: The result of the malaria test from the blood sample collected during the interview. This is the state of a study participant regarding the presence or absence of parasites that caused malaria.

Accepted Malaria Treatment Medication: This is whether the patient took malaria medication during malaria illness at least once. This may be any antimalarial drugs, including Artemisinin Combination Therapy (ACT), SP/Fansidar, Chloroquine, Amodiaquine, Quinine, Artesunate, and other antimalarial drugs.

Mosquito net use: Irrespective of when the net was purchased, the brand or type, obtained as a mass distribution campaign or purchased, or where it purchased or collected, the respondent to respond if the patient slept under the net the night before the survey. A type of meshed curtain that is circumferentially draped over a sleeping area (the bed, couch, mat, etc.) as a barrier or protection from mosquito bites and subsequent transmission of malaria parasite during bite (Scheu et al., 2019). The net is also used at the same time as protection from other pest insects that are bigger than the airways of the net (Scheu et al., 2019).

Parents' Educational Level: What is the highest level of school you attended: primary, secondary, or higher? The levels of education a child's parent attained. Parents' educational level is often associated with access to resources, such as income, time, community contacts, and parental involvement with their children. Bully, Jaureguizar, Bernaras, and Redondo (2019) suggested that higher level of education is related to higher socioeconomic status, higher paying occupation, and more resources and time to care for their family.

Residence Type: This is the type of place the patient was interviewed. The residence type is either urban or rural areas. The urban areas are classified into large cities (capital cities and cities with over one million population, small cities of populations of about 50,000, and towns. The rural area is the countryside (DHS, 2018).

Assumptions

I took an assumptive position that the parents of the study participants that qualified for this study provided correct information related to their child's malaria status and if the child slept under a mosquito net. It was also assumed that the parents' educational level provided by the children's parents were accurate. For the study participants that have anemia, malaria-Induced anemia is inferred if there is no visual bleeding from cuts or wound reported. Ultimately, it was assumed that participants' parents who responded to the questionnaire questions answered the questions with the strong belief that their privacy will be protected as required by the ethics administrators who approved the collection of the data for knowledge purposes. That they freely participated in the study led me to assume that they had not been coerced in any way and have the right not to participate by ending their participation in the study at any time during the interview without losing any entitlement. I was assumed that all the underlying privacy laws on which the IRBs of the local country's approval were given to collect the data were not breached in any way.

Scope and Delimitations

Although there was a significant focus that malaria was associated with anemia status in this study, other factors such as sickle cell anemia, shortage of iron, vitamin B12 deficiency, or the inability of a child's body system to process essential vitamins are also associated with anemia. The exposure to toxic chemicals, lack of folate (vitamin B9), bone marrow disease, inflammatory diseases, family history of hemolytic anemia, certain medications or treatments, and autoimmune diseases have each been suggested to be associated with anemia as well (Powers et al., 2020; Salazar, 2020). Thus, the study participants may not only have malaria associated with their anemia but any of the other factors. The scope of this study did not extend beyond those children that their parents were interviewed for their malarial status retrospectively, including those that were willing to give blood for the testing of their malaria and anemia statuses. The study did not exclude those study patients who may have anemia through the other factors.

The current study did not adjust the influences of some variables that might influence the relationship between malaria disease association with anemia. For example, social and physical environment, culture, political atmosphere, and economic stability are a huge part of social determinants of health and an influencer of behaviors and lifestyle (Bell, Bryman, & Harley, 2018; Erbe Healy, 2018) but were beyond the scope of this study. The current study assessed the impact of mosquito net use and parent's educational level. Another scope limitation for the present study was that the population of interest included individuals who were available for the interview when the study interviewer visited the home. Also, if a household did not have children aged between 0 and 60 months, the interviewer simply moved to the next household on the list. Other age groups were excluded from the study. Those children whose parents were usually not at home during the day may not have the opportunity to participate in the study even though their household was initially randomly selected for the study.

Limitations

When data are collected using the same protocol, but the data is obtained from different sources, cohort variation effects may exist. Cohort variation effects suggests that each cohort is conditioned by its environment. The variation in physical environment, social norms, culture, and socioeconomic status differences within a country could influence data collection variations within that country. Social norms, physical environment, culture, and socioeconomic status are part of social determinants of health and influencer of lifestyle behavior. In addition, since the current research is a cross-sectional design and is self-reported information, no verifiable clinical data were collected from the participants to validate the information provided in the survey. Also, a cross-sectional study may not be used to definitively determine the spatiotemporal sequence of the exposure-outcome sequence of an event. In other words, there is a possibility that there are cases where anemia may have been present in a patient unknowingly to the patient before the diagnosis of malaria. Therefore, a cross-sectional design, instead of an experimental or quasi-experimental design, resulted in only a correlational inference and not a causal inference. Incurring recall bias and misclassification biases are possible with a cross-sectional design subject to how far back the posed survey question prompts the participants to recall past events.

Although the use of secondary data saves time and money, and accessibility has substantially improved with the internet, the lack of control over data quality, even with the use of government and official institutions' data set, is a weakness (Bell et al., 2018). Possible inappropriateness of the data collection method or the amount of information collected, which are often more than needed, is another limitation (Bell et al., 2018; Erbe Healy, 2018). Other variables may be necessary for a study, but when those variables are not available in the original secondary data, the secondary data set user cannot add additional variables to the data set. Last, in some cases, secondary data may be outdated due to generational differences or cohort effects. They thus may not be useful or meaningful to address the current needs in a different environment (Bell et al., 2018).

Significance

The significance of this study is to validate the study conducted by Sumbele et al. (2016) regarding malaria impact on anemia. The authors specified the gap on the association between malaria and anemia using larger population in different settings. The association was analyzed in the current study using a much larger sample size and data collected from the most populous sub-Saharan African country of Nigeria so it would improve the generalizability of the previous study findings. This study is important in that it will add to the body of evidence needed to reduce the burden of malaria among the population under study. Many malaria researchers agree that complex and multi-factorial approaches, including anti-malarial stewardship program, are required to prevent and control malaria diseases. The strategy to use should include the healthcare provider, physician, pharmacist, medical student, and population or social levels (Bienvenu, Djmine, & Picot, 2019; WHO, 2019b)).

In sub-Saharan Africa, nearly all infants and young children (at a higher rate), and older children and adults, suffer from one form of reduced hemoglobin or the other (White, 2018). And the major cause of hospital admission when malaria transmission is highest in sub-Saharan Africa is life-threatening malaria-Induced anemia that requires blood transfusion (White, 2018). Although many interventions are in place to control malaria in children such as vector control, insecticide-treated bed nets, prompt and accurate diagnosis of the illness, and effective anti-malarial drug, White (2018) suggested that the thresholds of managing the transfusion remain uncertain. Hence, the gender difference of anemia among children that have malaria may suggest new antimalaria drugs (White, 2018). The findings from the current study targeting children in Nigeria may provide additional information on the risk of malaria, how anemia may affect children by gender, and malaria-Induced anemia health impacts. Also, important interventional ideas to help policymakers reform and transform the existing malaria policies may be proposed; thereby, creating a new transformation toward eradicating malaria in sub-Saharan Africa. The findings will possibly address the decline in the rate of reducing malaria cases, which was evidenced between 2015 and 2017 after the rapid success of eradicating the disease as experienced between 2010 and 2015.

Implications for Social Change

This study has the potential to create significant positive social change in Nigeria. Particularly how malaria can be controlled or cured before developing into a severe condition that leads to anemia (malaria-Induced anemia). In terms of access to available low or no cost insecticides, other malaria vector control tools, and information on how to reduce malaria cases, this study may inform policy makers in the country of interest to develop programs that would enhance current policies which in turn would lead to the goal of eradicating malaria. If the findings from this study suggest a strong relationship between malaria and anemia, using the large study population size intended to be analyzed for this study, and parents' educational level and mosquito net use are contributing factors toward the reduction of malaria cases in the country of interest, policies may be put in place with informed knowledge to effect social change. A replication at even a wider scope that extends further into more sub-Saharan African countries struggling with malaria endemic may go a long way towards the eradication of malaria in sub-Saharan African. That is, the range can even be extended further or generalized to much larger sub-Saharan African countries with similar topography.

Summary

In this Chapter, the study was introduced by describing the major variables of interest. I discussed the sections that are included in the chapter and provided the background and significance of the study. Also, the public health problems of malaria disease and anemia condition were stated, and the purpose of the study was discussed. Then, the research questions and their corresponding hypotheses were declared. For the theoretical foundation, how the SEM can be used to describe my research findings was explained, and I defined the study variables and other relevant terms used in the chapter. Finally, I provided the scope and delimitations for the study, the limitations, and the implication for social change.

Malaria is an eradicable disease, as evidenced in North America, Europe, parts of Australia, Asia, and South America. As I discuss in the next chapter, South Africa has applied to the WHO to be the first African country that is malaria-free. Although malaria control has proven immensely effective by averting an estimated 663 million clinical cases between 2000 and 2015 worldwide (Sherrard-Smith et al., 2019), the fact that 90% of malaria cases are in sub-Saharan Africa is inconceivable. Malaria continues to be a significant public health problem in sub-Saharan Africa and Nigeria in particular bears a quarter of the world's malaria burden (Cohee, & Laufer, 2018; WHO, 2018b). Also, for children in the age group of less than 5 years old to be the most affected makes this public health issue more mind bothering (WHO, 2018b). The current study targets these vulnerable children to advocate the need for social change so that public health policymakers may enhance their efforts in providing more information about how to fight malaria and more innovative intervention and services to the people.

Chapter 2 is the literature review chapter of this study and includes an extensive review of current articles on the study population, the independent and dependent variables, and the factors that may affect the association of the independent and dependent variables. I discussed how previous researchers' findings may support my research and how they approached their research on similar independent and dependent variables. Then, I discussed the gap in the literature to be addressed by this study to further contribute to the body of knowledge. The methodology of the study was discussed in Chapter 3. How the study was conducted was explained in the chapter and included the description of each variable, the statistical method used, and how I intended to demonstrate the gap I am trying to fill. In Chapter 4, the results of the study were presented in the most appropriate way for easy assimilation of the analysis conducted, using tables, graphs, and figures that are generated for descriptive and inferential statistical analysis. And in Chapter 5, I discussed the findings from the analysis conducted in Chapter 4, the implication to social change, and suggestions to further enhance public health practice.

Chapter 2: Literature Review

Introduction

In this study, I assessed the association between malaria and malaria-anemia among children younger than 5 years old with confirmed cases of malaria and those who do not have malaria in the sub-Sahara African country of Nigeria. Likewise, I explored the association of the use of malaria medication and malaria-induced anemia, and then with gender among those children with positive malaria. How residence type, parent's educational level, malaria medication use, and mosquito net use may influence malaria-induced anaemia status was analyzed. Literature showing the association between malaria and anemia among children in Nigeria and some other countries in sub-Saharan Africa with high prevalence of malaria cases are discussed in this chapter. Also, how gender may influence an outcome of malaria-induced anemia status in Nigerian children is discussed. Malaria is a public health crisis in most developing countries in sub-Saharan Africa, especially in Nigeria (Rosenthal et al., 2019). Malaria is often transmitted through the bite of a vector *Anopheles* mosquito. Malaria-borne parasite (*Plasmodium*) is released in bloodstream of individuals bitten by a mosquito (Rosenthal et al., 2019). The parasites are reproduced in the liver and after several days attack the red blood cells (Rosenthal et al., 2019). As such, untreated malaria cases could lead to malaria-Induced anemia (Rosenthal et al., 2019). Between 2000 and 2015, malaria interventions have shown to be effective as 663 million cases were prevented (Sherrard-Smith et al., 2019). In sub-Saharan Africa, children younger than 5 years of age bears highest burden of malaria cases and mortality (Sherrard-Smith et al., 2019).

In this chapter, I describe and summarize the current literature that establishes the relevance of this study. I discuss the library databases and search engine used to populate the relevant literature presented. Similarly, the key search terms and search approaches used was discussed. I also discussed the SEM constructs in detail and how it was used to explain the variables of interest under investigation in this study. I described how malaria parasites infect humans, presented effective interventions, and described how malaria funding sources have helped reduce malaria cases. I also described malaria control and eradication efforts in sub-Saharan African and the risk of malaria re-establishment in areas where malaria cases are under control.

Literature Search Strategy

The Walden University Library databases, Google Scholar, PubMed, MEDLINE, and ProQuest were the database sources used for the literature search. The terms used for the literature search were *malaria in sub-Saharan Africa, anemia in sub-Saharan Africa, malaria in Nigeria, malaria-Induced anemia in Nigeria, malaria-Induced anemia, anemia* and *malaria, anemia* and *malaria literacy in sub-Saharan Africa, malaria* and *mosquito net use in sub-Saharan Africa, malaria* and *school attendance, malaria in Cameroon, Chad, Ghana, Niger,* and *Nigeria, anemia in Cameroon, Chad, Chana, Niger,* and *Nigeria,* and *anemia*.

In Google Scholar, once I entered a search key term or phrase, such as '*malaria in sub-Saharan Africa'* in English language in the search box, full-text, and filtered the literature search between 2015 to 2020, roughly 21,500 articles were populated in the database within 0.07 seconds. For example, when the search term, '*malaria and anemia* *in Nigeria'* was entered in the Google Scholar search engine and searched without filtering the search by years (searched for all publication years), 23,000 articles were returned. Then, I narrowed the search for full-text articles between 2015 and 2020 only, and 10,300 articles were returned. I purposely selected relevant articles that are most recent, published in English, were primarily on malaria disease or anemia condition or both situations. Approximately 90 articles were selected. Of those 90 articles, I reviewed their abstracts to identify relevant literature that aligned with the current study subject. The abstracts that aligned with the study subject were selected for a full article review. In some cases, a relevant article could be found after the third or fourth abstract was read from the selected list of articles.

The selection of the articles considered relevant to my study was based on considering the most recent articles and primarily malaria and anemia studies, articles target location of Cameroon, Chad, Ghana, Niger, and Nigeria, and study population that focused on children but also on adults. These were the main inclusion and exclusion criteria process used for my article selection. Another approach used was by performing a direct search based on the information provided about articles cited or referenced in the published articles I had already read. This was done by placing the article tittle in Google search engine, Google Scholar search engine, or EBSCOhost databases accessed through the Walden University Library. In summary, my search was limited to English language, full text, abstract available, scholarly/peer-reviewed journals, and were within 2015-2020.

Selecting relevant articles from the reference list of publish articles was a meaningful way that I used to narrow the focus of my article search. The peer-reviewed articles used for the research were retrieved online. Most of the research articles selected were published within the last 5 years (2015–2020). However, some articles that discussed the origins of the SEM theoretical framework and/or research design were also reviewed and cited using articles published by the original inventors to advance scholarly credit to the inventors. In such cases, the year such articles were published were older than 5 years.

Theoretical Foundation: SEM

The SEM is the theoretical foundation that informs this study. SEM was be used to explore and explain interactions between age group, gender, malaria medication use, malaria status, malaria-induced anemia mosquito net use, and parent's educational level. Assessment of the relationship or interaction between malaria and anemia would be adjusted by mosquito net use and parents' educational level. The findings from this study could provide information on the impacts of malaria on malaria-induced anemia among children living in Nigeria. Sub-Saharan African countries have challenges and difficult barriers in their public health efforts to eradicate malaria because of multiple social, political, and capacity limitations (Panter-Brick et al., 2006). The SEM is a theory that is often used to explore human behavior or disease outcomes as it relates to public health and environmental, extrinsic, and intrinsic factors (Panter-Brick et al., 2006). SEM is important in understanding, exploring, and addressing social determinants of health at many levels of the social, economic, and political constructs (Panter-Brick et al., 2006).

The Socioecological Model

SEM was developed by sociologists in the 1970s to study behaviors based on individual, community, national level characteristics to develop meaningful public health strategies to promote health and public wellbeing (McLeroy et al., 1988). SEM is generally credited to the work of McLeroy, Bibeau, Steckler, and Glanz (1988). SEM is broad in scope and contains 4 to 5 overlapping levels that targets a wide range of intrinsic and extrinsic factors such as personal and interpersonal determinants, to include community, social, cultural, political factors, etc. (McLeroy et al., 1988). Organizational, community and public policy can also be influence by SEM, see Figure 1 (McLeroy et al., 1988).

Figure 1

SEM

A Social-Ecological Model for Physical Activity - Adapted from Heise, L., Ellsberg, M., & Gottemoeller, M. (1999)

Note. Adapted from "Ecology of Health and Medicine: The Online Text for Ecology of Health and Medicine (EHM)," by Helsa, L., Ellsberg, M., & Gottermoeller, M. (1999) (blogs.uw.edu/somehm/2017/08/12/social-ecological-model/). Copyright 2021 by Centers for Disease Control and Prevention. Royalty-free Reprinted Image.

The five-level of SEM are individual, interpersonal, community, organization, and policy/enabling environment (McLeroy et al., 1988). Urie Bronfenbrenner applied the revised model for human development to included biological and genetic aspects of a person in human development (Ferguson & Evans, 2019). In the current study, SEM was be used to explain the association between age group, gender, malaria-induced anemia, malaria medication use, malaria status, and parent's education level among individuals living in the sub-Saharan African country of Nigeria.

Individual Level

It is important to understand the way people interact with oneself, with each other, with their immediate family, with the community, and with the environment to understand the decision-making process (Poux, 2017). As it relates to this study, individual members of a unit or community can be educated on the risk of malaria and its link to malaria-induced anemia including ITN use to improve their health literacy on the subject. Therefore, educational level, gender, and residence type was explained using the individual level construct of SEM. Similarly, local clinics or community members can share essential malaria, anemia, malaria treatment medication, and mosquito-related resources with community members which in turn improves social cohesion, social networking, and social inclusion. All for the purpose of reducing the risk of malaria, anemia, and mosquito bites.

Interpersonal Level

At this level, an individual's relationship with family, friends, and other acquaintances are established. Public health practices are not limited at the individual level, but the ability to advance care for the primary purpose of protecting other people or members of their residence or community to maintain a healthy community and social well-being. For instance, maintaining good hygiene within the community to limit breeding sites for mosquito and adoption of mosquito net use in a family unit is an example of an interpersonal level approach that is important in this study.

Organizational Level

The organization level includes schools, religious establishments such as churches and mosques, marketplaces, offices, employment facilities, etc. In this study, parents' education obtained from an institution of learning (primary school, secondary school, or higher institution) and education relating to mosquito net use are factors explained under the organizational level. Primary and secondary school teachers may promote behavioral change when transmitting malaria prevention awareness to students (Arroz, 2017). The knowledge learned may influence future behavior toward malaria prevention. Furthermore, these students may be able to disseminate the information in their communities and households. Effective application of organizational level indicators could promote policy making-decision processes based on known evidence of the impacts of the indicator(s) in question in preventing and reducing the cases of malaria and anemia within the target population, residence type, or region. Similarly, the impacts of the region, sub-Sahara African countries of Cameroon, Chad, Ghana, and Niger (neighboring Nigerian countries), can be explained using the organizational level as well.

Community Level

The culmination of various components of organizations in an area forms a community (Panter-Brick, et al., 2006). The community includes an object of leadership. The organizations that make up the community are the stakeholders of that community. The stakeholders have a vested interest in the community they belong to. In this study, the sub-Sahara country of Nigeria, and each community within Nigerian is the stakeholder in this study setting. The organization that provides or produces the mosquito nets/ITN, malaria treatment, hospitals, public health departments, and the government, funding sources, etc., are part of the community.

Public Policy Level

Public policies often promote health through preventive measures. Policies are often proposed and implemented by the government with the intent to maintain uniformity in the application of services within the community. Government executes laws and guides how the laws can be enforced. In this study, the use of ITNs or other mosquito nets to control and prevent malaria can be explained under the public policy level of SEM. Similarly, policies addressing anemia conditions can be explained under the public policy level.

Literature Review Related Key Variables and/or Concepts

The underlying study concept of this study is malaria and its association with malaria-anemia among children less than 5 years old in the sub-Saharan African country of Nigeria. The variables of interest are malaria status, malaria-induced anemia status, gender, parent’s education, and mosquito net use. This section expanded on the literature that used similar variables. Studies that used SEM as their theoretical foundation to research and used similar variable were discussed. Then, the health and political structure in Nigeria were discussed as an example of the health care system in the sub-Saharan African country of interest. How the different levels of SEM may interact was discussed and the variables of interest for this study were defined.

Similar Studies Where SEM was Used

The role of social and behavior change communication was investigated by Arroz (2017) as a potential key intervention in the control of malaria in Mozambique, another sub-Saharan Africa country with high malaria incidence. Many studies reviewed for this study and the WHO suggested that insecticide-treated nets, antimalarial drugs, indoor residual spraying, and appropriate case management are key interventions used in sub-Saharan Africa in the fight against malaria. However, Arroz (2017) suggested that these interventions must consider the social determinants of health (SDOH), the SEM, and the social and behavior change communication, to be efficient. The sharing of malaria prevention information through “social and community networks” and the organizational and community levels of SEM may influence the education of persons and their individual and/or collective lifestyles (Arroz, 2017).

In Ghana where there are 3.5 million cases of malaria recorded every year of Ghana’s total population of 31 million, Awuah et al. (2018) conducted a cross-sectional study in three poor urban localities in Accra, Ghana, on study patients in their reproductive ages. The ages of men and women that participated in the study were 15-59 and 15-49 years old respectively. The authors were interested in accessing the factors associated with seeking alternative treatment as the first response to malaria, relative to orthodox treatment in three urban poor communities. The substantial increase in malaria was attributed to poor housing, low socioeconomic status and poor sanitation that leads to the development of breeding sites for mosquitos; thereby, control of malaria continues to be a challenge (Awuah et al., 2018).

The authors suggested that studies have shown that interpersonal factors like social networking and reliable support influence the use of a particular health service. Therefore, they employed the use of SEM, which predicts how multiple levels influence individual health behavior (Arroz, 2017; Awuah et al., 2018; Panter-Brick, et al., 2006). Individual factors such as gender, age, SES, educational level, and the structural institutional mechanisms in place to ensure healthcare access influence one's decision to engage in a particular health lifestyle. The analytic sample size for their study was 708 and the authors interviewed a total of 782 eligible men and women using an interviewer-administered questionnaire. They found that 31% of the study participants sought orthodox treatment, 8% sought traditional/herbal treatment, but a majority 61% self-medicated as the first response to malaria. Also, more males than females used traditional/ herbal treatment and self-medicated for malaria as their first treatment effort. Furthermore, it was found that the current health insurance status, perceived relative economic standing, level of social support, and locality of residence were associated with seeking alternative treatment for malaria relative to orthodox treatment (Awuah et al., 2018).

The eradication of mosquitos globally begun in the 1951 with the use of DDT and the intervention include the United States, Southern Europe, the Caribbean, South Asia, and only three African countries, South Africa, Zimbabwe, and Swaziland (Talapko et al., 2019). Within 20 years, Europe had joined the United States on the success of eradicating malaria with few reestablishment cases from traveling visitors and migrating case from endemic regions. The eradication campaign failed globally due to various problems, including mosquitoes' resistance to previously effective insecticides and resistance of malaria parasites to malaria treatment medication. Additionally, the initial eradication campaigns included only three African countries. The ever-increasing development of malaria parasites' resistance to drugs and the increased mosquito resistance to insecticides became one of the most critical problems in controlling malaria. Malaria medication use in endemic countries

Interaction of Different Levels of SEM

To understand the multifaceted levels within a society and how individuals and the community interact within a social system, the SEM framework is a model to consider. SEM construct employs different factors and determinants in the varying scope of the social and political levels (CDC, 2018c). According to Ferguson and Evans (2019), SEM application in public health efforts is critical in exploring prevention, control, and intervention measures. As such, different levels of SEM can overlap with one another in meaningful and useful ways (Ferguson & Evans, 2019). Particularly for this study, the multifaceted nature of SEM constructs is best in exploring the association between malaria, anemia, and gender after accounting for parents' education and mosquito net use.

Social Change through Communication

Behavior can be influenced by communication through individual and interpersonal efforts (Ferguson & Evans, 2019). Direct communication using the mass media campaigns or through the social media that can be used in targeting a specific audience to achieve a particular health measure goal, often enhances positive social behavioral change (Ferguson & Evans, 2019). For effective change to occur through communication, intervention approaches should be tailored and culturally relevant. For this study, the target audience is children living in the sub-Sahara African country of Nigeria. The target region is Nigeria to include the federal capital territory of Abuja.

Social Change through Social Mobilization

The social mobilization approach is made at the organizational level. It can promote malaria awareness at the individuals, interpersonal, organizational, community, and public policy levels. This approach is adopted to motivate community leaders, the public, private partners, and community organizations to improve healthy choices individually and collectively. At this level, each entity is empowered to make healthy choices, help with the development of appropriate health interventions, participate in the implementation of the intervention, and monitor the execution of behavioral change that leads to improved societal quality of life (Ferguson & Evans, 2019).

