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Investigating the Important Correlates of Maternal Education and Childhood Malaria Infections

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Abstract. The relationship between maternal education and child health has intrigued