Social Change through Advocacy

Advocacy can promote new policies to enhance current intervention; change existing laws, policies, and rules; or to enforce the existing policies (Ferguson & Evans, 2019). Advocacy can also be used to realign the current public health efforts or improve social norms (Ferguson & Evans, 2019). Similarly, funding decisions for specific initiatives could be influenced by advocacy (Ferguson & Evans, 2019). The advocacy influence of the SEM can be subdivided into three parts: policy, community, and media advocacy (Ferguson & Evans, 2019). Legislative, social, and infrastructural element changes are encouraged in the policy sub-level as well. The community advocacy sub-level encourages the demand for policy changes within an environment, and the media advocacy sub-level uses the media to influence policymakers.

Each of the 5 levels of SEM play a vital role to effect a healthier behavioral change, and in all contribute to positive social change for the wellbeing of the public interest. Behavioral change targeted at using multilevel approaches is the most effective. To effectively address malaria and anemia health problems in sub-Saharan African countries, the new approach will integrate the transformational thinking process into translational actions that may include a reinforced comprehensive approach. Such comprehensive approaches include infrastructural modifications, insecticide-treated net use compliance, safe use of insecticide, and improved mosquito net use policy that are tailored to the need of the population and focused on reducing the high burden of malaria, malaria-Induced anemia, and other related risk factors.

For instance, von Seidlein et al. (2019) suggested that dihydroartemisinin-piperaquine administration could help accelerate malaria elimination efforts if a comprehensive, well-organized, and well-resourced elimination program were put together. Therefore, the components that should be included in the holistic approach are infrastructural modifications, mosquito-treated net use compliance, safe use of insecticide, and improved mosquito net use policy (von Seidlein et al., 2019). The introduction of a comprehensive approach, such as those used in the US and most European countries that have resulted in malaria eradication, would substantially reduce the incidence and prevalence of malaria and malaria-Induced anemia in sub-Saharan Africa (von Seidlein et al., 2019). The morbidity and mortality due to mosquito-related anemia could be eliminated in Nigeria and other sub-Sahara African countries, an improvement that will produce a substantial public health benefit.

Health and Political Structure in Nigeria

Historically, the burden of diseases in Africa is dominated by acute and infectious diseases such as malaria, diarrheal diseases, tuberculosis, and measles; and in the past, two to three decades, HIV/AIDS, stroke, and diabetes joined the burden (Agyepong et al., 2017; Mash et al., 2018). Newer threats such as Ebola are a contributor to Africa’s disease burden and owing to the current and ongoing Corona Virus 2019 (COVID-19) pandemic, it will not be surprising that Africa bears the highest-burden by the time the pandemic is over. African governments are characterized by flawed democracies and authoritarian regimes that have not emphasized the healthcare needs of its citizens (Mash et al., 2018). As such, many African countries rely on missionary hospitals, non-government organizations, and external donors to fund their country’s healthcare needs. However, some African countries such Ghana and Kenya are introducing a national health insurance scheme with a focus on universal health coverage and community-oriented primary care (COPC); and several other countries are moving towards strengthening their healthcare system with a political commitment to the comprehensive primary healthcare system and universal health coverage (Bailey et al., 2016; Mash et al., 2018). In Cameroon, Chad, Ghana, Niger, Nigeria, Mozambique, and most other sub-African countries, home-based remedies like the use of herbs are often the first treatment strategies for malaria. Over-the-counter drugs and leftover drugs (sometimes expired) are also used as the first plan of action once malaria is suspected. It is only after malaria worsens or reaches an advanced stage that individuals process to a medical facility for treatment (Awuah et al., 2018).

The Federal Ministry of Health is one of the federal ministries concerned with the formulation and implementation of policies related to health care in Nigeria. The ministry is divided into several departments specializing in different aspects of health care, including the Public Health department that coordinates, formulates, implements, and evaluates public health policies and guidelines in Nigeria (Nigeria Center for Disease Control [NCDC], 2020). Adopted into law in 1992, the National Primary Health Care Development Agency Decree was signed into law. The decree is known as decree #29 and was established to provide support for Nigeria's National Health Policy and provide technical support to the planning, management, and implementation of primary health care (International Labor Organization [ILO], 2014).

Nigeria's Center for Disease Control department was established in 2011 with the assistance of the US Centers for Disease Control (US CDC) in response to public health challenges in Nigeria, to increase Nigeria's preparedness and response to public health emergencies, and to detect, investigate, prevent, and control communicable and non-communicable diseases (NCDC, 2020). An example of how the US CDC is assisting Nigeria's CDC are their support for malaria-endemic in Nigeria that includes the framework for a routine health information system, strengthening entomological monitoring and training, and strengthening malaria diagnostic capacity by using dried tube specimens for quality control of malaria rapid diagnostic tests (CDC, 2019).

The health care system in Nigeria is delivered at three levels: primary, secondary, and tertiary levels. The local government is responsible for the primary health care system, secondary by the state, and tertiary level by the federal government (Ugo et al., 2016). There are an estimated 23,640 health care facilities in Nigeria, 85% of which are primary health care facilities, which serve the majority of its current 190 million population; however, these facilities are unable to provide basic and cost-effective services (Adindu, 2010; Agyepong et al., 2017). Poor political commitment, poor accountability, lack of clearly defined roles and responsibilities, and poorly equipped health facilities are collective factors that are plaguing Nigeria's health care system. Another factor troubling Nigeria's health system is the lack of people seeking health care when necessary due to religious beliefs or lack of financial means to do so. A similar situation of non-health care-seeking behavior occurs in Kenya, Mali, and many other sub-Saharan countries (Klein et al., 2016; Rogerson et al., 2018; Yaya et al., 2018). Those people with malaria symptoms and do not seek medical care promptly until the situation becomes severe and develops into anemia condition could be the reason why the malaria mortality rate is high in sub-Saharan Africa than in other regions of the world.

The National Malaria Elimination Program (NMEP) of the Nigerian Federal Ministry of Health in collaboration with the U.S. President's Malaria Initiative (PMI) has been supporting Nigeria's malaria control efforts since 2011 by significantly expanding key interventions (insecticide-treated nets, targeted indoor residual spraying, intermittent preventive treatment in pregnancy, and effective case management). However, getting these tools to the people that need them cost-effectively as a policy remains a problem for many reasons, such as accountability of government officials to deliver the tools to the people as cost-effectively as intended, a catchment area of the intervention and the willingness of the people to accept and utilize the intervention.

Malaria

Malaria is a serious and sometimes fatal disease caused by parasites that infect certain types of mosquito that feeds on a human. Malaria can be transmitted from human to human or from animals to humans and vise visa through an infected mosquito. It can be cured if the right drugs are used timely, but if the malaria parasites are resistant to the drugs, the infection can develop into anemia, hypoglycemia, or cerebral malaria. And untreated cerebral malaria can cause coma, life-long-learning disabilities, and death (CDC, 2017).

The Malaria Parasites

Five parasite species are known to cause malaria in humans, two of which pose the greatest threat (WHO, 2016a). The *Plasmodium Falciparum* (*P. falciparum*) is the most prevalent malaria parasite in sub-Saharan Africa, while *Plasmodium vivax* (*P. vivax*) is dominant in other continents (Arroz, 2017; WHO, 2016a). Malaria is a life-threatening disease caused by the transmission of any of these two parasites to individuals through the bites of a vector such as female *Anopheles* mosquitoes. Malaria would typically appear ten to fifteen days after the bite and without treatment may progress to death (Ambe et al., 2020; WHO, 2016a). In Cameroon with Sumbele et al. (2016) study, most malaria infections were predominantly due to *P. falciparum* infection. *Plasmodium malariae* (*P. Malariae*) and *Plasmodium ovale* (*P. ovale*) malaria infections were present in patients in low amounts (Abuaku et al., 2018). Children younger than 5 years old had the highest burden of malaria infection (Abuaku et al., 2018; Sumbele et al., 2016; WHO, 2020). Also, caregivers' education level was associated with the odds of parasitemia presence in both transmission seasons (*OR* = 1.7, 95% CI: 1.5–2.0) for the high transmission season and (*OR* = 2.2, 95% CI: 1.8–2.7) for the low transmission season. In other words, caregivers who were farmers with no education had higher odds of parasitemia infection than non-farmers with some education (Abuaku et al., 2018).

Malarial Life Cycle

For malaria transmission to occur, malaria parasites, female *Anopheles*' mosquitoes, and humans in whom the vertebrate host can complete a half of their life cycle most be present. Only the female genus *Anopheles* mosquitoes are responsible for the transmission of malaria in humans (CDC, 2020a; Okwa, 2019). The *anopheles* mosquitoes' life cycle is through four stages: egg, larva, pupa, and adult. The first three stages last 7-14 days and is aquatic, and the fourth stage of the life cycle is generally short lived for about 10 days. Depending on the climate, the 50-200 eggs per oviposition hatch within 2-3 days but may take as long as 2-3 weeks in colder climates (CDC, 2020a). The larvae feed on algae, bacteria, and other microorganisms and develops through four levels before metamorphosizing into a pupae. The pupae are the transitional stage between larva and adulthood.

From egg to adulthood, the duration may be as little as 7 days but often takes 10-14 days. Although, the *Anopheles* mosquitoes feed on nectar and other sources of sugar as stated in the previous paragraph, the females also require blood meals for egg development. Therefore, the females must seek for blood to reproduce. The females will rest for a few days after a full blood meal for the blood to digest and the eggs to develop. Once the eggs are laid, the female seeks another blood meal to sustain another batch of eggs and the cycle repeats itself until the female dies (CDC, 2020a). The male *Anopheles* mosquitoes does not bite.

Anemia

One of the most important and numerous cells in the body are the red blood cells, (RBCs) and their purpose is to deliver oxygen from the lungs to other parts of the body (Kweku et al., 2017; Papaioannou et al., 2019; Saxena, 2018; Sumbele et al., 2016; WHO, 2016b). RBCs are also referred to as erythrocytes. The shortage of these cells or the condition in which the cells are low in the body is what is described as anemia. The hemoglobin molecule is the functional element of the RBCs (Papaioannou et al., 2019). Rather than being a disease, anemia is an indicator of a disease process that is usually classified as chronic (long period) or acute (occurs quickly) (Kweku et al., 2017). The three major types of anemia are microcytic, normocytic, and macrocytic anemia. Normocytic anemia is the type that accompanies a chronic disease such as malaria (Papaioannou et al., 2019; Saxena, 2018).

The common causes of anemia in humans include, but not limited to, active bleeding from heavy menstruation or wounds, iron deficiency, kidney disease, poor nutrition, pernicious anemia, pregnancy, sickle cell anemia, thalassemia, alcoholism, bone marrow-related anemia, aplastic anemia, hemolytic anemia, anemia related to medication side effects, thyroid problems, cancers, liver disease, autoimmune diseases (lupus), paroxysmal nocturnal hemoglobinuria, lead poisoning, AIDS, viral hepatitis, mononucleosis, parasitic infections like hookworm, bleeding disorders, insecticide exposure, and from chronic diseases like the long-term medical condition of malaria (Liu et al., & Li, 2019; Saxena, 2018). Depending on the underlying condition, the symptoms of anemia are fatigue, decreased energy, shortness of breath, lightheadedness, palpitations, and looking pale (Liu et al., 2019; Saxena, 2018). Severe anemia symptoms may include chest pain, angina, heart attack, dizziness, fainting, or rapid heart rate (Saxena, 2018). As the causes and symptoms of anemia are many, an evaluation by a physician is recommended to diagnose the exact cause of the anemia. For this study, malaria-Induced anemia is inferred if a patient has both malaria and is anemic with no alternative visual cause, such as bleeding.

Malaria-Induced Anemia

Anemia associated with malaria (malarial anemia or malaria-induced anemia) is multifactorial and is usually associated with *P falciparum* infection (Ackerman et al., 2020). It may also be secondary to erythrocyte infection and loss of infected RBCs. The malaria disease directly targets the RBCs by the infection and proliferation of the *P Falciparum* parasites. Malaria-induced anemia involves increased removal of circulating erythrocytes (or RBCs) as well as decreased production of erythrocytes in the bone marrow. In children, malaria's course is often shorter and rapidly progress to severe malaria and then malaria-induced anemia condition, which can lead to sudden death if not treated timely.

Like malaria-induced anemia, thrombocytopenia is also commonly associated with malaria, but while malaria-induced anemia is usually due to factors like parasitic infections that may be associated with folate, iron, and/or vitamin B12 deficiencies, the thrombocytopenia condition is when the blood platelet count is low. Platelets or thrombocytes are the colorless blood cells that helps blood clot. Anemia and thrombocytopenia are the most frequent malaria-associated hematological complications and may be fatal without treatment (Ackerman et al., 2020; Khan et al., 2020). Malaria increases the risk of malaria-Induced anemia and thrombocytopenia in regions of higher transmission and young children (infants in particular), and pregnant women have the greatest impact (Ackerman et al., 2020; Khan et al., 2020).

Cyclical Infection of Humans and Female Anopheles Mosquitoes

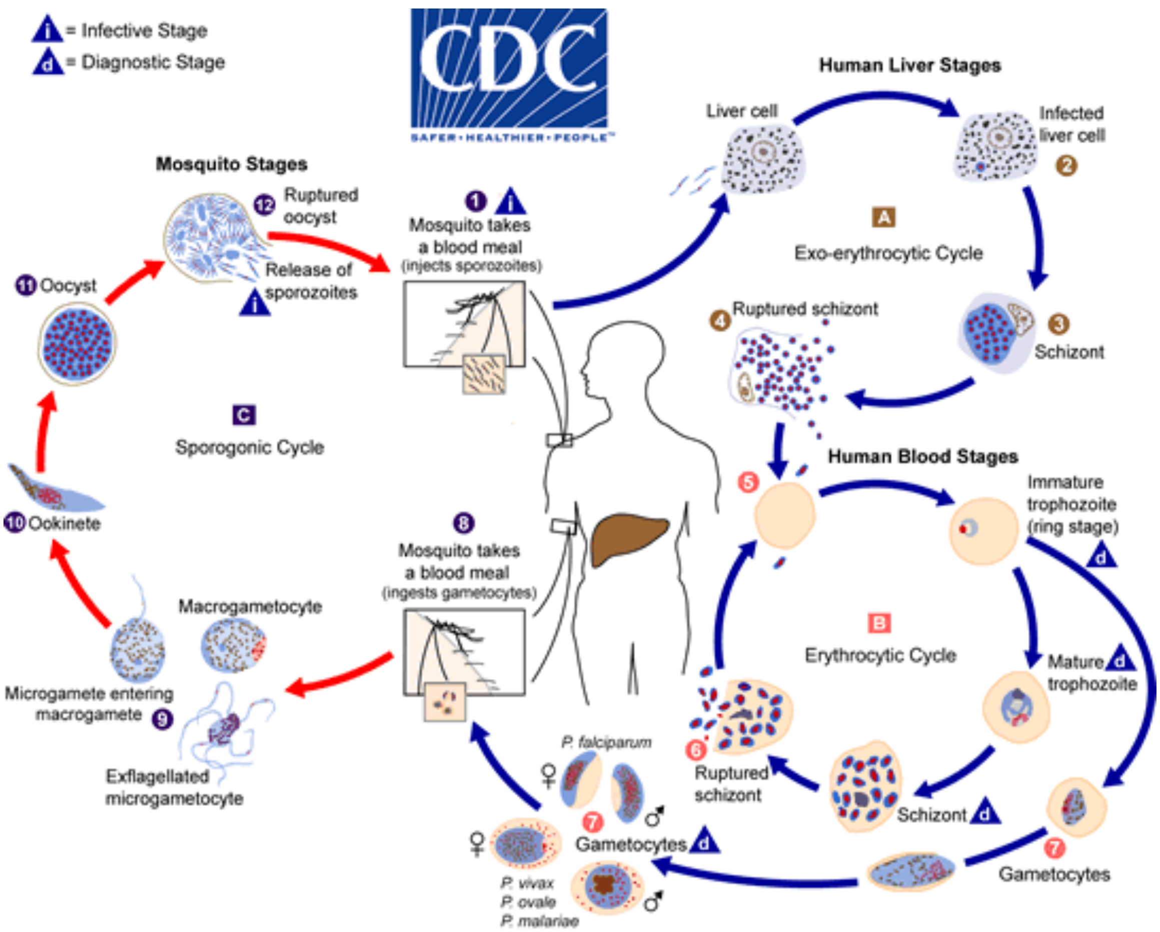
The infected mosquito carries the malaria parasite disease from one human to another and the infected human transmits the parasite to the mosquito that feed on infested humans; however, while the mosquito is a vector, the human is a host and suffers from the presence of malaria parasites (CDC, 2020a; Okwa, 2019). Once a human is infested, the parasites grow and multiply in the liver cells and then moves into the RBC. The parasites will continue growing and multiplying in the RBC, thereby destroying the RBCs. Merozoites are also released from the RBCs and invades other RBCs until it reaches the malaria symptoms stage.

When certain blood stage parasites are ingested by *Anopheles* mosquitoes during blood feeding, they mate in the mosquito's gut and starts a cycle of growth and multiplication in the mosquito, producing sporozoite parasite that migrates from the mosquito's gut to its salivary glands. During human socking, anticoagulant saliva and sporozoites are injected into the human, and migrates to the liver to begin another cycle. The cycle lowers the number of healthy RBCs in the body - a condition known as malarial anemia (or malaria-induced anemia) condition, and in a severe stage causes severe anemia.

Figure 2 depicts the malaria parasite life cycle. The cycle involves two hosts: when the human is the host and when a malaria-infected female *Anopheles* mosquito is the host. While a malaria-infected female *Anopheles* mosquito is feeding on human blood, she inoculates sporozoites into the human host (see 1 in Figure 2). The sporozoites will infect the liver cells (see 2) and stay there if left untreated for some time until they mature into schizonts (see 3). While in the liver, the sporozoites may enter a dormant stage known as hypnozoites for weeks or even years. The schizonts will rupture after some time and release merozoites (see 4). This is the initial replication process in the liver, and it is known as the exo-erythrocytic schizogony (see A in the figure). Also, in the liver, the parasites undergo asexual multiplication in the erythrocytes. This asexual multiplication is known as erythrocytic schizogony (see B).

Figure 2

Malaria Parasite Life Cycle (source: https://www.cdc.gov/malaria/about/biology/index.html)



Note. Adapted from "Global Health, Division of Parasitic Diseases and Malaria: The Malaria Parasite Life Cycle." (https://www.cdc.gov/malaria/images/graphs/life_cycle/Malaria_LifeCycle_1.gif). Copyright 2021 by Centers for Disease Control and Prevention. Royalty-free Reprinted Image.

The merozoites infect red blood cells (see 5) and the ring stage trophozoites mature into schizonts, which rupture and releases merozoites. The gametocytes stage (see 7) is when some parasites differentiate into sexual erythrocytic stages (CDC, 2020a). The clinical manifestations of malaria disease occur at the blood stage parasites and are responsible for the clinical manifestations of the disease. The *Anopheles* mosquitos ingests the gametocytes during a blood meal (see 8). The male gametocytes are known as microgametocytes and the female gametocytes are known as macrogametocytes (CDC, 2020a). The multiplication of these parasites in the mosquito is known as the sporogony cycle (see C). While in the mosquito's stomach, the microgametes will penetrate the macrogametes and form zygotes (see 9). The zygotes will in turn become motile and elongated (ookinetes) (see 10) and will invade the midgut wall of the mosquito where they develop into oocysts (see 11). The oocysts continue to grow, rupture, and release sporozoites, and make their way into the mosquito's salivary glands (CDC, 2020a). The inoculation of the sporozoites into a new human host and perpetuates the malaria life cycle (see 1 again).

Malaria-Induced Anemia in Children

More than 90% of malaria cases occur in sub-Saharan Africa, with immune-naïve individuals such as children younger than 5 years old and pregnant women bearing the most burden (CDC, 2020a, Sumbele et al., 2016; Okwa, 2019). The children of this age group are yet to develop the necessary immunity against the malaria parasite and unable to defend themselves as much as other age groups who have built some immunity as they grew older into other age groups from malaria prevention or malaria treatment medication in endemic regions (CDC, 2020a; Medicines for Malaria Venture [MMV], 2019). Also, when women are pregnant, their immunity is reduced making them more susceptible to infection and the risk of illness is greater; thereby, more susceptible to malaria-induced anemia and death if not treated timely (CDC, 2020a). Most sub-Saharan African's children's malaria-related morbidity and mortality are due to the infestation of the *P. falciparum* with cases of hyper-parasitemia, hypoglycemia, cerebral malaria, malaria-Induced anemia, and respiratory distress (Opoka et al., 2020). Of these sequelae of diseases, Opoka et al. (2020) suggested that malaria-Induced anemia is responsible for majority of malaria-related morbidity and mortality in children. Newborns are protected from malaria during the first few months of life from their mother's antibodies that are transferred to them from birth but as these antibodies decrease with time, the children become vulnerable to the disease and subsessile to death if malaria-Induced anemia becomes severe enough. With treatment and survival of repeated infections experienced in sub-Saharan African regions as they grow older, age of 2-5 years old and older, they start to rebuild their semi-immune status again (Opoka et al., 2020). That it, their immune against malaria gets stronger than when they were less than 5 years old.

Malaria Disease Burden

Malaria remains a primary cause of morbidity and mortality in Nigeria, other sub-Saharan countries, and some parts of Asia (Morakinyo et al., 2018; Sumbele et al., 2016). Of the malaria cases in Africa in 2015, 25% of the cases were in Nigeria (Morakinyo et al., 2018). Severe malaria usually manifests as extreme weakness, impaired consciousness, severe anemia, respiratory distress, convulsions, hypoglycemia, and other symptoms, and children less than 5 years of age are most at risk (Morakinyo et al., 2018).

Malaria is a major cause of anemia in children in sub-Saharan Africa than it is in other regions around the globe (Morakinyo et al., 2018; Oduwole et al., 2019). Anemia is the reduction in the expected level of hemoglobin in the blood (WHO, 2016b), and understanding the impact of the association between malaria and anemia caused by malaria in the Nigerian population is essential to understand the best public health approaches in implementing malaria interventions/evaluations and mitigation (Meremikwu et al., 2013). Anemia affects 273 million children and 529 million women globally (WHO, 2015). Like malaria, anemia cases from all causes are prevalent in children less than 5 years old, which represented about 62.3% of cases in sub-Saharan Africa (WHO, 2015). Anemia's public health impact ranges from a moderate to a severe condition and is associated with other health morbidity and mortality in Sub-Saharan Africa (Achidi et al., 2012). Less than half of the patients who had malaria were infected with the *plasmodium falciparum* parasite (Sumbele et al., 2016).

Economic Impact of Malaria

An estimated 228 million clinical cases of malaria and 405,000 malaria deaths occurred in 2018, most of which were sub-Saharan African children's cases and deaths (WHO, 2020). With these amounts of illnesses and deaths, malaria is a great drain on the economies of poorer nations, thereby maintaining a vicious cycle of disease and poverty. Factoring in the cost of healthcare, absenteeism, days lost in education, decreased productivity due to brain damage from cerebral malaria, and loss of investment and tourism, the economic impact of malaria on Africa is estimated at $12 billion each year (Centers for Communication Programs, 2020). African households spend $2 and $25 on malaria treatment and between $15 and $20 on prevention each month with consequent loss of resources (Alonso et al., 2019; Onwujekwe et al., 2013). Data analysis from the 2013 Nigeria Demographic and Health Survey showed that malaria treatments, prevention cost, and loss of man-hours set Nigeria's Gross Domestic Product (GDP) back by 40% annually costing an estimated 480 million naira (about 1.25 million U.S. dollars) (National Population Commission [NPC]; 2014).

In the cross-sectional study involving the community and hospital-based surveys, Onwujekwe et al. (2013) used a random sample of 500 households with an interviewer-administered questionnaire to interview the patients. Also, 125 exit interviews were done on inpatient department stays (IPD) and outpatient department visits (OPD) were conducted, and these were complemented with data abstraction from 125 patient records. They found that the average household expenditure per case was 12.57US$ and 23.20US$ for OPD and IPD respectively. The recurrent provider costs per malaria case were 30.42 US$ and 48.02 US$ for OPD and IPD, while non-recurrent provider malaria cost was 133.07 US$ and 1857.15 US$ for OPD and IPD respectively (Onwujekwe et al., 2013). They concluded that the removal or decrees of user fees or out-of-pocket spending for the treatment of malaria will significantly decrease the economic burden of malaria for the public and the health system.

Studies Related to Malaria and Anemia

In a cross-sectional study by Sumbele et al. (2016) to explore the impact of malaria on children between the ages of 1-14 years old in the Regional Hospital Annex-Buea in Cameroon, they found that the prevalence of anemia was 62.0%. Children younger than 5 years old had the highest cases of anemia from complications of malaria at 67.6% for the age group 1–5 years compared to other age groups (6–10 and 11–14 years age groups) (Sumbele et al., 2016). The difference in cases observed among this group was statistically significant, $p = 0.036$ (Sumbele et al., 2016). The mean age of the study participants was 6.3 +/- 4.1 years, and 216 patients were enrolled at an 85% enrollment rate (Sumbele et al., 2016). The sample size was calculated using the prevalence of *P. falciparum parasitemia* in the study region of 36.6% and anemia prevalence of 94.7% (the anemia prevalence in a hospital-based study in the Mount Cameroon area) (Sumbele et al., 2016). The sample size for their study was determined with the formula z^2pq/d^2. In this formula, the standard normal deviate, z, was 1.96 at 95% CI; p values were 36.6% and 94.7%; q was $1 - p$; and d was 0.05 (the accepted error). The average optimum sample size from both sample sizes was 217 (Sumbele et al., 2016). The sample size was optimal for the study and provided at least a minimum statistical power of 80%.

This study of malaria impact on children between the ages of one year old and 14 years old to assess the Moderate to Severe Anemia (MdSA), and Moderate to Severe Malaria-Induced Anemia (MdSMA) among this group of children was done during the peak of Cameroon’s malaria transmission season of May through August of 2014 (Sumbele et al., 2016). The prevalence of malaria was significantly higher in children who had a fever when compared to those without a fever, 41.1% and 26.6%, respectively with $\chi^2 = 5.09$, $p = 0.024$ (Sumbele et al., 2016). The children with a positive malaria parasite and those with a fever had significant anemia episodes *(*$\chi^2 = 3.96$, $p = 0.047$*; and* $\chi^2 = 4.57$, $p = 0.033$ respectively). Children with a fever and malaria parasitemia had higher anemia episodes (79.5%) compared to those with fever alone (61.9%) (Sumbele et al., 2016). For the study, age group, gender, socioeconomic status (SES), educational level, altitude, family size, splenic, and nutritional status were accounted in the analysis using multinomial logistic regression and the data was analyzed using the IBM's Statistical Package for Social Sciences (SPSS) version 20 software (Sumbele et al., 2016). Overall, Sumbele et al. (2016) concluded that residing in lowland altitude and being febrile were statistically significant predictors of MdSA, $p = 0.02$, and $p = 0.016$, respectively. They also emphasized that being febrile was the only statistically significant predictor of MdSMA, $p = 0.016$ (Sumbele et al., 2016).

Hashim and Ali (2017) conducted a prospective cohort study to explore the anemia pattern by malaria status among children hospitalized in Khartoum state in Sudan between August and November of 2014. They recruited 112 Children aged two months old to 15 years of both sexes. They reported that 55.6% of the children recruited and did not have malaria had anemia and 61% of the children recruited and have severe malaria had anemia. This study supported the findings described by Sumbele et al. (2016), suggesting that not all malarial patients developed anemia. According to Hashim and Ali (2017), anemia was significantly common in children younger than 5 years old (33.9%, versus 13%, $p = 0.010$) than any other age category (24.6% versus 25.5%, $p = 1.000$), regardless of malaria status.

Of 828 children enrolled in a study conducted in low and highland areas of Mount Cameroon, 41.7% had malaria, 56.2% had anemia from all causes (27.7% had malaria-Induced anemia and 28.5% were non-malarial-anemia) (Teh et al., 2018). The cross-sectional community-based survey was conducted to assess the prevalence, intensity, and risk factors associated with malaria parasitemia, anemia, and malnutrition among children in the low and highland areas of Mount Cameroon (Teh et al., 2018). Children between the age of 6 months to 14 years were included in the study that was conducted between July and November 2017 (Teh et al., 2018). Non-malarial-anemia was defined as children with anemia and without a malaria-positive smear for *P. falciparum*. Based on the logistic regression analysis of the study variables, malaria parasite infection ($OR = 2.07$, $p = < 0.001$) and fever ($OR = 1.52$, $p < 0.04$) were significant risk factors to anemia (Teh et al., 2018). Overall, the odds of having malaria parasitemia was highest in children 5-9 years of age ($p < 0.001$) than the risk observed among children younger than 5 years old (Teh et al., 2018). Anemia prevalence was significantly higher ($p < 0.001$) in the less than 5 years old children (66.1%) than the 5-9 and 10-14 age groups and among children that were positive for malaria parasite (66.4%) than those that were negative (Teh et al., 2018).

Vorasan et al. (2015) suggested that malaria may affect neurological cognition in children and may result in short-term impairment of memory and language functions. The long-term effects of malaria infection on cognitive function were not well known. A retrospective cohort study among children aged between six and 17 years old in a primary-secondary school setting in Thailand was conducted to explore malaria impact on school performance (Vorasan et al., 2015). Four hundred and fifty-seven study patients were enrolled in the study after the ethics committee approved the informed consent and assent were provided to the participants, parent, and their child, respectively, and consented to participate in the study (parent and their child) respectively (Vorasan et al., 2015).

The study analysis was conducted using the student *t*-test and Analysis of Variance (ANOVA) to estimate the mean differences between groups (Vorasan et al., 2015). Logistic regression was used to determine the crude odds ratio using a 95% confidence interval (CI) of school performance predictive factors (Vorasan et al., 2015). There was no statistically significant association between childhood malaria infection and school performance, but childhood malaria infection may affect cognitive functioning and could lead to impairment of memory and language functions (Vorasan et al., 2015). It is possible that there was no significant association in the study because the target location was a low malaria-endemic area, the duration of the malaria infection was short, and school absenteeism may have been caused by other issues other than malaria (Vorasan et al., 2015). Parents' SES, low emotional intelligence (the child's concentration, attention, behavior, etc.), and environmental factors are other indicators that could influence school performance (Vorasan et al., 2015).

The Risk Factors of Malaria

Nearly half of the world's population was at risk of malaria in 2018 and sub-Saharan Africa suffered the highest risk (WHO, 2020). Those population groups that cannot afford to seek health care due to financial means and those who will not seek medical care for religious or cultural reasons are at a higher risk of contracting malaria that will develop into malaria-Induced anemia, than other population groups. The first symptoms of malaria are fever, headache, body pain, and chills and if medical attention is sort within 24 hours, *P. falciparum* malaria may not progress to severe malaria and anemia condition (WHO, 2020). Children under the age of 5 years old, being pregnant, HIV/AIDS patients, and travelers are other risk factors for malaria.

Malaria Management

Although there is a current study on the development of the malaria vaccine, vector control remains the main prevention or reduction of malaria transmission. Insecticide-treated mosquito nets, indoor residual spraying, and antimalarial drugs have been an effective way to reduce malaria transmission, but the effectiveness has reduced in recent times. The reasons for the reduction in effectiveness are mosquito resistance to insecticide, switch to alternative pyrethroid insecticides, cost to fumigate the house. While these vectors have been encouraging, WHO recommends urgent new and improved tools, and apply effective insecticide resistance management strategies in the global malaria eradication effort (WHO, 2020).

Current Malaria Interventions

In efforts to eradicate malaria in many countries around the world, the WHO launched the Global Eradication Program (GMEP) in 1955 (WHO, 2016a). In this effort, the chloroquine drug was introduced as the treatment regimen for malaria, and the Dichlorodiphenyltrichloroethane (DDT) chemical was used for mosquito control (WHO, 2016a). Also, in the open-label, noncomparative trial to assess the effectiveness of a 6-dose regimen of Artemether-Lumefantrine for unsupervised treatment of uncomplicated childhood malaria in Calabar, Nigeria, the parasitemia load at follow-up visits was used to assess the effectiveness of the drug (Meremikwu et al., 2013). Many countries in the west achieved the goal entirely of eradicating malaria and mosquito breeding spots. However, the success achieved in sub-Saharan Africa was sub-optimal (WHO, 2016a). By 1969, the program was terminated because of the adverse events caused by the chloroquine drug and carcinogenic effects of DDT chemicals (WHO, 2016a). Although GMEP was discontinued in 1969, the US and fourteen other countries were confirmed malaria-free zones by 1972 (WHO, 2016a). By 1987, 7 more countries received certification as malaria-free zones as well (WHO, 2016a). No additional country was certified malaria-free zone between 1987 and 2007 (WHO, 2016). Between 2007 and 2015, 5 more countries were certified as malaria-free zones, and 13 other countries reported zero indigenous cases in 2014 (WHO, 2016a). A country must achieve 3 consecutive years of 0 indigenous cases to be eligible to apply for the malaria-free zone certification status from the WHO (WHO, 2016a).

Increased investments in research on the public health burden of malaria have yielded many highly effective control tools such as long-lasting insecticide-treated nets (LLINs), rapid diagnostic tests (RDT), and artemisinin-based combination therapies (ACTs). Prominent scientists and key funding organizations brought about the wide-scale deployment of these tools with funds from the Global Fund to Fight AIDS, Tuberculosis, and Malaria, the US President's Malaria Initiative, and other financing mechanisms (WHO, 2016a). Malaria intervention funding has increased substantially since 2005. The global investment for malaria control increased from US$960 million in 2005 to US$2.5 billion by 2014 (WHO, 2016a). These efforts facilitated a dramatic decline in the global malaria burden in terms of incidence and mortality rates, 37% and 60% respectively, between the years 2000 and 2015 (WHO, 2016a). Effective malarial interventions have resulted in the eradication of malaria in the European regions (all countries in Europe reported zero malaria cases by 2015), Canada, and the United States. Malaria incidence and mortality are still high in sub-Saharan Africa and some parts of south-east Asia, South America, the eastern Mediterranean region, and the western pacific region (WHO, 2016a). These regions still struggle with malaria eradication efforts (WHO, 2016a) because the infrastructures build to fight malaria is just slowly being implemented. Therefore, there is a need to continue to reinforce the eradication efforts in these regions.

Visitors and migrants are risk factors of restarting the transmission of malaria disease in areas where *Anopheles* mosquitoes are present, and conditions for spreading the disease are favorable (WHO, 2016a). Therefore, even when a country has achieved zero-malaria status, maintaining zero-malaria cases does not only require high-level political support and intense programmatic efforts but require continuous infrastructural support to reduce the breeding environment that cohabitates mosquito vectors (WHO, 2016a). These findings underscore the need for continuous intervention in Nigeria and other sub-Saharan African countries struggling to reduce the prevalence of malaria and malaria-driven anemia conditions even after the initial initiative target has been met. Otherwise, the disease may return, and previous efforts achieved would decline.

Malaria and malaria-Induced anemia are still a public health problem contributing to high cases of morbidity and mortality in people of all age groups especially among children in sub-Saharan Africa (Kweku et al., 2017; Sumbele et al., 2016). One in 5 deaths among children in sub-Saharan Africa is due to malaria (Okwa, 2019; WHO, 2019a). Thirty sub-Sahara countries account for 90% of the global malaria deaths (Meremikwu et al., 2013; Okwa, 2019; WHO, 2019a). Besides the Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome (HIV/AIDS), the leading cause of death from infectious diseases in Africa is Malaria (Okwa, 2019; WHO, 2019a). Nigeria accounts for more cases and deaths from malaria than any other country in the world, and roughly 97% of the total population of Nigeria (approximately 173 million people) are at risk for malaria infection every year (WHO, 2019a). The remaining 3% of the population not affected by malaria are those who live in the highlands and malaria-free environment (WHO, 2019a). Similarly, anemia is also a public health threat to most of the individuals in sub-Sahara Africa. About 1.62 billion people worldwide are anemic from all causes but iron deficiency anemia is the most common type (Jingi, Kuate-Mfeukeu, Hamadou, Ateba, & Nadege, 2018). Of these amounts, approximately 800 million infants are anemic from all causes but often from pregnancy-related conditions (Jingi et al., 2018).

Globally, malaria and anemia, including malaria-Induced anemia, are the major causes of morbidity and mortality among children under the age of 5 years old (Kweku et al., 2017). According to the 2015 survey report by WHO, 212 million cases of malaria and 429,000 malaria-related deaths were reported worldwide (WHO, 2016b). About two-thirds of the cases occurred among African children under the age of 5 years old (WHO, 2016b). In 2015, a quarter of Africa's malaria cases occurred in Nigeria (Morakinyo et al., 2018; WHO, 2016a). Also, 60% of the outpatient visits and 30% of all hospital admissions in Nigeria are malaria-related cases (WHO, 2016b).

Kweku et al. (2017) assessed the impact of malaria control interventions on malaria and anemia in children under 5 years old in Hohoe Municipality, Ghana. For their study, the authors collected data in the June and November high malaria season in Ghana of the years 2006, 2010, and 2015. A total of 1717 children were surveyed in June and November of 2006. A total of 2155 children were surveyed in June and November 2010. And a total of 1915 and 1697 children were surveyed in June and November of 2015 respectively to monitor the trend of LLIN ownership and use, and its impact on malaria and anemia among children under the age of 5 years old in an area of intense, prolonged, and seasonal malaria transmission in Ghana (Kweku et al., 2017).

The nature of the surveys was cross-sectional, and the surveys were done at the beginning of the rainy season in June and then at the end of the rainy season in November which are the high and low transmission periods for malaria in Ghana. Although malaria transmission occurs throughout the year in Ghana, the high malaria transmission begins in June and ends in November (Kweku et al., 2017). Kweku et al. (2017) reported that malaria incidence rates fell by 42% globally and 37% in Africa and malaria mortality rates fell by 66% globally and 60% in the African region between 2000 and 2015.

Malaria topped most outpatient department hospital visits and kills 3 children every day in Ghana (Kweku et al., 2017). Malaria intervention programs such as the Millennium Development Goals (MDGs) and the Abuja Declaration have facilitated the reductions in deaths and illnesses attributed to malaria (Kweku et al., 2017; Sarpong et al., 2015). LLINs, IRS, intermittent preventive therapy for pregnant women, artemisinin-based combination therapy, and other up-scaling of malaria prevention and control interventions are some of the malaria control initiatives that helped to reduce malaria cases (Kweku et al., 2017; Sarpong et al., 2015). However, there is a need for further investigation on malaria and malaria-Induced anemia preventive measures, control, and treatment, especially the at-risk children below the age of 5 years old (Kweku et al., 2017; Sarpong et al., 2015; Sumbele et al., 2016). One reason for this need is that while LLIN was very effective in controlling malaria and malaria-Induced anemia between 2006 and 2010, the effectiveness was not as impressive between 2010 and 2015 even with the increasing trend of LLIN ownership at 20.8%, 42.2%, and 68.3% for 2006, 2010, and 2015 respectively – a significant positive trend in LLIN ownership ($p < 0.001$).

Unsuccessful Control/Elimination of Malaria in Sub-Saharan Africa

The failure for sub-Saharan Africa to sustain the 1955 GMEP prior to the dissolution of the program in 1969 resulted in the resurgences of malaria (WHO, 2016a). During the GMEP implementation era, 15 countries and a territory (Bulgaria, Cyprus, Dominica, Grenada, Hungary, Italy, Jamaica, Netherlands, Poland, Romania, Saint Lucia, Spain, Taiwan, Trinidad and Tobago, United States of America, Venezuela) eliminated malaria and several countries greatly reduced their malaria burden. However, no major success occurred in sub-Saharan Africa (WHO, 2016a). Between 1972 and 1987, Australia, Brunei, Cuba, Mauritius, Portugal, Réunion, Singapore, Yugoslavia also joined the WHO's zero indigenous countries, but no country achieved this feat between 1987 and 2007 (WHO, 2016a). Of the 39 countries and territories that achieved this milestone by 2020, Algeria and Morocco were the only African countries that have achieved this feat and are not in the sub-Saharan African region (WHO, 2021).

Malaria transmission rates differ by local factors such as rainfall patterns, available infrastructure, proximity of mosquito breeding site to residential areas, and the type of mosquito species in the region. Of the 5 types of malaria parasites (*P. falciparum*, *P. Vivax*, *P. malariae*, *P. ovale* and *P. Knowlesi*), *P. falciparum* was the deadliest and responsible for 94% of malaria cases and deaths globally in 2019 (Al-Awadhi et al., 2021). *P. falciparum* is the most prevalent malaria parasite in sub-Saharan Africa, while *P. vivax* is dominant in other continents (Awadhi et al., 2021; Arroz, 2017; Olaso-Bengoechea et al., 2021; WHO, 2016a). In the Americas, 77% of the infections are due to *P*. vivax (Pan American Health Organization [PAHO], 2019). Malaria was eradicated in the United States, Europe, and other regions of the world through a combination of Insecticide Spraying, drug therapy, and environmental engineering. While sub-Saharan Africa and her stakeholders have invested heavily on these combination of malaria interventions, there is more work to be done in environmental engineering.

The development of the *P. falciparum* parasite depends on the region's temperature (Bancells et al., 2019). The parasite develops in the female Anopheles (sporogony) between 25°C and 30°C and the development ceases below 16°C (Bancells et al., 2019). That is, cold temperatures delay the growth of sporogony, and the period immediately after the infective bite by the female anopheles' mosquito on an infected human host is sensitive to temperature drops. Also, when the temperature is high, (above 35°C), sporogony slows down considerably and smaller and less fecund adult mosquitoes are formed, and at 40°C to 42°C, the mosquitoes die (Bancells et al., 2019). Because of the climate in sub-Saharan Africa there is several challenges to human habitation, including parasites and insects that breed prolifically in warm and wet climates (Thomson et al., 2017). These causes the spread of debilitating diseases such as malaria, if not treated timely, malaria-induced anemia. Secondly, the female Anopheles mosquitos cannot lay their eggs without stagnant surface water and rainfall helps the mosquitos' survival; therefore, covered drainage systems covering of potholes aided in the eradication of malaria in other regions but in sub-Saharan Africa.

Malaria Funding Sources

Countries with a high malaria burden are usually low income or lower-middle-income, therefore, access to resources needed to fight the disease is problematic (Haakenstad et al., 2019). As such, many countries in sub-Saharan Africa do not have the resources to reach or attain a zero indigenous malaria goal (Haakenstad et al., 2019). Using an economic modeling approach, Haakenstad et al. (2019) tracked the malaria screening financial sources on malaria in 106 malaria-endemic countries between 2000 and 2016. Government, Out-of-Pocket (OOP), and Prepaid Private Spending (PPS) are the three financing sources used to estimate the domestic malaria spending. The total malaria spending per country was linked to the region, malaria elimination status, and the income group of the country (Haakenstad et al., 2019). The bulk of the malaria spending between 2000 and 2016 was in the lower-middle-income countries (47.1%, 45.6–48.5; $19.3 billion, 18.4–20.4), followed by low-income countries (36.9%, 35.7–38.0; US$15.1 billion, 14.8–15.5), excluding Development Assistance for Health (DAH) costs (Haakenstad et al., 2019). In 2016, 86.2% of all malaria cases occurred in sub-Saharan Africa with a corresponding malaria spending of US$28.6 billion (27.7–29.7 at 95% Confidence Interval, CI) (Haakenstad et al., 2019).

About US$2.7 billion (2.6–2.8 CI) was spent in sub-Saharan Africa when compared to the global spending of US$4·3 billion (4·2–4·4 CI) spent on malaria worldwide (Haakenstad et al., 2019). The global spending increase in the year 2000 was 8·5% (I8·1 – 8·9 CI) per year, and since 2000, the spending has been increasing (Haakenstad et al., 2019). OOP spending increased by 3·8% (3·3 – 4·2 CI) per year (Haakenstad et al., 2019). Malaria's worldwide spending is estimated to reach US$6.6 billion annually by 2020 (Haakenstad et al., 2019). The three primary funding sources for malaria are "the US President's Malaria Initiative, the Global Fund, and the UNITAID. These funding sources have helped several malaria efforts and mobilization of resources in implementing and facilitating assistance for the eradication of the disease (Haakenstad et al., 2019).

The US President's Malaria Initiative, PMI

The initiative was launched in 2005 by the US president, George W. Bush (President's Malaria Initiative [PMI], 2019a). A public health effort to control and eliminate malaria in the world and has been continued by each president after him (PMI, 2019a). The US Government's role in funding malaria eradication programs is a remarkable public health effort (PMI, 2019a). Hundreds of millions of people worldwide have benefited from PMI through access to protective measures, diagnosis, and treatment for malaria (PMI, 2019b). Some of the benefits of PMI are that it expanded the coverage of life-saving malaria interventions, implementation of new malarial remedial approaches, and use of survey and information sharing for educational purposes (DHS, 2019; PMI, 2019b).

Malaria kills a child every 30 seconds, but with the collaborative partnership effort of PMI, the national governments, international organizations, and local partners, the initiative is now saving three of four children every two minutes that could die in the absence of the PMI (PMI, 2019b). Based on the 13th annual report of the US congress published in 2019, at least 90 million more people benefited from PMI in the 2018 fiscal year than they did in the 2017 fiscal year. That is, 570 million people benefitted in 2018 versus 480 million people who benefitted from PMI; and the total number of deaths dropped by 46,007 between 2017 and 2018 (PMI, 2019b). Approximately $723 million across 27 countries was allocated for malaria in 2018 (PMI, 2019b). Each country presented environmental, political, and unique challenges that influence malaria interventions and described progress made to reduce the cases of malaria before the new funds are released (PMI, 2019b). PMI also supports and funds open e-learning courses on assessing malaria trends via household surveys, training of health professionals, and creating a network of African scientists with advanced monitoring skillsets required to identify and address antimalarial drug resistance problems (PMI, 2019b). PMI established a strong partnership with the Global Fund, and Bill & Melinda Gates Foundation to advance the public health efforts in collecting, analyzing, sharing of malaria data, delivering proven tools and medicines, and improving intervention efficiency (PMI, 2019b).

The Global Fund

In 2019, US$12.5 billion was invested in malaria control programs and eradication efforts, globally (Global Fund, 2019). In comparison, roughly, US$2.7 billion was used in 2018, and US$3.2 billion was expensed in 2017 for global malaria efforts (Global Fund, 2019). Overall, the Global Fund funded about 65% of the global malaria efforts to support a comprehensive approach that includes the followings:

- The symptoms, prevention, and treatment education
- Use of mosquito nets, insecticides, and preventive treatment
- Rapid diagnostic tests to community health workers
- Treatment

UNITAID

Unitaid efforts are intended to improve access to HIV/AIDS, malaria, and tuberculosis treatments. The goal is to leverage price reductions of quality drugs and diagnostic approaches to accelerate its availability to the people (Unitaid, 2019). Unitaid was founded in 2006 and has received over US$2.5 billion for public health projects. Unitaid is funded by France, the United Kingdom, Norway, the Bill & Melinda Gates Foundation, Brazil, Spain, Chile, and the Republic of Korea (Unitaid, 2019). The donations are used to promote the accessibility of promising health solutions or intervention to many underserved communities (Unitaid, 2019). Unitaid currently partners with the Global Fund to promote malaria eradication efforts (Unitaid, 2019). The project cycle for this partnership is 2018 to 2022 with a grant budgeted at US$66 million (Unitaid, 2019). Both the Unitaid and Global Fund budgeted US$33 million each for the project to provide treated nets with insecticide combinations to sub-Saharan African countries (Unitaid, 2019).

Malaria Control and Eradication Efforts in Sub-Saharan African Countries

Since 2008, the US PMI program in partnership with Ghana's AngloGold Ashanti (AGA) provided an IRS for malaria control in Ghana (Abuaku et al., 2018). Abuaku et al. (2018) conducted two cross-sectional surveys in the high and low transmission season areas to assess the impact of the IRS scale-up exercise on malaria parasitemia among children younger than 5 years old (Abuaku et al., 2018). Chi-square and Fisher's exact tests were used to analyze the association between parasitemia and low and high transmission seasons (Abuaku et al., 2018). SPSS version 21 software was used to compute the data analysis (Abuaku et al., 2018). Also, multivariate logistic regression was used to examine the association after accounting for gender. The authors found that about 77.7% of the children had anemia (Hb $<$ 11 g/dl) at the end of the high transmission season pre-IRS survey. With the post-IRS survey assessment, about 67.8–72.5% had anemia following the application of pyrethroid insecticide. Post-IRS surveys and after the use of organophosphate insecticide, anemia cases were between 48.3–57.0% (Abuaku et al., 2018).

Mali had IRS intervention from the US PMI program. Mali explored two different non-pyrethroid insecticides spraying: bendiocarb in 2012 and 2013 and pirimiphos-methyl in 2014 and 2015 (Wagman et al., 2018). To assess the impact of the IRS campaign in Mali, Wagman et al. (2018) conducted a retrospective time-series analysis on over a million and a quarter rapid diagnostic test-confirmed cases of malaria in the Segou Region of Mali from January 2012 to January 2016. A quasi-experimental time-series approach was used for the analysis, and the study data were stratified by the status of IRS and non-IRS districts (Wagman et al., 2018). They found that IRS campaign was a cost-effective public health intervention (Wagman et al., 2018).

On the investigation of malaria and anemia control in Ghana, with the collaborative involvement of PMI and the Ghana Health Service, Kweku et al. (2017) monitored the trend of long-lasting insecticide net ownership, its use during a ten years-period, and the prevalence of malaria and anemia on children younger than 5 years old. A cross-sectional study covering 2006, 2010, and 2015 on two seasons in each of the years was performed (Kweku et al., 2017). Children aged 6-59 months were included in the study and the study spanned from June and November to correspond to the pre-rainy and post-rainy seasons, respectively, of the high transmission periods for malaria in Ghana (Kweku et al., 2017). The parents or guardians of the children signed the Ethical Review Committee's approved Informed Consent before study participation (Kweku et al., 2017). STATA statistical software version 12 was used to analyze the data. Malaria parasitemia, gametocytaemia, fever, and anemia data were collected in 2010 and 2015 for comparison with data collected in 2006. They concluded that LLIN ownership and use improved within 5 and 10 years after the intervention and recommended further investigation on the factors contributing to other malaria prevalence indicators (Kweku et al., 2017). Seasonal malaria indicators and indoor insecticide paints use were suggested as an improvement approach for malaria control indicators (Kweku et al., 2017).

Threat of Re-Establishment of Malaria

Eradication of malaria is important in maintaining quality public health efforts in any country or region. Therefore, once a low or zero-malaria zone is established the effort continues to ensure the maintenance of low or zero cases of malaria within that country or region. The WHO defined re-establishment of the disease transmission as the occurrence of three or more cases of malaria per year and caused by the same species within a given area or location in three consecutive years (WHO, 2018c). Re-establishment could occur through many factors, individual visitors and migrants exposed to *Anopheles* mosquitoes could be infected by malaria parasites (WHO, 2018c). Female *Anopheles* mosquitoes are the malaria parasite vector and the parasite reproduce in the mosquitoes (WHO, 2018c). *Anopheles* mosquitoes feed on human blood, as the parasite suck, the parasites are deposited into the bloodstream via the mosquito's salivary glands (WHO, 2016c).

Malaria symptoms may not manifest until three to seven days (and occasionally up to sixteen days) post malaria parasite infection (WHO, 2016c). Malaria transmission can occur in any location or geographic area and as a result countries that attained a "malaria-free-status" or those that made substantial progress in the reduction of malaria should maintain adequate surveillance systems and contact tracing to quickly detect malaria cases, diagnose, and treat individuals infected (WHO, 2016c). For instance, Sri Lanka reported first case of re-establishment of malaria after the disease has been eliminated (Karunasena et al., 2019). Sri Lanka achieved the malaria-free-status certification from WHO in 2012, and no cases were reported for six years after the certification until a case of imported vivax malaria was re-introduces into the country (Karunasena et al., 2019). Sri Lanka's surveillance and response team detected the parasite and was traced to a foreign migrant visiting the country. Genetic characterization and contact tracing occurrence were linked to the two cases confirmed (Karunasena et al., 2019). The cases were treated, and no further transmissions has been reported and surveillance and response infrastructure were instrumental in stopping further spread of the infection (Karunasena et al., 2019).

Current Knowledge and Next Steps

Many malaria, and malaria-Induced anemia studies described were conducted using a cross-sectional design approach. Population indicators such as prevalence, incidences, and mortality are key determinants of the level of the impacts of malaria (Olukosi & Afolabi, 2018; Saaka & Glover, 2017; Sadoine et al., 2018). Most of the malaria control measures described in many literature are bed nets (both insecticide-treated and non-treated nets) and artemisinin-based combination therapy (ACT). Ultimately, insecticide-treated bed nets, artemisinin-bases combination therapy, and insecticide residual spraying are the main contributors attributed to the control and prevention of malaria in sub-Saharan Africa (Sadoine et al., 2018). Improved living conditions, vector control interventions, and effective treatment measures are effective in controlling and preventing malaria (Sadoine et al., 2018; Sumbele et al., 2016). Similarly, alternative land use, population growth, inadequate housing and infrastructure, and malaria intervention awareness adversely affected malaria eradication efforts in Nigeria and other sub-Saharan countries (Sadoine et al., 2018; Sumbele et al., 2016).

Using 11 articles that met their inclusion criteria for the study, Sadoine et al. (2018) performed a meta-analysis to explore the association between malaria, interventions, and environment. They concluded that bed net ownership was statistically associate with decreasing malaria risk when controlling for the effects of environment with a pooled odds ratio (*OR*) of 0.75 (95% CI .060, 0.95) (Sadoine et al., 2018). In another cross-sectional study on malaria, anemia, and malaria-Induced anemia among children at presentation to hospital in the Mount Cameroon area, the prevalence of anemia is high in febrile and malaria parasite positive children with moderate to severe anemia (Sumbele et al., 2016). Similarly, Sumbele et al. (2018) found that environmental effects (lowland versus highland was significantly associated with moderate to severe malaria-Induced anemia (Sadoine et al., 2018; Sumbele et al., 2016).

Summary and Conclusion

The literature review on malaria and anemia described in this chapter included morbidity and mortality from malaria, malaria parasite types, and how humans are infested. The current malaria interventions implemented in sub-Saharan Africa and the primary malaria public health funding sources were also discussed. Similarly, the control measures and eradication efforts promoted in sub-Saharan African countries including treatments and successes achieved were presented. Preventing re-establishment of malaria was discussed as well. The theoretical foundation, SEM, used in explaining the variables of interest in this study was explained. Published public health interventions where SEM was implemented to facilitated health promotion measures was discussed in detail.

Financial and technical capacity are constant issues that most sub-Sahara African countries struggle with as they move in the direction of trying to eradicate malaria and mosquito in the region. Therefore, the funding sources for the fight against malaria in sub-Saharan Africa was included in my Chapter 2 discussion. Chapter 3 described the study design, methodology, sampling technique, inclusion and exclusion criteria, statistical analyses, and the benefits and limitations of using secondary data.

Chapter 3: Methods

Introduction

Malaria-induced anemia has not been adequately studied in many sub-Saharan Africa countries, including Nigeria, Chad, Cameroon, Ghana, Niger, Mali, and Mozambique (Sumbele et al., 2016). Many children are dying daily from malaria, though it is a preventable and treatable disease. Therefore, public health and epidemiological need to examine the link between malaria and anemia in children less than 5 years old. I also explored the association between malaria medication use and malaria-induced anemia status among these selected children among those who tested positive for malaria. I accounted for parents' education and mosquito net use in these associations. To further understand the association, I assessed how malaria-induced anemia may be associated with gender; and last, how residence type, parents' educational level, malaria medication use, and mosquito net use may be related to malaria-induced anemia were analyzed. The research design and rationale, methodology, and threats to validity were explained in detail in this dissertation section.

Research Design and Rational

In this quantitative study, I used secondary data for the data analysis of the current study. The DHS secondary data collected in 2015 was used for the study data analysis. The 2015 DHS dataset was collected using a cross-sectional design. A cross-sectional approach is a research design used to investigate the prevalence, incidence, and risks of a health outcome or even exposures at a given period (Creswell, 2013; Donald, 2007; Mann, 2003). A cross-sectional design is cheaper than other research designs, such as longitudinal designs (prospective cohort design), quasi-experimental, and experimental approaches (Creswell, 2013; Donald, 2007; Mann, 2003). In other words, by using a cross-sectional study design and a secondary data approach, the data collection timeframe was substantially reduced or nonexistent compared to the longitudinal or experimental design approach. All the key variables stated in the posed research questions (malaria, anemia, gender, parents' education level, and mosquito net use) were captured (collected and present) in the 2015 DHS dataset (DHS, 2018).

I did not use a longitudinal design or prospective cohort or any other research design in this current study because the 2015 DHS design was a cross-sectional approach. The cross-sectional design inherently can produce limitations such as recall, rumination, participants, selection, misclassification, and researcher's biases (Creswell, 2013). Another limitation of a cross-sectional design is that, in the absence of an experimental or a quasi-experiment finding, a causal inferential conclusion cannot be made regarding the association between a predictor or an exposure variable and an outcome variable (Creswell, 2013). In such cases, only a correlational decision could be drawn from such a study (Creswell, 2013). As such, the use of the 2015 DHS data to address the research questions posed in this current study was only used to draw a correlational association between the predictor and outcome variables of interest identified in the posed research questions.

The first research question, RQ1, is intended to investigate the risk of anemia among children less than 5 years old in the rural versus urban areas of Nigeria who had malaria against those who did not have malaria after accounting for parents' education and mosquito net use. The second research question, RQ2, is intended to investigate the relationship between malaria medication use in these children who tested positive for malaria after accounting for parents' education level and mosquito net use may be associated with malaria-induced anemia. For RQ3, I investigated how gender may be associated; RQ4 investigated the association of residence type, parents' education level, malaria medication use, mosquito net use, and age group associated with malaria-induced anemia.

The independent variable, dependent variable, confounder variable, the key research comparison criteria, and subject's inclusion criteria are listed in Table 1. The independent variable for RQ1 was malaria status, which can be determined by identifying children that tested positive and those that tested negative for malaria. Therefore, malaria status was grouped into two nominal groups (malaria and no malaria). Malaria medication use, determined by whether a child had ever used malaria medication at least once. This variable was also a nominal variable of yes or no. Gender was the independent variable for RQ3. For RQ4, the nominal variables residential type, parents' education level, malaria medication use, mosquito net use were the independent variables. The dependent variable for the four research questions was malaria-induced anemia. The controlling variables for RQ1, RQ2, and RQ3 were mosquito net use and parents' education level. Age group and gender were the controlling factors for RQ4. Gender was grouped into nominal groups as well (male and female). The size of the household location was used to determine the residence type. Urban areas were classified as large cities (capital cities and cities with over one million population), small cities (over 50,000 people), and towns. In contrast, all rural areas were assumed to be countryside.

Table 1

Study Variables

	Independent Variable	Dependent Variable	Confounders	Key Research Comparison Criteria	Key Unit of Analysis Inclusion Criteria
RQ1	Malaria status	Malaria-Induced Anemia status	Parent education and mosquito net use	Children who had malaria against those who did not have malaria.	Children ages 0-5 years old. Residence type (rural or urban) in Nigeria.
RQ2	Malaria Medication Use	Malaria-Induced Anemia status	Parent's education and mosquito net use	Children who have used Malaria Medication vs. those who have not.	Children ages 0-5 years old who tested positive for malaria.
RQ3	Gender	Malaria-induced Anemia Status	Parents' education and mosquito net use	Boy or Girl.	Children ages 0-5 years old in Nigeria.
RQ4	Residence type, Parent's educational level, Malaria Medication use, Mosquito net use.	Malaria-induced Anemia Status	Gender and Age	Residence Type, Parent's Educational Level, Malaria Medication use, and Mosquito net use.	Children ages 0-5 years old in Nigeria.

Malaria and anemia status are nominal variables grouped into 'yes' for the positive cases and 'no' for the negative cases. Gender was grouped into two categories (female or male). The parents' educational level was grouped into three ordinal measurement levels: primary, secondary, and higher education. Mosquito net use was grouped into two categories (net use and no net use); residence type and malaria medication use are grouped into two categories (Rural or Urban) and (whether a malaria medication was ever used at least once, respectively. Age group is a nominal variable of whether the child's age is 36 months old and below, and those that are older than 36 months but less than 5 years. See Table 2.

Table 2

Study Variable and Level of Measurements

Study Variables	Level of Measurement	Survey Questions	Response Options
Anemia status	Nominal	Hemoglobin Result (Q#116)	Below 8.0 G/DL = Anemia (Anemia = 1), 8.0 G/DL and above = (No Anemia = 2)
Malaria status	Nominal	Record the result of the malaria Rapid Diagnostic Test (RDT) here (Q#115)	Positive (Yes Malaria = 1), Negative (No Malaria = 2)
Gender	Nominal	Is (Name) a boy or a girl? (Q#214)	Boy (1) or Girl (2)
Parents' Education	Ordinal	What is the highest level of school you attended?: (Q# 105). Parent's highest education achieved.	Primary Education (1), Secondary Education (2), or Higher (3)
Mosquito net use	Nominal	Did anyone sleep under this mosquito net last night? (Q#128)	Yes (1) or No (2)
Region	Nominal	Participant's parent's place of residence at the time of interview	Rural (1) or Urban (2)
Malaria medication use	Nominal	At any time during the malaria illness, did (Name) take any malaria drugs for the illness? (Q# 411)? (Artemisinin Combination Therapy (ACT), SP/Fansidar, Chloroquine, Amodiaquine, Quinine, Artesunate, and other antimalarial drugs)	Yes (1) or No (2)

Based on Tables 1 and 2, I used a quantitative research method to assess the relationship between the independent and dependent variables for each research question. For instance, in the first research question, malaria-induced anemia status (anemia or no anemia) is the dependent variable, and malaria status (malaria or no malaria) is the independent variable. For the second research question, malaria medication use (ever used or no use) is the independent variable, while malaria-induced anemia (anemia or no anemia) is the dependent variable. Parents' education and mosquito net use are the confounders for research questions 1, 2, and 3. The third research question has gender as the dependent variables and malaria-induced anemia status as the independent variable. Residence type, parent's educational level, Malaria medication use, and Mosquito net use are the independent variables, and Malaria-induced anemia is the dependent variable for the fourth research question; and was controlled by gender and age.

Methodology

The current research questions are quantitative. The dependent and independent variables levels of measurements are essential in determining the appropriate statistical analysis for the research inquiry. Also, the use of secondary data as the data source for any research will influence how the research questions are framed or posed. In other words, for secondary data-driven research questions, the variables (dependent, independent, confounder, and covariate) stated in the research questions must have been observed and captured in the secondary data source. The variable being explored in the current research questions were captured approximately 6 years ago in the 2015 DHS dataset. The 2015 DHS variables and measurements were obtained via a cross-sectional approach, which aligned with the current research design described in this study.

The United States Agency for International Development (USAID) funds the DHS program (DHS, 2018). The DHS project and the program's implementation are also sponsored by the ICF in several U.S. regions, including Rockville and Maryland, in partnership with the Johns Hopkins Bloomberg School of Public Health, Center for Communication Programs, the Program for Appropriate Technology in Health (PATH), EnCompass, Kimetrica, Vysnova, Blue Raster, and Avenir Health (DHS, 2018). The ICF was founded in 1969 by a former Tuskegee Airman and three U.S. Department of Defense analysts to finance minority-owned businesses in the Washington District of Columbia (DHS, 2018). The DHS administers its surveys every 5 years (DHS, 2018). The DHS surveillance goal is to help institutions collect and analyze data to facilitate planning, monitoring, and evaluating the population, projecting health outcomes, and nutrition-based interventions (DHS, 2018).

The activities of the DHS Program are intended to: 1). improved information through appropriate data collection, analysis, and evaluation; 2). enhance coordination and partnerships in data collection at the international and country levels; 3). increase host-country data collection capacity within the institutions; 4). improve data collection and analysis tools and methodologies, and 5). promote the dissemination and utilization of data (DHS, 2018).

Population

DHS employs several types of questionnaires for primary data collection processes (DHS, 2018). For instance, the household questionnaire is used to collect information on household demographic profiles such as member's composition, characteristics of the household's dwelling unit, and the use of insecticide mosquito nets (DHS, 2018). A biomarker questionnaire is used to collect data related to height and weight, malaria, hemoglobin, and each country’s specific indicator or indicators of particular interest such as HIV dry blood sample for an eligible household member if acceptable by local laws (DHS, 2018). Also, biomarker questionnaires are used to identify household members who are eligible for a self-reported interview (DHS, 2018).

Most DHS eligible participants are women of the reproductive age of 15-49 years and men aged 15-59 years. In some cases, the age may range between 15-54 years (DHS, 2018). In some instances, only women were interviewed in some countries (DHS, 2018). The Woman's Individual Level questionnaires include information on maternal and child health, fertility, family planning, contraceptive use, maternal mortality, circumcision, HIV knowledge, domestic violence, and other topics (DHS, 2018). De-identified datasets are available and accessible on the DHS website (DHS, 2018).

The DHS dataset is available in both raw and recodes formats (DHS, 2018). The raw data include information in their original format without any structural changes or recodes. They are not generally distributed (DHS, 2018). All recode datasets are generated from the raw dataset (DHS, 2018). Also, all variables captured and recorded in the raw data are represented in the recode data in a standardized format and contain the same structure across participating countries in each DHS phase (DHS, 2018). The standardized format facilitates internal validity and provides uniform questionnaire questions across participating countries (DHS, 2018). Per a country's request, DHS collects information from participants with other types of surveys and questionnaires pertinent to the country (DHS, 2018). Some of the additional data collected include information about education, health service providers, communities, young adults, household health expenditures, etc. (DHS, 2018). The additional data and information are available, but not all the data were structured in a standard format (DHS, 2018).

Study Population Inclusion and Exclusion Criteria

The population for this study was collected from the 2015 DHS secondary dataset. Children, both boys and girls, less than 5 years old, were selected for this study. These children are either exposed to malaria or have reported at least one episode of malaria. Similarly, these children have a clinical record of anemia. However, all children with a history of sickle-cell anemia, chronic anemia, and familial history of anemia condition were excluded from the secondary data analysis. The children whose parents did not report their education levels were excluded from the study. Both children who sleep with a mosquito netted bed and those who did not sleep in a mosquito netted bed were included.

Data Analysis Plan

SPSS version 27 software was used to perform the descriptive and inferential analyses. Descriptive analysis was performed to describe the count, frequency, and percentage or proportion distribution of event or outcome and exposure among the selected target population. Count, frequency, and percent was used to describe malaria status (malaria and no malaria), malaria-induced anemia status (anemia and no anemia), gender (girl or boy), parents' education level (primary education, secondary education, or higher education), mosquito net use (mosquito net use or no mosquito net use), Malaria medication use (ever used or never used), and residence type (rural and urban). Malaria and malaria-induced anemia statuses in the research questions are nominal variables.

Malaria Medication use, malaria-induced anemia, residential type, parent's education, mosquito net use, and malaria-induced anemia in the third research question are also nominal variables. Residential type, Parent's educational level was an ordinal variable.

The frequency distribution table and bar charts are the appropriate descriptive statistics to describe the variables specified in the current research inquiry based on the level of measurement. The levels of measurement of the variables determine the type of descriptive analysis that could be used to describe the variables. For instance, malaria status (malaria episode or no malaria episode) is a mutually exclusive nominal variable. As such, it is not appropriate to estimate the mean of patients with malaria episodes or those with no malaria episodes. Instead, it is reasonable to perform distribution count and percent distribution of malaria status.

For inferential statistics, the level of measurement is also critical for determining the appropriate statistical tool to be used when conducting an inferential analysis. Multinomial logistic regression was used to perform the inferential analysis. According to Forthofer, Lee, and Hernandez (2007), when the dependent variable's level of measurement is a nominal or categorical variable, or an ordinal variable, a multinomial logistic regression can be used for the inferential analysis. Similarly, based on the multinomial logistic regression assumptions, the corresponding independent variable's level of measurement must either be a categorical, nominal, or continuous variable to apply a multinomial logistic regression analysis (Forthofer, Lee, & Hernandez, 2007). Multinomial logistic regression has assumptions of independence among the dependent variable choices, which states that the choice of or membership in one category is not related to the choice of membership of another category (i.e., the dependent variable). Multinomial logistic regression was used for the inferential analysis of the third and fourth research questions considering all assumptions are met: multivariate normality (the assumption that the residuals are normally distributed), no multicollinearity, and the assumption was tested using the Variance Inflation Factor (VIF) values (Forthofer, Lee, & Hernandez, 2007).

Data Entry and Validation

The DHS program is intended to collect a wealth of information on different topics for a sample of the participating countries. The information is processed and presented in reports and data formats. Many steps are put in place to ensure that the data adequately represents the intended situation. Also, the data formats are presented to be comparable across participating countries (DHS, 2020). Depending on the survey time, instruments, and sample size, the survey takes an average of 18-20 months, and it is executed in four phases.

The first step, Survey Preparation and Questionnaire Design involve designing the samples and developing the survey questionnaires. The second step is the Training and Fieldwork, which involves training field staff and conducting the fieldwork. Data Processing is the third stage. It involves data processing, editing, coding, entering the data, and verifying the data by checking for consistency. They do data collection, entry, and editing simultaneously for quality control and provide preliminary results by the end of the data collection. The final phase is the Final Report, Data Preparation, and

Dissemination phase. The last step involves data analysis, a final country-specific report, and dissemination of the survey results.

Data Collection and Extraction Technique

When biomarker testing is done in DHS surveys, the well-being of study participants is paramount. DHS ensures privacy and confidentiality are maintained. The current rapid testing technologies used in DHS surveys allow respondents to be tested for many biomarkers and receive test results at home. For the present study dataset, the interviewers promptly provided the test results for malaria during the interview. That is, once the malaria status of a child is known after the onsite blood testing, the result about a child's malaria status is communicated promptly to the child's parent. The interviewer also suggests referrals and information on malaria care are presented as appropriate. For severe malaria conditions, the parent is advised to seek medical attention at once (DHS, 2018). In the Nigerian 2015 surveys, for children with malaria testing result of positive, medication is offered to the children, and referred to a local health care facility for further treatment, as appropriate.

The biomarker for the anemia test is collected at the interview time, but the results are not available immediately because the tests are done at the laboratory. Those children with moderate to severe anemia are referred to the local health care facility for appropriate care. Verbal counseling and printed information are provided to respondents for all biomarker testing, and test results are kept confidential (DHS, 2018).

Diagnostic Tests for Malaria

The three major diagnostic tests for malaria in nationally representative household surveys to measure malaria parasitemia prevalence are Rapid Diagnostic Tests (RDTs), Microscopy, and polymerase chain reaction (PCR) techniques (Falade et al., 2016; Florey, 2014). The Loop-Mediated Isothermal Amplification (LAMP) is most recently becoming the fourth widely available tool. For the 2015 DHS dataset, RDT was used to identify malaria infection and provided immediate results to participants' parents. With RDT, medication is provided immediately for treatment of malaria-positive subjects or referral for follow-up treatment in a health facility (DHS, 2018). The major advantage of RDT is its relative simplicity that requires a single drop of blood and does not require skilled technicians or access to laboratory equipment.

Study Power Analysis

For this current inquiry, the statistical power calculation for sample size estimation is 80% power and 20% beta (Type II error). For the test statistic predetermined values, 95% (0.95) confidence level and 5% (0.05) alpha level (Type I error) were used for the inferential analysis to assess the statistical significance of the association between malaria status (malaria episode or no malaria episode) and malaria-induced anemia status (anemia or no anemia) for research question 1. Accepted malaria treatment medication of any kind at least once, or the child never used malaria treatment medication, for research question 2. For research question 3, the statistical significance of the risk of malaria-induced anemia status (anemia or no anemia) on gender (girl or boy) was investigated. And for research question 4, the statistical significance of residence type, parent’s educational level, malaria medication use, and mosquito net use on malaria-induced anemia was investigated.

To reduce or minimize spurious errors or biases associated with age group, gender, parent’s educational level, and the use of mosquito nets, I accounted for parent’s educational level and mosquito net use as confounders for research questions 1, 2, and 3. I accounted for age group and gender in research question 4. The levels of parent’s educational level and mosquito net use by the children have been demonstrated to protect children from mosquito bites and indirectly prevent malaria episodes (Cohee & Laufer, 2018; Dawaki et al., 2016; Degarege et al., 2019; Saaka & Glover, 2017). How malaria-induced anemia may be affected by gender and age group in children less than 5 years old has not been widely studied. The confounders' presence creates internal and external validity threats and distorts findings (Brownson, Gurney, & Land, 1999). For instance, if malaria, malaria-induced anemia, and gender's true effects are compromised in this analysis due to unaccounted confounders or covariates, internal or external validity would not be established in the study.

Sampling and Sampling Procedures

The 2015 DHS data are considered secondary data because the data was collected by DHS and available for public use of those who have a legitimate purpose (DHS, 2018). In other words, I did not conduct the survey nor collect the information directly from the study participants to address the current research questions. The 2015 survey was designed and archived by the Demographic and Health Survey Program (DHS, 2018). The DHS standardized all their survey data, and the original raw data structure was transformed into a "DHS Recode Data" format (DHS, 2018). The original raw data is a replica of the paper questionnaires (DHS, 2018).

On the other hand, the recode version includes all original questions. But it is converted into a standard structure that provides for some extra, transformed variables to improve data analysis (DHS, 2018). For the survey data collected in Nigeria in 2015, the standardized recode version became available for distribution in 2018 even though the survey data was made available for distribution after the data was collected in 2015.

The rationale for transforming and recoding the variables or the level of measurement is to provide a different level of description of the dataset's physical structure and enhance the data's availability (DHS, 2018). The coding standards and transformation process for the 2015 DHS data were performed by DHS (DHS, 2018). The location identification information was assigned and recorded (DHS, 2018). Dates by year, month, and day were adequately coded as well (DHS, 2018). The description of individual variables captured in the data file was provided and added in the data dictionary (DHS, 2018).

The 2015 DHS data is commonly referred to as DHS VII because the 2015 DHS is the 7th survey conducted by the DHS program. DHS data transformation was performed for several reasons, including but are not limited to:

a) Incomplete or missing information for key variables or events is imputed as much data analysis is based on these events. Besides, imputed data improves result consistency and time-saving (DHS, 2018).

b) The original raw data are not always in the format for analysis (DHS, 2018).

d) Eliminate duplication or repeats (DHS, 2018).

Standardization of data transformation is part of the DHS policy for improving accessibility of data (DHS, 2018). The transformation or recode data dictionary includes two parts: standard records and country-specific records (DHS, 2018). The same number of variables with the same name, length, and position locations for all participating countries are included in the standard records (DHS, 2018). The variables specific to a country are not standardized across countries but included in the country-specific records. The DHS recode data files for each country has its survey-specific documentation and are distributed accordingly (DHS, 2018). The details of the questionnaires are described in the survey-specific documentation (DHS, 2018).

The DHS recode data file is available in two different structures, the flat and hierarchical structures (DHS, 2018). For the flat structure, each record represents one case (DHS, 2018). The hierarchy contains the standard structure of the original raw data (DHS, 2018). There is no limit on the number of records per case in the hierarchical structure (DHS, 2018). Multiple records exist only when necessary. For instance, for a family with six children under the age of 5 years old, there would be 6 records in the birth history (DHS, 2018). The hierarchical data structure is designed and distributed for use with CSPro and dictionary (DHS, 2018). The birth record of children is part of the Biomarker questionnaire. However, birth records are not available for children who a). died, b). did not live in the household, c). are older, and d). had no record of their height and weight reported by the households (DHS, 2018).

The type of place the respondent was interviewed is the de facto residence (DHS, 2018). For the DHS data collection settings, urban areas are classified into large and small cities (DHS, 2018). Large cities include capital cities and cities with over 1 million people (DHS, 2018). Small cities have a population of over 50,000 people, towns, other urban areas, and all rural areas or the countryside (DHS, 2018).

Sample Size

The estimated minimum sample size for this study using a G*Power software is 721. The power estimation was based on a statistical power of 80%. The criteria inputted for this sample size estimation are the *z*-test statistical family for the logistic regression test because it is the preferred test intended for this study. Other criteria inputted in the G*Power estimation other than the 80% (0.80) predetermined statistical power are 5% (0.05) alpha value, two-tail test condition, and a 1.3 effect size (see Table 3). Even when the minimum sample size estimation to produce a statistical power of 80% is 721, for this current study, all valid counts recorded in the 2015 DHS data was included in the statistical analysis to address research questions 1, 2, 3, and 4.

Table 3

Minimum Sample Size Estimation

z tests - Logistic regression			
Options:	Large sample z-Test, Demidenko (2007)		
Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	Two
	Odds ratio	=	1.3
	α err prob	=	0.05
	Power (1-β err prob)	=	0.80
	R^2 other X	=	0
	X distribution	=	Normal
	X parm μ	=	0

	X parm σ	= 1
Output:	Critical z	= 1.9599640
	Total sample size	**= 721**
	Actual power	= 0.8001115

Archival Data

DHS is the source of the secondary data intended for use in addressing the posed research questions. Specifically, the 2015 DHS data was used for the statistical analysis. The DHS Program is authorized to distribute, at no cost, and free survey data files. The 2015 DHS data is available and accessible on the DHS website and open to the public for educational purposes, experienced researchers use, and policymakers to make informed health decisions (DHS, 2018). However, registration on DHS's website is required for access to data. After the registration and request are made for the specific dataset set, the DHS grants access to the dataset in a couple of days. Also, the data published in the public domain is de-identified; as such, no identifiable information was available or included in this analysis (DHS, 2018). For maintaining the integrity, oversight of transparency, and respect of human participants involved in research, I acquired IRB approval through Walden University.

The 2015 DHS questionnaire was developed by DHS (DHS, 2018). The 2015 DHS survey was also implemented and administered by the DHS team in Nigeria to eligible participants (DHS, 2018). Several stakeholders reviewed the 2015 DHS questionnaire for relevance and validity (DHS, 2018). The 2015 DHS survey was funded by the ICF and DHS Program (DHS, 2018). The 2015 DHS questionnaires were administered to the eligible members of households (DHS, 2018). Eligible households accounting for 3,254 samples were evaluated (DHS, 2018). The 2015 DHS data included variables with different levels of measurements, such as nominal or categorical, ordinal, interval, and ratio measures. Malaria episodes' measurement levels were operationalized as mutually exclusive binary outcomes: malaria (yes) or no malaria (no).

Data Storage and Access

For statistical analysis, I saved the exported 2015 DHS dataset in a password-protected personal computer only accessible by me. I performed the necessary data recording and transformation before analyzing the data using this computer. For the coding purposes for all the nominal variables such as malaria (malaria or no malaria) and anemia (anemia or no anemia), the presence of or 'yes' to the condition was coded with the value zero (0). In contrast, 'the absence of' or 'no' to the condition was coded with the value of "1" in the SPSS. Also, gender was coded as "1" for females and "2" for males. This coding represents a nominal variable.

Similarly, mosquito net use was coded as a nominal variable. Parents' education levels were grouped into three ordinal levels; primary education, secondary education, and higher education and coded with values "1", "2", and "3," respectively, for the statistical analysis. The specified codes have no statistical significance; instead, was applied to identify the group of cases or events in the dataset.

Assumptions

The fundamental assumption made for this study was that the dependent and independent variables were categorical and dichotomous (Forthofer et al., 2007). Also, there would be no multicollinearity, no substantial outliers, and the data is normally distributed (Forthofer et al., 2007).

Selection Criteria

The sample size for the current study consisted of children under 5 years old in randomly selected households across Nigeria. Malaria status, malaria-induced anemia presence or absence, malaria medication use, the child's gender, and mosquito net use were categorized as yes or no (mutually exclusive). The child's age was divided into two groups, those below 36 months old and 36 months old and higher.

Research Questions and Hypothesis

The research questions and hypothesis are as follows:

Research Question 1 (RQ1): Is there an association between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and Mosquito net use?

$H_0$1: There is no relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

H_a1: There is a relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

Research Question 2 (RQ2): Is there an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use?

$H_0$2: There is no association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

H_a2: There is an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

Research Question 3 (RQ3): Is there an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and Mosquito net use?

$H_0$3: There is no association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

H_a3: There is an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

Research Question 4 (RQ4): Is there an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria?

$H_0$4: There is no association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria.

H_a4: There is an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria.

Statistical Testing

The findings' statistical significance was interpreted by evaluating the estimated *p*-value for each research question. If the estimated *p*-value was less than the predetermined alpha value of 0.05 (5%) [$p < 0.05$], the analysis was statistically significant; therefore, I rejected the null hypothesis. On the other hand, if the estimated *p*-value was greater than the predetermined alpha value of 0.05 (5%) [$p > 0.05$], the analysis was not statistically significant. In such a case, I failed to reject the null hypothesis. In this current study, for research question 1, the rejection of the null hypothesis suggested that malaria significantly predicts anemia among children with malaria compared to those who did not have malaria. Failing to reject the null hypothesis suggested that malaria did not significantly predict anemia among children with malaria compared to those who did not have malaria. Similarly, for research question 2, the rejection of the null hypothesis suggested that the use of malaria treatment medication significantly predicted the outcome of malaria-induced anemia among children who tested positive for malaria. Failing to reject the null hypothesis suggested that the use of malaria treatment medication did not significantly predict anemia among children who tested positive for malaria. For research question 3, the rejection of the null hypothesis suggested that gender significantly predicted malaria-induced anemia among children and failing to reject the null hypothesis indicated that gender does not significantly predict malaria-induced anemia. The rejection of the null hypothesis in research question 4 suggested that residence type, parents' education, malaria medication use, and mosquito net use significantly predicted malaria-induced anemia among children and failing to reject the null hypothesis suggested that these factors did not significantly predict malaria-induced anemia.

The assessment of the risk of anemia from malaria episodes or in the absence of malaria episodes was examined based on the odds ratio (*OR*) calculation from the ordinal logistic analysis. An *OR* value of 1.00 indicated no difference in the risk of an outcome between individuals exposed compared to those not exposed to the same risk factor. An *OR* value greater than 1.00 suggested that exposure to a risk factor is positively associated with the outcome, which meant that the exposed group had a higher risk than the non-exposed group. In contrast, an *OR* value of less than 1.00 suggested that the exposure in question was protective or negatively correlated, which meant that the exposed group had a lower risk of that outcome than the non-exposed group.

Threats to Validity

Threats to validity focus on aspects of the study rationale, design, method, process, and methodology induce internal and external validity problems in any part of the study processes (Creswell, 2013; Forthofer et al., 2007). Establishing internal validity is the fundamental basis for maintaining external validity (Creswell, 2013; Forthofer et al., 2007). In other words, external validity cannot be established without internal validity (Creswell, 2013; Forthofer et al., 2007). Consistency and accuracy of study procedures are not limited to sampling and subject selection (Creswell, 2013; Forthofer et al., 2007). The sample selection influences the study validity (Creswell, 2013; Forthofer et al., 2007). The key determinants of internal and external validity relevant to this current study was discussed in this section of the manuscript. Meaningful suggestions or recommendations to address the unique internal and external validity identified in this present study was also addressed.

Internal Validity

External validity cannot be established without internal accuracy (Creswell, 2013; Forthofer et al., 2007). Internal validity deals with other factors that influence the outcomes other than the selected primary independent variable (Creswell, 2013; Forthofer et al., 2007). The quality of a study or approach applied in a study heavily depends on the established internal consistency of operationalized instruments, procedural design, and sample methods (Creswell, 2013; Forthofer et al., 2007). Cronbach's alpha is a standard tool used in evaluating the reliability of scale instruments (Creswell, 2013; Forthofer et al., 2007). Construct validity is another type of accuracy evaluation that focuses on assessing the operational definition of constructs (Creswell, 2013). Instruments that cannot accurately measure operational constructs or contents generates spurious errors (Creswell, 2013; Forthofer et al., 2007). The 2015 DHS study and surveys/questionnaires were mainly evaluated and validated using a self-reported response, which in many cases is problematic because recall and rumination biases are common limitations of self-reported information (Creswell, 2013; Forthofer et al., 2007).

The 2015 DHS questionnaire was not tailored to the specifics of the current research question. Therefore, the instruments' content accuracy or data collection procedures related to the current study lack high-level specificity and sensitivity. Lack of random assignment of the exposure factors is inherently a major limitation for a cross-sectional design (Creswell, 2013; Forthofer et al., 2007). Also, inadequate statistical power or sample size, effect size estimation, confidence level might distort the research findings and conclusions (Creswell, 2013; Forthofer et al., 2007).

External Validity

External validity can be operationally defined as the extent to which an event or outcome is generalized in different settings or populations (Creswell, 2013; Forthofer et al., 2007). Sampling, interview content validity, consistency and accuracy of instruments, and variable specificity and sensitivity are some components of validity determinants that can be examined to establish external validity (Creswell, 2013; Forthofer et al., 2007). Some of the data collection approaches applied to address common internal and external validity in this current study include the following: the 2015 DHS data sampling selection was randomized and had only participants within the country of interest, in this case, Nigeria, in both urban and rural areas of Nigeria (DHS, 2018). Nevertheless, the exposure factors of interest were not randomly assigned to participants, thus limiting the current study to correlation inference by using a cross-sectional design (DHS, 2018). Cross-sectional design lacks accuracy or reliability in determining the spatiotemporal sequence of predictors and outcomes (Creswell, 2013; Forthofer et al., 2007). As such, it is essential to exercise extreme caution on the use of generalization and causality for this current study's findings. Instead, the conclusions drawn should be correlational and limited to the target population used in this study (Creswell, 2013; Forthofer et al., 2007).

Variation of interviewer's and participants' demographic characteristics could pose a threat to the   and validity of interview contents and responses generated (Creswell, 2013; Forthofer et al., 2007). For instance, interviewer methods and approaches, personal characteristics, and procedure quality could influence interview responses (Creswell, 2013; Forthofer et al., 2007). Quality interviewer's training process and procedures with a high level of consistency and accuracy substantially reduced interviewers' or researchers' bias (Creswell, 2013; Forthofer et al., 2007). In other words, unreliable interview methods adversely affect participants' responses and subsequently distort study findings (Creswell, 2013; Forthofer et al., 2007). Such distortion could induce a Type I or II error (Creswell, 2013; Forthofer et al., 2007). DHS provided a series of key informative training to interviewers to minimize the errors associated with interviewers' biases and other internal and external factors (DHS, 2018). The interview questions or questionnaires were piloted to assess its reliability and accuracy before it was publicly administered to selected target populations (DHS, 2018). During the training sessions, observed errors in procedural processes were corrected, and ambiguities were addressed (DHS, 2018). As needed, training enhancements were provided to improve the interviewer's adherence to the procedures (DHS, 2018).

Ethical Procedures

DHS obtained IRB approval for the 2015 DHS study before the survey was administered to the study participants (DHS, 2018). Informed consent was presented to and obtained from all the participants by DHS staff before study participation. And before the interview or survey process was administered (DHS, 2015). The informed consent was approved for the 2015 DHS study by the IRB (DHS, 2015). For this current study and to maintain the required ethical integrity when conducting research involving human subjects, I obtained IRB approval from Walden University before acquiring the DHS dataset or performing any statistical analysis with the 2015 DHS dataset.

According to DHS (2018), ethical consideration regarding cultural competency was applied in the training process, and an appropriate actionable plan was in place before the 2015 DHS study began (DHS, 2018). For instance, interviewers, who administered the survey, were trained on cultural competency (DHS, 2018). The 2015 DHS study aims to promote several areas and disciplines that facilitate health promotion and preventative measures in public health (DHS, 2018). However, in this region of the globe, inefficient public health malaria policies and lack of adequate key infrastructures seem to promote favorable conditions for mosquito breeding in the rural areas within the country of interest (Al-Mendalawi, 2019; Okwa, 2019).

Summary

The methodology, cross-sectional design, data collection tools, and 2015 DHS data described in this section of the manuscript addressed the posed research questions. The assessment of the risk of anemia arising from malaria status and the impact of anemia on gender was examined in this current study using a cross-sectional design. Secondary data from the 2015 DHS data was a feasible alternative to a primary data approach because it was already collected and included all the key variables intended for this study. Also, the overall cost of the use of secondary data, in this case, is cost-effective. The application of an ordinal logistic regression aligns with the variables' levels of measurements described in this research inquiry. The method section described here laid out the plan and approaches used or implemented to analyze and interpret the results in Chapter 4 and Chapter 5.

Chapter 4: Results

Introduction

In this study, the association between malaria and malaria-Induced anemia among children younger than 5 years old with confirmed cases of malaria compared to those who do not have malaria in the sub-Sahara African country of Nigeria were examined. Likewise, the association between the use of malaria medication and malaria-induced anemia, and with gender among those children with positive malaria were explored. Also, the impact of residence type, parent's educational level, malaria medication use, and mosquito net use on malaria-induced anemia status was examined.

The study data source was collected by DHS in every state in Nigeria, including the federal capital territory, Abuja in 2015. A descriptive analysis was performed to describe the distribution of the study variables. The inferential analysis was conducted to analyze each of the four research questions' statistical significance and effect size. The association between malaria and malaria-induced anemia among children younger than 5 years old in the urban versus the rural areas of Nigeria after controlling for parent's education and mosquito net use. Secondly, the impact of the use of malaria medication among children on malaria-induced anemia after controlling for parents' education, and mosquito net use. Thirdly, the relationship between malaria-induced anemia status and gender after controlling for parent's education and mosquito net use was examined. Last, the association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia after controlling for gender and age of these children were analyzed.

Research Questions and Hypotheses

Research Question 1 (RQ1): Is there an association between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and Mosquito net use?

$H_0$1: There is no relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

H_a1: There is a relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

Research Question 2 (RQ2): Is there an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use?

$H_0$2: There is no association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

H_a2: There is an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

Research Question 3 (RQ3): Is there an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and Mosquito net use?

$H_0$3: There is no association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

H_a3: There is an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

Research Question 4 (RQ4): Is there an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria?

$H_0$4: There is no association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria.

H_a4: There is an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age) among children younger than 5 years old in Nigeria.

Data Collection

DHS is a nationally representative household survey that provides data on a wide range of public health indicators and are usually collected every 5 years. The survey sample size can range from 5,000 to 30,000 households. DHS survey and surveillance areas include information about anemia, education, household and respondent characteristics, malaria, and other social determinants (DHS, 2018). While some data are collected via questionnaires, some data such as anemia and malaria status are clinically diagnosed. DHS administer their survey to women ages 15-49 years old to obtain information about them and the status of anemia and malaria among their children younger than 60 months old (under 5 years old). The 2015 DHS dataset was used for this analysis.

The data collection instruments used in the 2015 DHS surveys are questionnaires, clinical biomarkers, and geographic information. There are four model questionnaires (household, woman's, man's, and biomarker questionnaires). Other several standard questionnaire modules unique to countries of interest in specific health areas were included as well. Biomarker data are collected for conditions such as infections, sexually transmitted diseases, chronic illnesses, toxins exposures, etc. Geographic information is collected routinely in all surveyed countries and are represented nationally and sub-national areas. The 2015 DHS sampling is generally representative at the national, residence type (urban or rural), and regional levels. The 2015 DHS sample was stratified into two-stage cluster design. The Enumeration Areas (EA) drawn from census files and in each EA selected, a sample of households was drawn from an updated list of households (DHS, 2018).

2015 DHS Survey Timeline

The 2015 DHS surveys was conducted over a period of 20 months. The standard timeline was represented in the table below:

Table 4

2015 DHS Survey Timeline

Timeline	Topics
Month 1	Survey design visit
Month 2	Sample Design
Month 3	Questionnaire design
Month 3-4	Household listing
Month 5	Pretest
Month 6	Revision of questionnaires and manuals
Month 7	Training of field personnel
Month 8	Data processing set up
Month 8-11	Fieldwork
Month 9-12	Data entry and editing
Month 13	Preparation of the Key Indicators Report
Month 14-16	Tabulation, analysis, and preparation of the Final Report
Month 17	First draft of the report
Month 18	Review and revision of report
Month 19	Printing of the final report
Month 20	National seminar
Month 20	Further analysis and/or data dissemination activities

In the 2015 DHS dataset, a total of 7,745 cases was reported. All the children included in the dataset are younger than 5 years old (less than 60 months). These children lived in Nigeria at the time the data was collected. The fieldwork was done between October 2015 and November 2015. There was a sample size of 8,034 female respondents (aged between 15 and 49 years old) and no male respondents. The actual response rate was 96.4%. The population of Nigerian children younger than 5 years old was 31 million and it was estimated that at least seven million babies are born each year (United Nations International Children's Emergency Fund [UNICEF], 2018). There were no discrepancies in data collection from the plan presented in Chapter 3.

Results

For the descriptive analysis, the study variables (dependent variable, independent variable, unit of analysis, and confounders) were described using a univariate approach. For RQ1, RQ2.and RQ3, there is one independent variable (malaria status, malaria medication use, and malaria-induced anemia status, respectively) and one dependent variable (malaria-induced anemia for RQ1 and RQ2, and gender for research RQ3). RQ4 on the other hand has four independent variables (residence type, parent's educational level, mosquito net use, parent's educational level, and malaria medication use). The dependent variable for RQ4 is malaria-induced anemia. The independent variables, including sociodemographic confounding variables are described using a descriptive analysis. Of these variables, age was the only ratio variable transformed into an interval level for this analysis. The controlling variables selected for each research question were important in estimating malaria-induced anemia status in children younger than 5 years old living in Nigeria. These confounding variables play a role in determining the significance, strength, magnitude, and direction of the association between the independent variables and malaria-induced anemia status for the inferential analysis.

Descriptive Statistics

Using SPSS version 27, the descriptive analysis for all the study variables (child age, gender, malaria-induced anemia status, malaria status, parent’s educational level, residence type, Mosquito net use, and malaria medication use) was conducted. Except for the parent’s education level and child age, all the other study variables’ level of measurement was a nominal level. The parent’s education level was an ordinal level, while the child’s age in months was an interval level. Three of the four research questions’ dependent variable is malaria-induced anemia, and the fourth (research question 3) is gender. The independent variable for research question 1is malaria status, 2 is accepted malaria treatment medication, 3 is malaria-anemia status. In contrast, the independent variables for research question 4 are residence type, parent’s educational level, accepted malaria medication use, and mosquito net use. The confounders for research questions 1, 2, and 3 are parent’s educational level and mosquito net use. For research question 4, the confounders are gender and age group.

Child Age Group in Months

In this study, of 7,745 children who participated in the study, 4,125 (53%) had their age reported by their parents, while 3,620 (47%) were recorded as system missing for child age. The child’s age in months was grouped into two interval groups, children aged 0-36 months old and those 37-59 months old. Among 4,125 parents who reported their child’s age, 1,858 (45%) indicated that their child’s age is between 0-36 months, while 2,267 (55%) reported that their child’s age is between 37-59 months old, Table 5 and Figure 3.

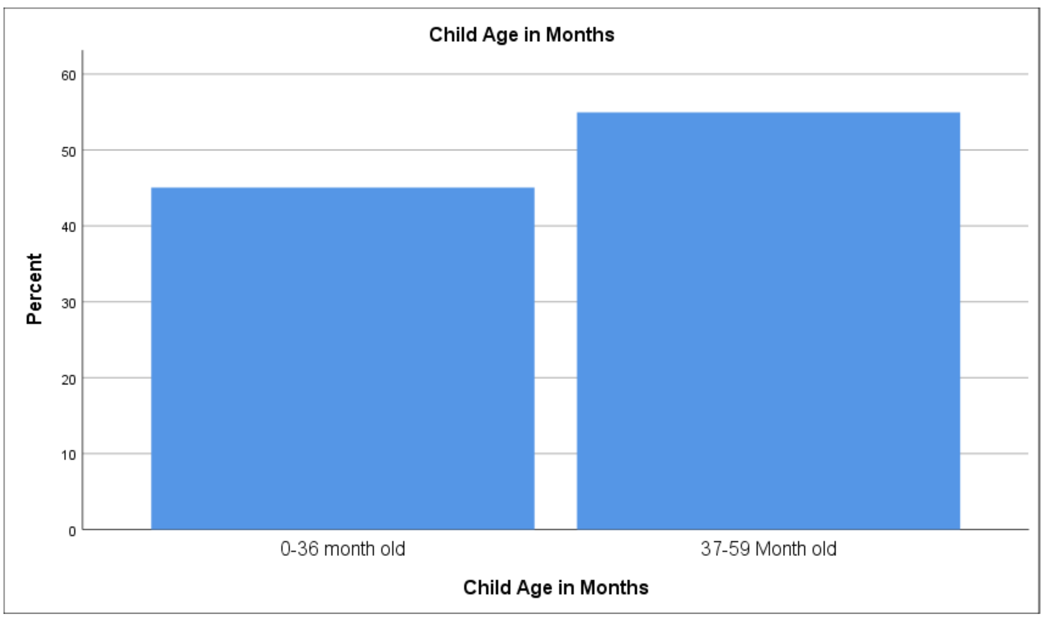
Table 5

Child Age in Months in the Nigerian 2015 DHS Data

		Frequency	Percent	Valid Percent
Valid	0-36 months old	1858	24.0	45.0
	37-59 months old	2267	29.3	55.0
	Total	4125	53.3	100.0
Missing	System	3620	46.7	
Total		7745	100.0	

Figure 3

Child Age in Months in the Nigerian 2015 DHS Data



Gender

Out of the 7,745 children who participated in the study, 4135 (53%) had their gender reported by their parents while 3,610 (47%) recorded as system missing. Among 4,135 children whose gender was reported, 2,095 (51%) indicated that their child's gender is a boy, while 2,040 (49%) reported that their child's gender is a girl, Table 6.

Table 6

Child Gender in the Nigerian 2015 DHS Data

		Frequency	Percent	Valid Percent
Valid	Boys	2095	27.0	50.7
	Girls	2040	26.3	49.3
	Total	4135	53.4	100.0
Missing	System	3610	46.6	
Total		7745	100.0	

Anemia Status

Of the same number of children who participated in the study, 3,739 (48%) had their anemic status reported, while 4,006 (52%) children had their anemic status as system missing. Of the children with their anemic status reported, 2,395 (64%) were anemic, and 1,344 (36%) children were not anemic, Table 7.

Table 7

Anemia Status of Children under the Age of 5 Represented in Nigerian 2015 DHS Data

		Frequency	Percent	Valid Percent
Valid	Anemic	2395	30.9	64.1
	Not Anemic	1344	17.4	35.9
	Total	3739	48.3	100.0
Missing	System	4006	51.7	
Total		7745	100.0	

Malaria Status

Out of 7,745 children whose information were included in the 2015 DHS, 1,009 (13%) malaria status was reported while 6,736 (87%) children malaria status was classified as system missing. Of 1,009 children that had their malaria status reported, 386 (38%) had malaria, and 623 (62%) children did not have malaria, Table 8.

Table 8

Malaria Status of Parents Represented in the Nigerian 2015 DHS Data

		Frequency	Percent	Valid Percent
Valid	Malaria	386	5.0	38.3
	No Malaria	623	8.0	61.7
	Total	1009	13.0	100.0
Missing	System	6736	87.0	
Total		7745	100.0	

Parent's Education Level

Of a total population of 7,745 children, 5,067 (65%) parents reported their education level while 2,678 (35%) of their parent's education level were classified as system missing. Of the children whose parents reported their education level, 1,528 (30%) reported primary education as the highest education level attained; 2,253 (45%) reported secondary education; and the remaining 1,286 (25%) parents' highest education attained was higher education, Table 9.

Table 9

Parent's Education Level of Children Represented in the Nigerian 2015 DHS Data

		Frequency	Percent	Valid Percent
Valid	Primary Education	1528	19.7	30.2
	Secondary Education	2253	29.1	44.5
	Higher Education	1286	16.6	25.4
	Total	5067	65.4	100.0
Missing	System	2678	34.6	

Total		7745	100.0	

Residence Type

The data for the residence type of children who were included in the 2015 DHS and this study was reported for every child. There were 3,166 (41%) of the children who lived in urban areas of Nigeria. On the other hand, 4,579 (59%) of the children lived in rural areas, Table 10.

Table 10

Residence Type of Children Represented in the Nigerian 2015 DHS Data

		Frequency	Percent	Valid Percent
Valid	Urban	3166	40.9	40.9
	Rural	4579	59.1	59.1
	Total	7745	100.0	100.0

Mosquito Net Use

Of the children who were included in the 2015 DHS and this study, 5,432 (70%) sleeps under a mosquito at night while 2,313 (30%) do not sleep under a mosquito net at night, Table 11.

Table 11

Mosquito Net Use Status for Children Represented in the Nigerian 2015 DHS Data

		Frequency	Percent	Valid Percent
Valid	Mosquito Net	5432	70.1	70.1
	No Mosquito Net	2313	29.9	29.9
	Total	7745	100.0	100.0

Medication Use

Of the 7,745 children who were included in the 2015 DHS and this study, 957 (12%) of these children had their malaria medication use status reported while 6,788 (88%) were recorded as system missing for malaria medication use. Of the 957 children whose malaria medication use status were reported, 955 (99.8%) used a malaria medication at least once, while 2 (0.2%) children never used any malaria treatment medication, Table 12.

Table 12

Medication Use Status of Children Represented in the Nigerian 2015 DHS Data

		Frequency	Percent	Valid Percent
Valid	Used Malaria Medication (Artemisinin Combination Therapy (ACT), SP/Fansidar, Chloroquine, Amodiaquine, Quinine, Artesunate, and other antimalarial drugs)	955	12.3	99.8
	No Malaria Medication	2	.0	.2
	Total	957	12.4	100.0
Missing	System	6788	87.6	
Total		7745	100.0	

Inferential Analysis

Research Question 1 (RQ1): Is there an association between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and Mosquito net use?

$H_0$1: There is no relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

H_a1: There is a relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

Among children under 5 years old or 60 months old whose parents reported information on anemia and malaria, 731 children were included in the research question 1 analysis, Table 13.

Table 13

Anemia and Malaria Case Summary of Children Represented in the Nigerian 2015 DHS Data

Study Variables		N	Marginal Percentage
Anemia Status	Anemic	452	61.8%
	Not Anemic	279	38.2%
Malaria Status	Malaria	222	30.4%
	No Malaria	509	69.6%
Total		731	100.0%

Based on Cox and Snell value, 10.6% of the malaria predicted malaria-induced anemia. Nagelkerke suggested that 14.4% of malaria predicted anemia while McFadden analysis showed that 8.4% of malaria predicted anemia in this study, Table 14.

Table 14

Pseudo R-Square of Anemia Status Among Children Represented in the Nigerian 2015 DHS Data

Pseudo-R-Square Model	Estimated Value

Cox and Snell	.106
Nagelkerke	.144
McFadden	.084

In Table 15 there is a statistically significant *(***p <0.001*) relationship between malaria-induced anemia and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use. It also shows that level of parent's education and mosquito net use has no significant (*p value 0.22 and 0.54* respectively) impact on anemia status among these children investigated. Overall, children with malaria are 5.1 times more likely to have anemia than children without malaria. The odds ratios for parent's education and mosquito net use are relatively low and less than 1 (0.86 and 0.89 respectively), Table 15.

Table 15

Parameter Estimate of Anemia Status Among Children Represented in the Nigerian 2015 DHS Data

Anemia Status[a]		*B*	*df*	Sig.	Odds Ratio	95% Confidence Interval for odds ratio: Lower Bound	Upper Bound
Anemic	Intercept	.53	1	.16			
	Parent's Education Level	-.14	2	.22	.86	.68	1.10
	Mosquito Net Use	-.12	1	.54	.89	.62	1.28
	Malaria	1.64	1	.000	5.13	3.39	7.76

Research Question 2 (RQ2): Is there an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use?

$H_0$2: There is no association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

H_a2: There is an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

Among children under 5 years old or 60 months old whose parents reported their information on anemia and medication use, and tested positive for malaria, 543 children were included in this analysis. A substantial amount of information was missing on medication use, Table 16.

Table 16

Anemia and Medication Use Case Summary of Children Represented in the Nigerian 2015 DHS Data

Study Variables		*N*	Marginal Percentage
Anemia Status	Anemic	410	75.5%
	Not Anemic	133	24.5%
Medication Use	Used Malaria Medication	541	99.6%
	No Malaria Medication	2	0.4%
Valid Total		543	100.0%

According to the analysis shown in Table 17, Cox and Snell suggested that 6% of the malaria predicted malaria-induced anemia while 8% of malaria predicted anemia based on the Nagelkerke analysis. McFadden analysis showed that 5% of malaria predicted anemia in this study, Table 17.

Table 17

Pseudo R-Square of Anemia Status of Children Represented in the Nigerian 2015 DHS Data

Pseudo-R-Square Model	Estimated Value
Cox and Snell	.006
Nagelkerke	.008
McFadden	.005

In Table 18 there is a statistically significant *(***p* <0.001) relationship between the use of any type of malaria medication and malaria-induced anemia among children younger than 5 years old after controlling for parents' education and mosquito net use. That is, the children that used any type of malaria medication were statistically significantly less likely to have malaria-induced anemia than those who do not use any type of malaria treatment medication. However, the data is not stable. In Table 12 above, 543 children were reported for using any type of malaria medication in the 2015 DHS while only 2 children were reported for not using any malaria medication for malaria. Due to insufficient data for malaria medication use variable, the statistical analysis for this variable is unstable. However, the expectation is that the use of malaria medication should decrease malaria parasite count in the bloodstream, and thus reduce malaria-induced anemia. Also, as Nigeria is a malaria endemic country with approximately 97%

of the population susceptible to the disease (WHO, 2019a), the situation where nearly all the children have not used one type of malaria medication or the other is unlikely. Olukosi & Afolabi (2018), Yeo et al. (2017), and White (2018) found that anti-malarial drugs substantially reduced the burden of malaria-induced anemia; therefore, it can be inferred that malaria medication use is associated with malaria induced anemia. Parent's level of education and mosquito net use has no significant impact on this relationship (*p* value 0.18 and 0.64 respectively). Overall, children who reported medication use are 1.13E-6 times less likely to have anemia compared to those that that do not use medication. Also, the odds ratio estimate for malaria medication use is unstable because only two children out of 543 did not use any type of malaria medication. The odds ratio for parent's education is less than 1 (0.82) while 1.1 for mosquito net use, Table 18.

Table 18

Parameter Estimate of Children Represented in the Nigerian 2015 DHS Data

						95% Confidence Interval for odds ratio	
Anemia Status[a]		*B*	*df*	Sig.	Odds Ratio	Lower Bound	Upper Bound
Anemic	Intercept	14.9	1	.000			
	Parent's Education Level	-.20	2	.18	.823	.617	1.097
	Mosquito Net Use	.12	1	.64	1.122	.696	1.809
	Use Malaria Medication	13.5	1	.000	1.314E-6	1.314E-6	1.314E-6
	No Malaria Medication				Reference level		

Research Question 3 (RQ3): Is there an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and Mosquito net use?

$H_0$3: There is no association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

H_a3: There is an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

RQ3: Is there an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and Mosquito Net Use?

$H_0 3$: There is no association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

$H_a 3$: There is an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

Among Children under 5 years old or 60 months old whose parents reported their information on anemia, gender, and malaria status, a total of 731 children were included in this analysis, Table 19.

Table 19

Anemia, Gender, and Malaria Case Summary of Children Represented in the Nigerian 2015 DHS Data

Study variables		*N*	Marginal Percentage
Anemia Status	Anemic	452	61.8%
	Not Anemic	279	38.2%
Gender	Boys	374	51.2%
	Girls	357	48.8%
Malaria Status	Malaria	222	30.4%
	No Malaria	509	69.6%
Valid Total		731	100.0%

According to the analysis shown in Table 20, Cox and Snell analysis suggested that 10.6% of malaria-induced anemia was predicted by gender while 14.5% was predicted by gender using the Nagelkerke analysis. Only 8.5% malaria induced anemia was predicted by gender according to the McFadden analysis.

Table 20

Pseudo R-*Square of Children Represented in the Nigerian 2015 DHS Data*

Pseudo-R-Square Model	Estimated Value
Cox and Snell	.106
Nagelkerke	.145
McFadden	.085

In Table 21, the relationship between malaria induced anemia and gender among children younger than 5 years old was not statistically significant (p = 0.747, *OR* = 1.05). Parent's level of education and mosquito net use were not significant in the association between gender and malaria induced anemia (p value 0.23 and 0.55 respectively).

Overall, among children included in this analysis, those that have malaria are 5.1 times likely to have anemia than those that do not have malaria.

Table 21

Parameter Estimate of Malaria-Induced Anemia Among Children Represented in the Nigerian 2015 DHS Data

						95% Confidence Interval for odds ratio	
Anemia Status[a]		*B*	*df*	Sig.	Odds Ratio	Lower Bound	Upper Bound
Anemic	Intercept	.495	1	.199			
	Parent's Education Level	-.149	2	.225	.862	.678	1.096
	Mosquito Net Use	-.112	1	.546	.894	.622	1.286
	Boys	.052	1	.747	1.053	.768	1.444
	Girls				Reference level		
	Malaria	1.635	1	.000	5.131	3.391	7.764
	No Malaria				Reference level		

Research Question 4 (RQ4): Is there an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age group) among children younger than 5 years old in Nigeria?

$H_0 4$: There is no association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age group) among children younger than 5 years old in Nigeria.

*H*a4: There is an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age group) among children younger than 5 years old in Nigeria.

Among children under 5 years old or 60 months old whose parents reported their information on anemia, residence type, parent's education level, malaria medication use status, mosquito net use status, gender, and child age group, a total of 542 children were included in this analysis, Table 22.

Table 22

Case Summary of Anemia, Residence type, Parent's Education Level, Medication Use, ad Mosquito Net Use of Children Represented in the Nigerian 2015 DHS Data

Study Variables		N	Marginal Percentage
Anemia Status	Anemic	410	75.5%
	Not Anemic	133	24.5%
Residence Type	Urban	162	29.8%
	Rural	381	70.2%
Parent's Education Level	Primary Education	220	40.5%
	Secondary Education	253	46.6%
	Higher Education	70	12.9%
Medication Use	Used Malaria Medication	541	99.6%
	No Malaria Medication	2	0.4%
Mosquito Net Use	Mosquito Net	422	77.7%
	No Mosquito Net	121	22.3%

Valid Total	543	100.0%

According to the analysis shown in Table 23, Cox and Snell analysis suggested that 2.3% of malaria-induced anemia was predicted by combined effect of residence type (urban and rural), parent's education level, malaria medication use status, mosquito net use status, gender, and child age group while 3.4% was predicted by the combined factor using the Nagelkerke analysis. Only 2.1% malaria induced anemia according to the McFadden analysis was predicted by combined effect of residence type (urban and rural), parent's education level, malaria medication use status, mosquito net use status, gender, and child age group.

Table 23

Pseudo R-*Square of Children Represented in the Nigerian 2015 DHS Data*

Pseudo-R-Square Model	Estimated Value
Cox and Snell	.023
Nagelkerke	.034
McFadden	.021

In Table 24, only child age group and parent's secondary education level had statistically significant ($p = 0.04$, $OR = 0.64$; *and* $p = 0.03$, $OR = 1.94$) relationship between malaria-induced anemia among children younger than 5 years old after controlling for gender and age group. Among children included in this analysis, the highest odds ratio observed were among parent's primary education and secondary education, 1.7 and 1.9, respectively.

Table 24

Parameter Estimate of Anemia Among Children Represented in the Nigerian 2015 DHS Data

Anemia Status[a]		*B*	*df*	Sig.	Odds Ratio	95% Confidence Interval for odds ratio Lower Bound	Upper Bound
Anemic	Intercept	14.7	1	.000			
	Gender	.1	1	.608	1.11	.75	1.65
	Child Age in Months	-.5	1	.041	.64	.41	.98
	Residence Type-Urban	-.2	1	.322	.81	.53	1.24
	Residence Type-Rural				Reference level		
	Parent's Primary Education	.5	1	.070	1.72	.96	3.10
	Parent's Secondary Education	.7	2	.026	1.94	1.08	3.46
	Parent's Higher Education				Reference level		
	Medication Use	-13.4	2	.	1.49E-6	1.49E-6	1.49E-6
	No Medication Use				Reference level		
	Mosquito Net Used	-.05	1	.84	.95	.59	1.55
	No Mosquito Net Use				Reference level		

Note. a. The reference category is: Not Anemic.

b. This parameter is set to zero because it is redundant.

Summary

In this study, four research questions and corresponding hypotheses (null and alternative hypothesis for each research question) were analyzed. The first research question was to analyze the association between malaria-induced anemia and the presence of malaria among children less than 5 years old in urban and rural areas of Nigeria. Based on the inferential analysis, children under 5 years old living in urban or rural area in Nigeria who had malaria significantly (***p <0.001) had malaria-induced anemia than those who did not have malaria, after controlling for parents' education and mosquito net use. Therefore, the null hypothesis which stated that "there is no relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use" was rejected.

The second research question focused on whether there "is a relationship or association between malaria medication use and malaria-induced anemia among children less than 5 years old who tested positive for malaria after controlling for parents' educational level and mosquito net use." The finding was that children under 5 years old who used any type of malaria medication significantly (***p <0.001) did not have malaria-induced anemia compared to those who did not use any type of malaria medication after controlling for parents' educational level and mosquito net use. Therefore, the null hypothesis was rejected. It is important to note, for this analysis, only 2 children were recorded for no medication use while 541 were recorded for medication use. Therefore, the analysis is unstable and unreliable. Further targeted studies are needed to explore and examine the association of malaria medication use and malaria-induced anemia among this age group in Nigeria.

The third research question focused on the association between malaria-induced anemia and gender among children younger than years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use. In this analysis, gender was not a predictor of malaria-induced anemia ($p = 0.75$) among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use. In other words, boys and girls have similar cases of malaria-induce anemia. Therefore, the null hypothesis was not rejected.

The fourth research question focused on the association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-anemia status (controlling for gender and age group) among children younger than 5 years old in Nigeria. For the combined effect of the predictors listed in research question 4, only medication use, child age group, and parents' secondary education level statistically *(****$p < 0.001$*;* $p = 0.041$ *and* $OR = 0.64$*; and* $p = 0.026$ *and* $OR = 1.94$) predicted malaria-induced anemia. In other words, children that use any type of malaria medication significantly (***$p < 0.001$) did not have malaria-induced anemia compared to those that did not use any malaria medication. Children between 0-36 months old are significantly ($p = 0.04$) associated with malaria-induced anemia compared to those ages 37 – 59 months old. Among children under 5 years old, those with parents who attained secondary education are significantly ($p = 0.03$) did not have malaria-induced anemia compared to parents of children with primary education. Therefore, the null hypothesis was rejected.

In Chapter 5, the study findings on the effect size implications of the study were interpreted further. The social implications of the study findings and provided recommendations on its relevance to public health practices and community engagement were also discussed. Other recommendations including additional gaps and limitations identified in the study were provided for further inquiry.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

In this study, the association between malaria illness and malaria-induced anemia among children younger than 5 years old in Nigeria was examined. The study analysis focused on the association between malaria-induced anemia status and the presence of malaria, medication use, and gender among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use. In addition, the association between residence type, parent's education level, mosquito net use, malaria medication use, and malaria-induced anemia after controlling for age group and gender among children younger than 5 years old living in Nigeria were examined. The analyses were conducted using secondary data from the 2015 DHS dataset. The 2015 DHS dataset is publicly available on DHS website. Overall, a total of 7,745 children participated in the 2015 DHS study. In this study, the SEM theoretical framework was used to explain how multiple levels of a social systems, personal interactions, and environment influence malaria-induced anemia. In some cases, age group, gender, resident type, parent's education level, and mosquito net use were included as covariates to malaria-induced anemia.

SPSS version 27 software was used for descriptive and inferential analyses. The results of the inferential analyses provided the basis to either reject or failure to reject the null hypothesis. There was a statistically significant association between malaria and malaria-induced anemia. Also, there was a statistically significant association between malaria medication use and malaria-induced anemia. On the other hand, there was no statistically significant association between gender and malaria-induced anemia among children under the age of 5 years old living in Nigeria. For combined effect of residence type, parent's educational level, malaria medication use, mosquito net use on malaria-anemia status, the only two statistically significant associations were those of secondary level parent's education ($p = 0.03$) and child age group ($p = 0.04$).

Interpretation of the Findings

The findings of this study are consistent with results from other studies on the association between malaria and malaria-induced anemia.

Research Question 1

Research Question 1 (RQ1): Is there an association between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and Mosquito net use?

> $H_0$1: There is no relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.
>
> H_a1: There is a relationship between malaria-induced anemia status and the presence of malaria among children younger than 5 years old in urban and rural areas of Nigeria after controlling for parents' education and mosquito net use.

For this finding, among children younger than 5 years old, malaria significantly predicted malaria-induced anemia ($p < 0.001$) after controlling for parents' education and mosquito net use. Therefore, the null hypothesis for RQ1 was rejected. Overall, parent's education and mosquito are not statistically significant (*p* value 0.22 and 0.54 respectively). In addition, children with malaria were 5.1 times more likely to have anemia than children without malaria.

In past studies, parent's education level, mosquito net use, and the residence type significantly confound malaria-induced anemia status among children under the age of 5 years old (Chacky et al., 2018; Degarege et al., 2019; Iwuafor et al., 2016; Mbako et al., 2017; Sumbele et al., 2016), In this study, mosquito nets use, and resident type significantly did not predict malaria-induced anemia. The findings by Chacky et al. (2018), Wold and Mittelmark (2018), Rahman et al. (2019), and Sowunmi et al. (2017) that higher education level advances knowledge on malaria prevention was not proven in this study. However, it is possible that no significant difference was found in education level simply because the parents are health literate about mosquito and malaria, not necessarily due to their education level but because of the enhanced awareness created over the years about mosquito and malaria in Nigeria. Also, resident type (urban or rural area) did not show a statistically significant difference as well. Perhaps, the association was due to increased awareness of mosquito and malaria in Nigeria, and not necessarily due to built-in infrastructures. Though this current study supported the concession in the association between malaria and anemia from any cause (Arroz, 2017; Awuah et al., 2018; Klein et al., 2016; Rogerson et al., 2018; von Seidlein et al., 2019; Yaya et al., 2018); however, the results of this study were not consistent with other findings suggesting that higher education and mosquito net use statistically influenced malaria-induced anemia (Arroz, 2017; Awuah et al., 2018; Klein et al., 2016; Rogerson et al., 2018; von Seidlein et al., 2019; Yaya et al., 2018). The findings of this study supported Iwuafor et al. (2016), Sumbele et al. (2016), and White (2018) whose conclusions suggested that malaria statistically predicted anemia, but there was no statistically significant association between reduction in malaria parasitemia and ITN use. Also, according to Afulani (2015), Sumbele et al. (2016), and Yusuf et al. (2016), there was no statistically significant association between malaria and educational level.

Research Question 2

RQ2: Is there an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use?

$H_0 2$: There is no association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

$H_a 2$: There is an association between malaria medication use and malaria-induced anemia among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' educational level and mosquito net use.

In this analysis, there was a statistically significant (***p <0.001) relationship between malaria medication use and malaria-induced anemia among children younger than 5 years old after controlling for parents' education and mosquito net use. Therefore, the null hypothesis for research question 2 was rejected. However, the inferential analysis for the malaria medication us is unstable and unreliable because only two children out of 543 who reported information about their child's malaria medication use did not take any type of malaria medication. On the other hand, a total of 541 children out of 543 took a type of malaria medication.

Parent's level of education and mosquito net use has no significant impact (*p* value 0.18 and 0.64 respectively) on the relationship between medication use and malaria-induced anemia. Children who used any type of malaria medication were 1.13^{E-6} times less likely to develop anemia compared to those that did not use medication. Also, the odds ratio estimation for the malaria medication use is unstable and unreliable because only two children out of 543 who reported information about malaria medication use did not take any type of malaria medication. A total of 541 children out of 543 took a type of malaria medication. The odds ratio for parent's education is less than 1 (0.82) while 1.1 for mosquito net use ($p = 0.18$ *and* 0.64 respectively).

In past studies, the American Association for the Advancement of Science (2017), Iwuafor et al. (2016), Sowunmi et al. (2017), Sumbele et al. (2016), and White (2018) suggested that that malaria medication use prevented anemia in children. The current study findings supported these previous findings as it shows in this study that children under 5 years old who used any type of malaria medication significantly (***$p < 0.001$) prevented malaria-induced anemia compared to children who do not use any malaria medication after accounting for parents' education and Mosquito net use. Also, Sumbele et al. (2016) showed that children whose parent had no formal education, significantly had higher prevalence of medium to severe anemia. Furthermore, both Iwuafor (2016) and Sumbele (2016) showed that there is no significant relationship between ITN use and malaria-induced anemia. In this study, children who sleep under a mosquito net did not significantly ($p = 0.64$) have malaria-induced anemia compared to those who did not sleep under a mosquito net.

Research Question 3 (RQ3): Is there an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and Mosquito net use?

> $H_0$3: There is no association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.
>
> H_a3: There is an association between malaria-induced anemia and gender among children younger than 5 years old in Nigeria who tested positive for malaria after controlling for parents' education and mosquito net use.

For research question 3, there was no statistically significant association between malaria-induced anemia and gender after controlling for parent's education level and mosquito net use ($p = 0.747$, $OR = 1.05$). Therefore, the null hypothesis for research question 3 was not rejected. Parent's education level and mosquito net use was also not statistically significant (*p* value 0.23 and 0.55 respectively). Though in Table 21, children with malaria are 5.1 times more likely to have anemia than those that do not have malaria.

In contrast to this current study, in the cross-sectional study conducted among school children in Kuwait, Shaban et al. (2020) which explored factors associated with the prevalence of anemia from varying causes including malaria disease. They found that gender and other factors such as age, iron concentration, and ferritin were associated with anemia from all causes. The current study did not support the findings described by Shaban et al. (2020) on the relationship between anemia and gender. Unlike in Nigeria, children in Kuwait have high standard of health care including other free education and medical care, paucity of vegetation and standing bodies of water, and Kuwait have eliminated most of the common parasites that contributes to malaria-induced anemia (Shaban et al., 2020). Anabire et al. (2018) and Latif et al. (2018) found that gender did not have any association with anemia from any causes in children, which is in line with the current inquiry.

Research Question 4 (RQ4): Is there an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age group) among children younger than 5 years old in Nigeria?

$H_0$4: There is no association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age group) among children younger than 5 years old in Nigeria.

Ha4: There is an association between residence type, parent's educational level, malaria medication use, mosquito net use, and malaria-induced anemia status (controlling for gender and age group) among children younger than 5 years old in Nigeria.

For research question 4, child age group and parent's secondary education level shown in Table 24 had a statistically significant relationship ($p = 0.04$, $OR = 0.64$; *and* p

= 0.03*, OR* = 1.94) relationship between malaria-induced anemia among children younger than 5 years old after controlling for gender and age group. Therefore, the null hypothesis was not rejected for the combined effect. For research question 4, among children included in this analysis, the highest odds ratio observed were among parent's primary education and secondary education, 1.7 and 1.9, respectively. Gender, residence type, malaria medication use, and mosquito net use are not statistically significant predictor of malaria-Induced anemia status among children younger than 5 years old in Nigeria after controlling for gender and age group.

None of the literature reviewed in this study showed a combined effect of these factors on malaria-induced anemia. However, Sumbele et al. (2016) and Nambiema et al. (2019) found that no formal education of the children's parents or guardian significantly predicted malaria-induced anemia. According to Rahman et al. (2019), Rudasingwa and Cho (2020), and Tazebew et al. (2021), age group, higher education level of the children's parent or guardian, and socioeconomic status significantly predicted anemia from all causes, which is contrary to the findings described in this study.

Theoretical Framework

The SEM is often used to explain intrinsic and extrinsic factors that influences an event or a health condition. Four constructs of SEM were used to explain the association between malaria and malaria-induced anemia. The four constructs include the individual, interpersonal relationship, community, and societal factors. These constructs or factors are essential in explaining the risks of malaria-induced anemia and malaria condition and perhaps how to protect vulnerable population from the health conditions.

At the individual level, biological characteristics and personal factors may increase or prevent mosquito infestation, malaria-induced anemia, and malaria. Some factors in this current study attributed to the individual level construct are child age group, parents or guardians' education, malaria medication use, ITNs or mosquito net use. The prevention strategies at the individual level promotes attitude, beliefs, and behaviors that protects children and individuals from mosquito bites and subsequently malaria-induced anemia and malaria. Parents' education or through enhanced health literacy and awareness of malaria and anemia risk factors, the impacts of malaria and malaria-induced anemia could be substantially reduced. According to Saaka and Glover (2017), despite a high level of awareness of the benefits and effectiveness of ITN and availability due to the subsidized cost of the ITN, there were low compliance to use of ITN because of other uncomfortable environmental conditions such as heat and humidity.

Interpersonal relationships influence health outcomes because peers, partners, and family members influence an individual's behavior. Arroz (2017), Awuah et al. (2018), and Panter-Brick, et al. (2006) suggested that interpersonal factors such as social networking, age, SES educational level, and the structural institutional mechanisms (such as healthcare access) influences a person's lifestyle. Awuah et al. (2018) found that many urban residents self-medicate as their first choice to treat malaria. On the other hand, parents with high level of social support seek alternative treatments for malaria.

At the community level of the SEM construct such as the schools, workplace, and neighborhoods, there are wealth of information and resources on malaria and malaria-induced anemia preventative measures (CDC, 2016). Malaria preventive strategies at the community level focus on improving not only the physical environment but also the social environment or settings. The urban, and rural areas of Nigeria are examples of community constructs explained in the SEM. Health care system, public health department, medical centers, pharmacy locations, and local business as a community or stakeholders provide support and needed training/resources on malaria and malaria-induced anemia prevention.

Societal factors such as social and cultural norms often promote the use of malaria medication use and ITN/ mosquito net use. Societal factors also include health system, economic structure, education system, and social policies that help maintain economic or social structures between groups in the society (CDC, 2016). The prevention strategies at this level include efforts that promote societal norms to promote mosquito net use to prevent or eradicate mosquito in the community or at the household level (CDC, 2016).

Limitations of the Study

The 2015 DHS secondary data is not inherently unique to this current study. I did not have control over how the original data was collected. In other words, the 2015 DHS data was not primarily designed to address the four research questions posed in this current study. The design of my study was completely subject to the variables already collected in the 2015 DHS, as such, I could not account for other confounders known to influence anemia such as sickle cell or sickle cell carrier. Thus, there is possibility of misclassification and selection bias in this study. Variables controlled in this study are those identified in the 2015 DHS secondary dataset. The DHS is a credible institution. DHS designed and collected the 2015 DHS data from participants yet recall bias could not have been eliminated from the study all of which could influence the internal and external validity of this study. There were many missing data points in the dataset which may also affect the internal validity of the study.

In addition, the 2015 DHS dataset was not designed to the specific need of the current research questions. Therefore, the instruments' content validity, accuracy, and data collection procedures lack high-level specificity and sensitivity to this current study. Due to large the missing data, low statistical power, sample size, effect size estimation, confidence level could lead to a type I and II errors. This is a cross-sectional study design, and the exposure to malaria was not and cannot be randomly assigned to the children included in this analysis. Thus, the findings are limited to only a correlational inference and not a causal association. Also, the findings of this study cannot be generalized outside of children under the age of 5 years old living in Nigeria. In addition, the findings cannot not extend beyond the children and population included in this study even within Nigeria.

The fact that malaria treatment medication was taken by 541 out of the 543 children who reported a response was also a main limitation. The analysis for children who did not use malaria medication against those that used malaria medication was not plausible. As Nigeria is an endemic country for malaria and ethical reservation may exist such that it is unethical not to give malaria medications to malaria positive patients.

Recommendations

The best practices to combat malaria and prevent malaria-induced anemia condition is to prevent malaria spread. Antimalarial tablets, DEET insect repellents (not for children less than two months old), insecticide-treatment nets, indoor residual spraying, malaria treatment medications, and chemoprevention options are very effective for malaria intervention and treatment. These intervention strategies should be subsidized to be affordable to families with low income. Residents should be encouraged to use antimalaria tables and/or DEET insect repellents when they are in open places where mosquito is endemic. Also, the use of door and window screens are highly recommended to prevent mosquito from getting into the house. Windows and doors should be always closed properly. Wearing of long sleeves rather than short sleeves is encouraged.

For those that were unable to prevent malaria and need treatment (those having malaria symptoms), medical advice and diagnose is recommended. The public health agencies should implement a program where parents of children that cannot afford malaria treatment medication be provided with the malaria drugs at no cost or at a subsidized rate. IRS should also be provided to low-income communities so that parents with low income can benefit from IRS.

Implications for Social Change

While malaria is a disease of the past in North America, Europe, Australia, and parts of Asia, malaria remains a major public health challenge in sub-Saharan Africa, and Nigeria bears the highest burden. Furthermore, children under 5 years old are most affected by the disease when compared to other older age groups. Many malaria interventions have been effective in reducing the burden of malaria. Body of literature shows that many countries implemented a comprehensive intervention approach to attain and maintain zero malaria incidence decline for decades. Such comprehensive intervention approaches should be tailored accordingly to Nigeria social structure to help improve the decline of malaria in Nigeria. The review of literature for this study clearly showed that there are effective malaria interventions; however, these tools are not reaching the people that need them because they reside in hard-to-reach rural areas or they simply cannot afford mosquito nets and malaria treatment medication. The Nigeria federal ministry of health's malaria program (National Malaria Control Program) should therefore not only concentrate their efforts on the urban areas of the country, but they must also get malaria intervention to the people in hard-to-reach rural areas as well.

This study adds to the body of literature on the association of malaria and malaria-induced anemia but further found that once a child has malaria, the use of mosquito net or parent's education does not affect the relationship. Also, the residence type does not affect the relationship between malaria and malaria-induced anemia. The goal for the National Malaria Control Program is to prevent malaria by promoting the use of mosquito net. The use of any type of malaria treatment medication at any time in the past reduces the chances of a malaria-induced anemia condition but gender discrimination did not exist. Specific public health measures should be put in place to target children 3 years and younger (0-36 months old) who are the most susceptible to malaria-induced anemia than those children older than 3 years but younger than 5 years old (37-59 months old) because they are yet to develop immunity against the malaria parasite and unable to defend themselves as much. The Nigeria's federal ministry of health's malaria program may lunch an intervention that would subsidize the cost of malaria treatment medication or provide such medication at no cost.

Other sub-Saharan African countries with similar topography as Nigeria and regions where malaria is an endemic can benefit from the findings of this study especially from these recommendations to develop a tailored malaria intervention approach that fit their need and target population. The findings of this study will also be shared with the DHS as a fulfilment of the stipulated agreement for the use of their dataset for this study. It is likely that through the gaps and limitations specified in this study, DHS will be better informed on how to improve their subsequent data collection to address these gaps and limitations.

Conclusion

In this cross-sectional design study using the 2015 DHS secondary dataset, malaria was found to significantly predict malaria-induced anemia. The association between malaria medication use and malaria-induced anemia was not reliable due to the sample size attained in one group that used malaria medication compared to the other group of children that did not use any time of malaria medication. However, results from the literature showed that the use of malaria medication and effective anti-malarial drugs substantially reduced malaria-induced anemia (White, 2018; Zwang et al., 2017). The idea of malaria treatment medication is to reduce malaria parasitemia in infested patients which in turn would reduce the number of RBC destroyed in the body. Thereby, the malaria is treated and not progress to the severe stage to cause malaria-induced anemia. The analysis also showed that gender did not significantly predict malaria-induced anemia among children under than 5 years old. The confounding factors, parents' education level and mosquito net use, did not contribute to the association between the predictor and the outcome variables. Finally, the results revealed that child age group and parent's secondary educational level significantly predicted malaria-induced anemia among children under than 5 years old after controlling for gender and age group. These findings were analyzed using multinomial logistic regression analysis of the predictor and outcome variables with all the covariates included in the investigation.

The National Malaria Control Program (NMCP) faces a promising future not only regarding the reduction in death of children under 5 years old due to malaria-induced anemia but eventually leading to a complete elimination of malaria in Nigeria, and other sub-Saharan African countries. The malaria intervention program that targets low-income groups who cannot afford to pay for intervention tools is desirable. These interventions may help to reduce malaria in children under 5 years old. These interventions may also include strategic health care assistance to parents who cannot afford mosquito nets and malaria treatment medication for their children. The intervention may include educating parents on available intervention tools and promoting healthy behaviors at community gardening's and through social media. A new public health strategy that includes parent's assistance program and outright donation of intervention tools like insecticide-treated nets, effective drugs against malaria, and Indoor Residual Spraying, in hard-to-reach rural areas, would be desirable for NMCP to implement. Nigeria and indeed other sub-Saharan African countries should engage in public health strategies aimed at modifying infrastructure to control mosquito breeding, improve malaria intervention adherence to include mosquito net use, age specific intervention measures, and mosquito awareness via education.

In view of the multiple anemia-inducing conditions and the complexity of their etiology, more research is required to assist in better understanding of malaria-induced anemia within this study population. Anemia conditions due to when the body does not make enough hemoglobin, the hemoglobin that the body makes may not work appropriately, enough red blood cells not produced by the body, the body breaking down the red blood cells too quickly, or anemia through internal bleeding. Other types of anemia are iron-deficiency and sickle cell anemia. Such robust information would be very helpful in designing a holistic strategy to address malaria-induced anemia from all causes of anemia among children under 5 years old. Malaria control program should include health programs and interventions for these other causes of anemia to further support and strengthen the program's health effort as they would significantly contribute to the reduction of death of child under 5 years old in sub-Saharan Africa.

References

Abuaku, B., Ahorlu, C., Psychas, P., Ricks, P., Oppong, S., Mensah, S., Sackey, W., & Koram, K. A. (2018). Impact of indoor residual spraying on malaria parasitaemia in the Bunkpurugu-Yunyoo District in northern Ghana. *Parasites & vectors, 11*(1), 555. https://doi.org/10.1186/s13071-018-3130-z

Ackerman, H., Ayestaran, A., Olola, C. H., Jallow, M., Agbenyega, T., Bojang, K., Roberts, D., Krishna, S., Kremsner, P., Newton, C., Taylor, T., Valim, C., & Casals-Pascual, C. (2020). The effect of blood transfusion on outcomes among African children admitted to hospital with *Plasmodium falciparum* malaria: A prospective, multicenter observational study. *The Lancet Hematology, 7*(11), e789-e797. https://www.sciencedirect.com/science/article/abs/pii/S235230262030288X

Achidi, E. A., Apinjoh, T. O., Anchang-Kimbi, J. K., Mugri, R. N., Ngwai, A. N., & Yafi, C. N. (2012). Severe and uncomplicated falciparum malaria in children from three regions and three ethnic groups in Cameroon: prospective study. *Malaria Journal, 11*(1), 215. https://malariajournal.biomedcentral.com/articles/10.1186/1475-2875-11-215

Adepoju, K. A., & Akpan, G. E. (2017). Historical assessment of malaria hazard and mortality in Nigeria—Cases and Deaths: 1955–2015. Int J Environ. *Bioener, 12*(1), 30-46. https://www.researchgate.net/profile/K-Adepoju/publication/315657804_Historical_Assessment_of_Malaria_Hazard_and_Mortality_in_Nigeria-Cases_and_Deaths_1955_-

_2015/links/58d8f59aa6fdcc1baebab4ec/Historical-Assessment-of-Malaria-Hazard-and-Mortality-in-Nigeria-Cases-and-Deaths-1955-2015.pdf

Adindu, A. (2010). Assessing and assuring quality of health care in Africa. *African Journal of Medical Sciences, 3*(1), 31-36. https://d1wqtxts1xzle7.cloudfront.net/29432905/assessing_quality_of_care_in_africa-with-cover-page-v2.pdf?Expires=1632775491&Signature=TylIrgPZ~20hbdZ5yuyv5ykJHAtAxL4AS0hOAkDEx1rAn1TSlwvCO8524OXu~cqPrPhZ4m124SdBz~JkHh-zsziq5DwdQVuZec-df8ngVvOmPM4KPSa6v6PyLErG5Vnm6MsJIy9cD3PWHYUoh41EykFW0ASZQ7XUc-6-2UDZ3agHsEJaJXvYQf6iUyiDPqTjiyhW16UUYYBFA0mRbg-DpSQCGKh0HWAor~h5V4Xhud8rXSHbQITaOxAC3n0iv3T0cf4jXqheVUSDXNqrsV7g01D0qeOJBGUg3SwdM8Z1LUw1KY21sGZh1RpXG864onWFe-Ld3yDfZan9zoBH1dWkEQ__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

Agyepong, I. A., Sewankambo, N., Binagwaho, A., Coll-Seck, A. M., Corrah, T., Ezeh, A., Fekadu, A., Kilonzo, N., Lamptey, P., Masiye, F., Mayosi, B., Mboup, S., Muyembe, J., Pate, M., Sidibe, M., Simons, B., Tlou, S., Gheorghe, A., Legido-Quigley, H., … & Piot, P. (2017). The path to longer and healthier lives for all Africans by 2030: The Lancet Commission on the future of health in sub-Saharan Africa. *The Lancet, 390(10114),* 2803-2859. https://doi.org/10.1016/S0140-6736(17)31509-X

Ahorlu, C. S., Adongo, P., Koenker, H., Zigirumugabe, S., Sika-Bright, S., Koka, E., Tabong, P., Piccinini, D., Segbaya, S., Olapeju, B., & Monroe, A. (2019). Understanding the gap between access and use: A qualitative study on barriers and facilitators to insecticide-treated net use in Ghana. *Malaria Journal, 18*(1), 417. https://link.springer.com/article/10.1186/s12936-019-3051-0

Afulani, P. A. (2015). Rural/urban and socioeconomic differentials in quality of antenatal care in Ghana. *PloS one, 10*(2), e0117996. https://doi.org/10.1371/journal.pone.0117996

Alonso, S., Chaccour, C. J., Elobolobo, E., Nacima, A., Candrinho, B., Saifodine, A., Saute, F., Robertson, M., & Zulliger, R. (2019). The economic burden of malaria on households and the health system in a high transmission district of Mozambique. *Malaria Journal, 18*(1), 360. https://link.springer.com/article/10.1186/s12936-019-2995-4

Alliance, V. (2019). Public health round-up. *Bull World Health Organ*, 97, 4-5. https://apps.who.int/iris/bitstream/handle/10665/279407/PMC6307506.pdf

Al-Awadhi, M., Ahmad, S., & Iqbal, J. (2021). Current Status and the Epidemiology of Malaria in the Middle East Region and Beyond. *Microorganisms, 9*(2), 338. https://doi.org/10.3390/microorganisms9020338

Al-Mendalawi, M. (2019). Investigation of malaria by microscopy among febrile outpatients of a semirural Nigerian medical center: What happened to malaria control programs? *The Nigerian Journal of General Practice, 17*(2), 68-68.

http://www.njgp.org/printarticle.asp?issn=1118-4647;year=2019;volume=17;issue=1;spage=23;epage=30;aulast=Michael

Ambe, J. P., Balogun, S. T., Waziri, M. B., Nglass, I. N., & Saddiq, A. (2020). Impacts of seasonal malaria chemoprevention on malaria burden among under five-year-old children in Borno state, *Nigeria. Journal of Tropical Medicine*, *2020*. https://doi.org/10.1155/2020/9372457

American Association for the Advancement of Science. (2017). Simple blood test predicts anemia risk after malaria treatment. *ScienceDaily*. https://www.sciencedaily.com/releases/2017/07/170705164538.htm

Anabire, N. G., Aryee, P. A., & Helegbe, G. K. (2018). Hematological abnormalities in patients with malaria and typhoid in Tamale Metropolis of Ghana. *BMC research notes, 11*(1), 1-6. https://link.springer.com/article/10.1186/s13104-018-3456-9

Arroz, J. A. H. (2017). Social and behavior change communication in the fight against malaria in Mozambique. *Revista de saude publica, 51*, 18. https://doi.org/10.1590/s1518-8787.2017051006360

Asakitikpi, A. E. (2019). Healthcare coverage and affordability in Nigeria: An alternative model to equitable healthcare delivery. In *Universal Health Coverage*. IntechOpen. https://www.intechopen.com/books/universal-health-coverage/healthcare-coverage-and-affordability-in-nigeria-an-alternative-model-to-equitable-healthcare-delive

Awuah, R. B., Asante, P. Y., Sakyi, L., Biney, A. A., Kushitor, M. K., Agyei, F., & Aikins, A. D. G. (2018). Factors associated with treatment-seeking for malaria in urban poor communities in Accra, Ghana. *Malaria Journal, 17*(1), 1-8. https://doi.org/10.1186/s12936-018-2311-8

Bailey, C., Blake, C., Schriver, M., Cubaka, V. K., Thomas, T., & Martin Hilber, A. (2016). A systematic review of supportive supervision as a strategy to improve primary healthcare services in Sub-Saharan Africa. *International Journal of Gynecology & Obstetrics, 132*(1), 117-125. https://doi.org/10.1016/j.ijgo.2015.10.004

Bancells, C., Llorà-Batlle, O., Poran, A., Nötzel, C., Rovira-Graells, N., Elemento, O., Kafsack, B.F. and Cortés, A. (2019). Revisiting the initial steps of sexual development in the malaria parasite Plasmodium falciparum. *Nature microbiology, 4*(1), 144-154. https://doi.org/10.1038/s41564-018-0291-7

Bell, E., Bryman, A., & Harley, B. (2018). *Business research methods*. Oxford university press. https://doc1.bibliothek.li/aca/FLMF037012.pdf

Bienvenu, A. L., Djimdé, A., & Picot, S. (2019). Antimalarial stewardship programs are urgently needed for malaria elimination: A perspective. Parasite, 26, 16. https://www.parasite-journal.org/articles/parasite/abs/2019/01/parasite190016/parasite190016.html

Bronfenbrenner, U. (1979). The ecology of human development. Harvard University Press: Cambridge. https://doi.org/10.1080/00131728109336000

Brownson, R. C., Gurney, J. G., & Land, G. G. (1999). Evidence-based decision making in public health. *Journal of Public Health Management Practice, 5*(5), 86-97. https://doi.org/10.1.1.526.9394&rep=rep1&type=pdf

Bully, P., Jaureguizar, J., Bernaras, E., & Redondo, I. (2019). Relationship between parental socialization, emotional symptoms, and academic performance during adolescence: The influence of parents' and teenagers' gender. *International Journal of Environmental Research and Public Health, 16*(12*),* 2231. https://www.mdpi.com/1660-4601/16/12/2231

Centers for Disease Control and Prevention. (2016). The social-ecological model: A framework for prevention. https://www.cdc.gov/violenceprevention/about/social-ecologicalmodel.html

Center for Communication Programs. (2020). Voices for a malaria-free future. https://www.malariafreefuture.org/malaria

Centers for Disease Control and Prevention. (2020a). Biology: Anopheles Mosquitoes. https://www.cdc.gov/malaria/about/biology/index.html

Centers for Disease Control and Prevention. (2020b). Mosquitoes in the United States. https://www.cdc.gov/mosquitoes/about/mosquitoes-in-the-us.html

Centers for Disease Control and Prevention. (2019). Global health – Nigeria. https://www.cdc.gov/globalhealth/countries/nigeria/default.htm

Chacky, F., Runge, M., Rumisha, S. F., Machafuko, P., Chaki, P., Massaga, J., Mohamed, A., Pothin, E., Molteni, F., Snow, R., Lengeler, C., & Mandike, R. (2018). Nationwide school malaria parasitaemia survey in public primary schools, the United Republic of Tanzania. *Malaria Journal, 17*(1), 1-16. https://malariajournal.biomedcentral.com/articles/10.1186/s12936-018-2601-1

Cheng, H. G., & Phillips, M. R. (2014). Secondary analysis of existing data: opportunities and implementation. *Shanghai archives of psychiatry, 26*(6), 371–375. https://doi.org/10.11919/j.issn.1002-0829.214171

Cohee, L., & Laufer, M. (2018). Tackling malaria transmission in sub-Saharan Africa. *The Lancet Global Health, 6*(6), e598-e599. https://www.thelancet.com/action/showPdf?pii=S2214-109X%2818%2930197-9

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Degarege, A., Fennie, K., Degarege, D., Chennupati, S., & Madhivanan, P. (2019). Improving socioeconomic status may reduce the burden of malaria in sub-Saharan Africa: A systematic review and meta-analysis. *PloS one, 14(1),* e0211205. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0211205

Demographic and Health Surveys. (2019). Team and partners. https://dhsprogram.com/Who-We-Are/About-Us.cfm

Devi, S. (2018). Crisis in the Chad basin. The Lancet, 392(10151), 904-905. https://www.thelancet.com/action/showPdf?pii=S0140-6736%2818%2932250-5

Donald, B. R. (2007). The design versus the analysis of observational studies for causal effects: parallels with the design of randomized trials. *Statistics in Medicine, 26*, 20-36. https://doi:10.1002/sim.2739

Erbe Healy, A. (2018). Comparative research using secondary data analysis: Exploring Europe’s changing food consumption practices (Pre-published version). https://doi:10.1177/0020715214561132

Ferguson, K. T., & Evans, G. W. (2019). Social ecological theory: Family systems and family psychology in bioecological and bioecocultural perspective. https://psycnet.apa.org/record/2018-59956-009

Forthofer, R. N., Lee, E. S., & Hernandez, M. (2007). *Biostatistics: A guide to design, analysis, and discovery*. Amsterdam, Netherlands: Elsevier Academic Press

Golden, S. D., McLeroy, K. R., Green, L. W., Earp, J. A. L., & Lieberman, L. D. (2015). Upending the social ecological model to guide health promotion efforts toward policy and environmental change. *Health Education & Behavior, 42*(1_suppl), 8S-14S. https://doi.org/10.1177/1090198115575098

Greenhouse, B., Daily, J., Guinovart, C., Goncalves, B., Beeson, J., Bell, D., ... & Eisele, T. P. (2019). Priority use cases for antibody-detecting assays of recent malaria exposure as tools to achieve and sustain malaria elimination. *Gates Open Research, 3*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6545519/

Glanz, K., Rimer, B. K., & Viswanath, K. (Eds). (2008). *Health behavior and health education: Theory, research, and practice* (4th ed.). San Francisco, CA: John Wiley & Sons

Guillebaud, J., Mahamadou, A., Zamanka, H., Katzelma, M., Arzika, I., Ibrahim, M. L., ... & Fandeur, T. (2013). Epidemiology of malaria in an area of seasonal transmission in Niger and implications for the design of a seasonal malaria chemoprevention strategy. *Malaria journal, 12*(1), 379. https://malariajournal.biomedcentral.com/articles/10.1186/1475-2875-12-379

Haakenstad, A., Harle, A. C., Tsakalos, G., Micah, A. E., Tao, T., Anjomshoa, M., Cohen, J., Fullman, N., Hay, S., Mestrovic, T., Mohammed, S., Mousavi, S., Nixon, M., Pigott, D., Tran, K., Murray, C., & Dieleman, J. (2019). Tracking spending on malaria by source in 106 countries, 2000–16: an economic modelling study. *The Lancet Infectious Diseases*. https://doi.org/10.1016/S1473-3099(19)30165-3

Hashim, H. A., & Ali, E. M. A. (2017). Pattern of malaria in hospitalized children in Khartoum state. *Sudanese Journal of Paediatrics, 17*(2), 35. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5845454/

Hassan, C. M., Djekonbe, D., Dombou, T., & Dany, R. (2018). The efficiency of the health system in Chad. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3176950

International Labor Organization. (2014). Nigeria: Occupational safety and health. http://www.ilo.org/dyn/natlex/natlex4.detailp_lang=en&p_isn=58758&p_country=NGA&p_classification=14

Iwuafor, A. A., Egwuatu, C. C., Nnachi, A. U., Ita, I. O., Ogban, G. I., Akujobi, C. N., & Egwuatu, T. O. (2016). Malaria parasitemia and the use of insecticide-treated nets (INTs) for malaria control amongst under-5 years old children in Calabar, Nigeria. *BMC infectious diseases, 16,* 151. https://doi.org/10.1186/s12879-016-1459-5

Jingi, A. M., Kuate-Mfeukeu, L., Hamadou, B., Ateba, N. A., & Nadege, C. (2018). Prevalence and associates of anemia in adult men and women urban dwellers in

Cameroon: A cross-sectional study in a Sub-Saharan setting. http://aob.amegroups.com/article/view/4510/5255

Karunasena, V. M., Marasinghe, M., Koo, C., Amarasinghe, S., Senaratne, A. S., Hasantha, R., ... & Mendis, K. N. (2019). The first introduced malaria case reported from Sri Lanka after elimination: Implications for preventing the re-introduction of malaria in recently eliminated countries. *Malaria Journal, 18*(1)*,* 210. https://malariajournal.biomedcentral.com/articles/10.1186/s12936-019-2843-6

Khan, H. A., Khan, Z., Iqbal, S., Ali, S., Umam, S., & Abbas, G. (2020). Frequency of thrombocytopenia in patient with malaria presenting to Khyber teaching hospital, Peshawar, Pakistan. *Journal Of Medical Sciences, 28*(4), 337-340. https://doi.org/10.52764/jms.20.28.4.6

Kibret, S., Wilson, G. G., Ryder, D., Tekie, H., & Petros, B. (2019). Environmental and meteorological factors linked to malaria transmission around large dams at three ecological settings in Ethiopia. *Malaria Journal, 18*(1*),* 54. https://doi.org/10.1186/s12936-019-2689-y

Klein, M. C., Harvey, S. A., Diarra, H., Hurley, E. A., Rao, N., Diop, S., & Doumbia, S. (2016). "There is no free here, you have to pay": actual and perceived costs as barriers to intermittent preventive treatment of malaria in pregnancy in Mali. *Malaria Journal, 15*(1), 1-8. https://doi.org/10.1186/s12936-016-1210-0

Kweku, M., Appiah, E. K., Enuameh, Y., Adjuik, M., Takramah, W., Tarkang, E., & Gyapong, J. (2017). The impact of malaria control interventions on malaria and anemia in children under five after ten years of implementation in the Hohoe Municipality of Ghana. *Advances in Infectious Diseases*, *7*(03), 93. https://www.scirp.org/journal/PaperInformation.aspx?paperID=79196

Latif, M., Ayaz, S. B., Manzoor, M., & Ishaq, M. (2018). Frequency and severity of anemia in children less than 15 years of age at Gwadar development authority hospital, Gwadar, Bakuchistan. *Pakistan Armed Forces Medical Journal, 68*(5), 1088-92.

Liu, Z., Sun, R., Li, J., Cheng, W., & Li, L. (2019). Relations of anemia with the all-cause mortality and cardiovascular mortality in general population: A meta-analysis. *The American Journal of the Medical Sciences, 358*(3), 191-199. https://www.amjmedsci.org/article/S0002-9629(19)30221-6/fulltext

Mayo Clinic. (2017). Fever. https://www.mayoclinic.org/diseases-conditions/fever/symptoms-causes/syc-20352759

Mann, C. J. (2003). Observational research methods. Research design II: cohort, cross sectional, and case-control studies. *Emergency Medical Journal, 20*(1), 54-60. https://doi.org/10.1136/emj.20.1.54

Mash, R., Howe, A., Olayemi, O., Makwero, M., Ray, S., Zerihun, M., ... & Goodyear-Smith, F. (2018). Reflections on family medicine and primary healthcare in sub-Saharan Africa. https://doi.org/10.1136/bmjgh-2017-000662

Mbako, J. D., Barffo, D., Nuotol, R. K., Alebshehy, R., & Shuaib, N. M. (2017). Enhancing malaria prevention in Cameroon through community participation: An in-depth review. *Central African Journal of Public Health, 3*(6), 97. http://dx.doi.org/10.11648/j.cajph.20170306.12

Medicines for Malaria Venture. (2019). Children and malaria: Treating and protecting the most vulnerable. https://www.mmv.org/newsroom/publications/children-and-malaria-treating-and-protecting-most-vulnerable

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health education quarterly, 15*(4), 351-377. Https://doi.org/10.1177/109019818801500401

Meremikwu, M., Odey, F., Oringanje, C., Oyo-Ita, A., Udoh, E., Eyong, K., & Oduwole, O. (2013). Effectiveness of a 6-dose regimen of Artemether-Lumefantrine for unsupervised treatment of uncomplicated childhood malaria in Calabar, Nigeria. *Nigerian Journal of Paediatrics, 40*(2), 145-149. https://doi.org/10.4314/njp.v40i2.7

Morakinyo, O. M., Balogun, F. M., & Fagbamigbe, A. F. (2018). Housing type and risk of malaria among under-five children in Nigeria: evidence from the malaria indicator survey. *Malaria journal, 17*(1), 311. https://malariajournal.biomedcentral.com/articles/10.1186/s12936-018-2463-6

Nambiema, A., Robert, A., & Yaya, I. (2019). Prevalence and risk factors of anemia in children aged from 6 to 59 months in Togo: Analysis from Togo demographic and health survey data, 2013–2014. *BMC public health, 19*(1), 1-9. https://doi.org/10.1186/s12889-019-6547-1

National Population Commission. (2014). *Nigeria demographic and health survey 2013*. Abuja, Nigeria, and Rockville, Maryland, USA: NPC and International. http://ngfrepository.org.ng:8080/jspui/handle/123456789/3139

Njunda, A. L., Njumkeng, C., Nsagha, S. D., Assob, J. C. N., & Kwenti, T. E. (2016). The prevalence of malaria in people living with HIV in Yaounde, Cameroon. *BMC public health, 16*(1), 964. https://doi.org/10.1186/s12889-016-3647-z

Oduwole, O. A., Ameh, S., Esu, E. B., Oringanje, C. M., Meremikwu, J. T., & Meremikwu, M. M. (2019). Assessing agreement of hemoglobin and three-fold conversion of hematocrit as methods for detecting anemia in children living in malaria-endemic areas of Calabar, Nigeria. *Nigerian journal of clinical practice, 22*(8), 1078. https://doi.org/10.1186/s12889-016-3647-z

Olukosi, A., & Afolabi, B. M. (2018). Malaria and anemia among pregnant women living in communities along the coast of Lagos Lagoon, South-west Nigeria. *Int J Pregn & Chi Birth, 4*(6), 175-182. https://www.researchgate.net/profile/Bamgboye_Afolabi/publication/330614176_Malaria_and_anemia_among_pregnant_women_living_in_communities_along_the_coast_of_Lagos_Lagoon_South-west_Nigeria/links/5c4efc17a6fdccd6b5cf3572/Malaria-and-anemia-among-pregnant-women-living-in-communities-along-the-coast-of-Lagos-Lagoon-South-west-Nigeria.pdf

Okwa, O. O. (2019). Nipping the Malaria Vectors in the Bud: Focus on Nigeria. In Malaria. IntechOpen. https://www.intechopen.com/online-first/nipping-the-malaria-vectors-in-the-bud-foc

Olaso-Bengoechea, A., López-Ballero, M., & Ferrer-Gimeno, T. (2021). Plasmodium vivax within European borders. https://doi.org/10.15761/GMO.1000108

Olukosi, A., & Afolabi, B. (2018). Malaria and anemia among pregnant women living in communities along the coast of Lagos Lagoon, South-west Nigeria. *Int J Pregnancy Child Birth, 4*, 175-182. https://doi.org/10.15406/ipcb.2018.04.00122

Onwujekwe, O., Uguru, N., Etiaba, E., Chikezie, I., Uzochukwu, B., & Adjagba, A. (2013). The economic burden of malaria on households and the health system in Enugu State Southeast Nigeria. *PloS one, 8*(11*),* e78362. https://doi.org/10.1371/journal.pone.0078362

Opoka, R. O., Conroy, A. L., Waiswa, A., Wasswa, R., Tumwine, J. K., Karamagi, C., & John, C. C. (2020). Severe anemia is associated with systemic inflammation in young children presenting to a tertiary hospital in Uganda. *The American Journal of Tropical Medicine and Hygiene, 103*(6), 2574-2580. https://dx.doi.org/10.4269%2Fajtmh.20-0199

Pan American Health Organization. (2019). Malaria: Key facts. https://www.paho.org/en/topics/malaria

Panter-Brick, C., Clarke, S. E., Lomas, H., Pinder, M., & Lindsay, S. W. (2006). Culturally compelling strategies for behaviour change: A social ecology model and case study in malaria prevention. *Social Science & Medicine, 62*(11), 2810-

2825. https://www.researchgate.net/profile/Catherine_Panter-Brick/publication/7418357_Culturally_Compelling_Strategies_for_Behaviour_Change_A_Social_Ecology_Model_and_Case_Study_in_Malaria_Prevention/links/5c36199b299bf12be3ba5fde/Culturally-Compelling-Strategies-for-Behaviour-Change-A-Social-Ecology-Model-and-Case-Study-in-Malaria-Prevention.pdf

Papaioannou, I., Utzinger, J., & Vounatsou, P. (2019). Malaria-anemia comorbidity prevalence as a measure of malaria-related deaths in sub-Saharan Africa. *Scientific reports, 9*(1), 1-9. https://www.nature.com/articles/s41598-019-47614-6.pdf

Pasricha, S. R., Armitage, A. E., Prentice, A. M., & Drakesmith, H. (2018). Reducing anemia in low income countries: Control of infection is essential. *BMJ, 362*, k3165. https://www.bmj.com/content/362/bmj.k3165

President's Malaria Initiative. (2019a). Fighting malaria and saving lives. https://www.pmi.gov

President's Malaria Initiative. (2019b). 2019 PMI thirteenth annual report. https://www.pmi.gov/about/pmi-annual-report-2019

Poux, S. (2017). Social ecological model offers new approach to public health. https://blogs.uw.edu/somehm/2017/08/12/social-ecological-model/

Pasricha, S. R., Armitage, A. E., Prentice, A. M., & Drakesmith, H. (2018). Reducing anemia in low income countries: Control of infection is essential. *BMJ, 362*, k3165. https://www.bmj.com/content/362/bmj.k3165

Powers, J. M., Nagel, M., Raphael, J. L., Mahoney, D. H., Buchanan, G. R., & Thompson, D. I. (2020). Barriers to and facilitators of iron therapy in children with iron deficiency anemia. *The Journal of Pediatrics*. https://www.sciencedirect.com/science/article/abs/pii/S0022347619317196

Rahman, M. S., Mushfiquee, M., Masud, M. S., & Howlader, T. (2019). Association between malnutrition and anemia in under-five children and women of reproductive age: Evidence from Bangladesh Demographic and Health Survey 2011. *PloS one, 14*(7), e0219170. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0219170

Rogerson, S. J., Desai, M., Mayor, A., Sicuri, E., Taylor, S. M., & van Eijk, A. M. (2018). Burden, pathology, and costs of malaria in pregnancy: new developments for an old problem. *The Lancet infectious diseases, 18*(4), e107-e118. https://doi.org/10.1016/S1473-3099(18)30066-5

Rosenthal, P. J., John, C. C., & Rabinovitch, N. R. (2019). Malaria: How are we doing and how can we do better?. *The American Journal of Tropical Medicine and Hygiene, 100*(2), 239–241. https://doi.org/10.4269/ajtmh.18-0997

Rudasingwa, G., & Cho, S. I. (2020). Determinants of the persistence of malaria in Rwanda. *Malaria journal, 19*(1), 36. https://link.springer.com/article/10.1186/s12936-020-3117-z

Saaka, M., & Glover, K. (2017). Assessing the prevalence of malaria and the use of insecticide treated bed nets in Ghana. *UDS International Journal of Development*, *4*(1), 10-19. http://udsijd.org/index.php/udsijd/article/view/152

Sadoine, M. L., Smargiassi, A., Ridde, V., Tusting, L. S., & Zinszer, K. (2018). The associations between malaria, interventions, and the environment: a systematic review and meta-analysis. *Malaria journal, 17*(1), 73. https://malariajournal.biomedcentral.com/track/pdf/10.1186/s12936-018-2220-x

Salazar, M. (2020). 10 causes of anemia you need to know. https://www.newlifeticket.com/conditions/10-causes-of-anemia-you-need-to-know/

Sarpong, N., Owusu-Dabo, E., Kreuels, B., Fobil, J. N., Segbaya, S., Amoyaw, F., Hahn, A., Kruppa, T., & May, J. (2015). Prevalence of malaria parasitaemia in school children from two districts of Ghana earmarked for indoor residual spraying: A cross-sectional study. *Malaria journal, 14*(1), 260. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4479317/

Saxena, R. (2018). Clinical Evaluation of Different Types of Anemia. *World, 2*(1), 26-30. https://pdfs.semanticscholar.org/cec0/18814295945065842fc60556737046d12a7d.pdf

Schaber, C. L., Katta, N., Bollinger, L. B., Mwale, M., Mlotha-Mitole, R., Trehan, I., Raman, B., & Odom John, A. (2018). Breathprinting reveals malaria-associated biomarkers and mosquito attractants. *The Journal of infectious diseases, 217*(10), 1553-1560. https://doi.org/10.1093/infdis/jiy072

Scheu, K., Adegnika, A. A., Addo, M. M., Ansong, D., Cramer, J. P., Fürst, S., Kremsner, P., Kurth, F., Jacobs, T., May, J., Ramharter, M., Sylverken, C., Vinnemeier, C., Agbenyega, T., & Rolling, T. (2019). Determinants of post-malaria-anemia in African children treated with parenteral artesunate. *Scientific Reports, 9*(1), *1-8*. Retrieved from https://www.nature.com/articles/s41598-019-54639-4

Shaban, L., Al-Taiar, A., Rahman, A., Al-Sabah, R., & Mojiminiyi, O. (2020). Anemia and its associated factors among Adolescents in Kuwait. *Scientific reports, 10*(1), 1-9. https://www.nature.com/articles/s41598-020-60816-7

Sherrard-Smith, E., Skarp, J. E., Beale, A. D., Fornadel, C., Norris, L. C., Moore, S., Mihreteab, S., Charlwood, J., Bhatt, S., Winskill, P., Griffin, J., & Churcher, T. (2019). Mosquito feeding behavior and how it influences residual malaria transmission across Africa. *Proceedings of the National Academy of Sciences, 116*(30), 15086-15095. https://www.pnas.org/content/pnas/116/30/15086.full.pdf

Sowunmi, A., Fatunmbi, B., Akano, K., Wewe, O. A., Agomo, C., Finomo, F., Ebenebe, J., Jiya, N., Ambe, J., Wammanda, R., Ntadom, G., Mokuolu, O., Emechebe, G., Ezeigwe, N., Ayede, A. I., Adewoye, E. O., Gbotosho, G. O., Folarin, O. A., Happi, C. T., Oguche, S., Oyibo, W., & Useh, F. (2017). Factors contributing to anaemia after uncomplicated falciparum malaria in under five year-old Nigerian children ten years following adoption of artemisinin-based combination therapies as first-line antimalarials. *BMC infectious diseases, 17*(1), 781. https://doi.org/10.1186/s12879-017-2876-9

Sumbele, I. U. N., Sama, S. O., Kimbi, H. K., & Taiwe, G. S. (2016). Malaria, moderate to severe anemia, and malaria-anemia in children at presentation to hospital in the

Mount Cameroon area: a cross-sectional study. *Anemia*, 2016. https://www.hindawi.com/journals/anemia/2016/5725634/abs/

Swick, K. J., & Williams, R. D. (2006). An analysis of Bronfenbrenner's bio-ecological perspective for early childhood educators: Implications for working with families experiencing stress. *Early childhood education Journal, 33*(5), 371-378. https://doi.org/10.1007/s10643-006-0078-y

Talapko, J., Škrlec, I., Alebić, T., Jukić, M., & Včev, A. (2019). Malaria: The past and the present. *Microorganisms, 7*(6), 179. https://doi.org/10.3390/microorganisms7060179

Tazebew, B., Munshea, A., & Nibret, E. (2021). Prevalence and association of malaria with ABO blood group and hemoglobin level in individuals visiting Mekaneeyesus Primary Hospital, Estie District, northwest Ethiopia: A cross-sectional study. *Parasitology Research*, 1-15. https://doi.org/10.1007/s00436-021-07093-z

Teh, R. N., Sumbele, I. U. N., Meduke, D. N., Ojong, S. T., & Kimbi, H. K. (2018). Malaria parasitaemia, anemia and malnutrition in children less than 15 years residing in different altitudes along the slope of Mount Cameroon: Prevalence, intensity and risk factors. *Malaria Journal, 17*(1), 336. https://malariajournal.biomedcentral.com/track/pdf/10.1186/s12936-018-2492-1

The Global Fund. (2019). Malaria. https://www.theglobalfund.org/en/malaria/

Thomson, M., Ukawuba, I., Hershey, C., Bennett, A., Ceccato, P., Lyon, B., & Dinku, T. (2017). Using rainfall and temperature data in the evaluation of national malaria control programs in Africa. *The American Journal of Tropical Medicine and Hygiene, 97*(3 Suppl), 32. https://dx.doi.org/10.4269%2Fajtmh.16-0696

Ugo, O., Ezinne, E. A., Modupe, O., Nicole, S., Winifred, E., & Kelechi, O. (2016). Improving quality of care in primary health-care facilities in rural Nigeria: Successes and challenges. *Health services research and managerial epidemiology, 3*, 2333392816662581. https://doi.org/10.1177%2F2333392816662581

United Nations International Children's Emergency Fund. (2018). Situation of women and children in Nigeria. https://www.unicef.org/nigeria/situation-women-and-children-nigeria

Unitaid. (2019). The new nets project in partnership with the global fund. https://unitaid.org/project/the-new-nets-project-in-partnership-with-the-global-fund/#en

von Seidlein, L., Peto, T. , Landier, J., Nguyen, T., Tripura, R., Phommasone, K., Pongvongsa, T., Lwin, K., Keereecharoen, L, Kajeechiwa, L, Thwin, M., Parker, D., Wiladphaingen, J., Nosten, S., Proux, S., Corbel, V., Tuong-Vy, N., Phuc-Nhi, T., Don, D., … & Huong-Yhu, P. (2019). The impact of targeted malaria elimination with mass drug administrations on falciparum malaria in Southeast Asia: A cluster randomised trial. *PLoS Medicine, 16*(2), e1002745. https://doi.org/10.1371/journal.pmed.1002745 https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1002745

Vorasan, N., Pan-Ngum, W., Jittamala, P., Maneeboonyang, W., Rukmanee, P., & Lawpoolsri, S. (2015). Long-term impact of childhood malaria infection on school performance among school children in a malaria endemic area along the Thai–Myanmar border. *Malaria Journal, 14*(1), 401. https://malariajournal.biomedcentral.com/articles/10.1186/s12936-015-0917-7

Wagman, J., Gogue, C., Tynuv, K., Mihigo, J., Bankineza, E., Bah, M., ... & Fomba, S. (2018). An observational analysis of the impact of indoor residual spraying with non-pyrethroid insecticides on the incidence of malaria in Ségou Region, Mali: 2012–2015. *Malaria journal, 17*(1), 19. https://malariajournal.biomedcentral.com/articles/10.1186/s12936-017-2168-2

White N. J. (2018). Anemia and malaria. *Malaria Journal, 17*(1), 371. https://doi.org/10.1186/s12936-018-2509-9

Wold, B., & Mittelmark, M. B. (2018). Health-promotion research over three decades: The social-ecological model and challenges in implementation of interventions. *Scandinavian Journal of Public Health, 46*(20_suppl), 20-26. https://doi.org/10.1177%2F1403494817743893

World Health Organization. (2015a). Malaria fact sheet: World malaria report 2015. https://www.who.int/malaria/media/world-malaria-report-2015/en/

World Health Organization. (2015b). The global prevalence of anemia in 2011. https://apps.who.int/iris/bitstream/handle/10665/177094/9789241564960_eng.pdf

World Health Organization. (2016a). *Eliminating malaria* (No. WHO/HTM/GMP/2016.3). World Health Organization.

https://apps.who.int/iris/bitstream/handle/10665/205565/WHO_HTM_GMP_2016.3_eng.pdf

World Health Organization. (2016b). *World malaria report 2015*. https://books.google.com/books?hl=en&lr=&id=rg4LDgAAQBAJ&oi=fnd&pg=PP1&ots=XSnESXTXMH&sig=Mko7RIR3RXYnTuf3sVl7xVVXcT0#v=onepage&q&f=false

World Health Organization. (2016c). Do all mosquitos transmit malaria?. https://www.who.int/features/qa/10/en/

World Health Organization. (2016d). History of malaria elimination in the European Region. https://www.euro.who.int/__data/assets/pdf_file/0003/307272/Facsheet-malaria-elimination.pdf

World Health Organization. (2018a). This year's world malaria report at a glance. https://www.who.int/malaria/media/world-malaria-report-2018/en/

World Health Organization. (2018b). World malaria day 2018 "Ready to beat Malaria": Key messages (No. WHO/CDS/GMP/2018.06). https://malariajournal.biomedcentral.com/articles/10.1186/s12936-015-0917-7

World Health Organization. (2018c). Malaria: Prevention of re-establishment. https://www.who.int/malaria/areas/elimination/prevention_of_reestablishment/en/

World Health Organization. (2018d). *High burden to high impact: A targeted malaria response* (No. WHO/CDS/GMP/2018.25 Rev. 1). World Health Organization. https://www.who.int/malaria/publications/atoz/high-impact-response/en/

World Health Organization. (2019a). Malaria: Key facts. https://www.who.int/news-room/fact-sheets/detail/malaria

World Health Organization (2019b). World malaria day 2019. https://www.who.int/campaigns/world-malaria-day/world-malaria-day-2019

World Health Organization. (2020). Malaria: Key facts. https://www.who.int/news-room/fact-sheets/detail/malaria

World Health Organization. (2021). World malaria day: WHO launches effort to stamp out malaria in 25 more countries by 2025. https://www.who.int/news/item/21-04-2021-world-malaria-day-who-launches-effort-to-stamp-out-malaria-in-25-more-countries-by-2025

Yaya, S., Uthman, O. A., Amouzou, A., & Bishwajit, G. (2018). Use of intermittent preventive treatment among pregnant women in sub-Saharan Africa: Evidence from malaria indicator surveys. *Tropical medicine and infectious disease, 3*(1), 18. https://doi.org/10.3390/tropicalmed3010018

Yeo, S. J., Liu, D. X., Kim, H. S., & Park, H. (2017). Anti-malarial effect of novel chloroquine derivatives as agents for the treatment of malaria. *Malaria Journal, 16*(1), 1-9. https://doi.org/10.1186/s12936-017-1725-z

Yusuf, O. B., Akinyemi, J. O., Fagbamigbe, A. F., Ajayi, I. O., Bamgboye, E. A., Ngige, E., Issa, K., Abatta, E., Ezire, O., Amida, P., & Bashorun, A. (2016). Controlling malaria in pregnancy: How far from the Abuja targets? *Malaria World Journal, 7*, 7. https://malariaworld.org/sites/default/files/mwjournal/article/MWJ2016_7_7.pdf

Zwang, J., D'Alessandro, U., Ndiaye, J., Djimdé, A., Dorsey, G., Mårtensson, A., Karema, C., and Olliaro, P. (2017). Haemoglobin changes and risk of anaemia following treatment for uncomplicated falciparum malaria in sub-Saharan Africa. *BMC infectious diseases, 17*(1), 1-10. https://dx.doi.org/10.1186%2Fs12879-017-2530-6

Appendix A: Permission to use Data

Feb 11, 2021

Temitope Bamgbose
Walden University
United States
Phone: 215-431-4332
Email: Temitope.Bamgbose@waldenu.edu Request Date: 02/11/2021

Dear Temitope Bamgbose:

This is to confirm that you are approved to use the following Survey Datasets for your registered research paper titled: "Analysis of Malaria-Induced Anemia and Gender Differences among Children in Nigeria":

Nigeria, Nigeria (Ondo State)

To access the datasets, please login at: https://www.dhsprogram.com/data/dataset_admin/login_main.cfm. The user name is the registered email address, and the password is the one selected during registration.

The IRB-approved procedures for DHS public-use datasets do not in any way allow respondents, households, or sample communities to be identified. There are no names of individuals or household addresses in the data files. The geographic identifiers only go down to the regional level (where regions are typically very large geographical areas encompassing several states/provinces). Each enumeration area (Primary Sampling Unit) has a PSU number in the data file, but the PSU numbers do not have any labels to indicate their names or locations. In surveys that collect GIS coordinates in the field, the coordinates are only for the enumeration area (EA) as a whole, and not for individual households, and the measured coordinates are randomly displaced within a large geographic area so that specific enumeration areas cannot be identified.

The DHS Data may be used only for the purpose of statistical reporting and analysis, and only for your registered research. To use the data for another purpose, a new research project must be registered. All DHS data should be treated as confidential, and no effort should be made to identify any household or individual respondent interviewed in the survey. Please reference the complete terms of use at: https://dhsprogram.com/Data/terms -of-use.cfm.

The data must not be passed on to other researchers without the written consent of DHS. However, if you have coresearchers registered in your account for this research paper, you are authorized to share the data with them. All data users are required to submit an electronic copy (pdf) of any reports/publications resulting from using the DHS data files to: references@dhsprogram.com.

Sincerely,

Bridgette Wellington
Data Archivist
The Demographic and Health Surveys (DHS) Program

Bridgette Wellington

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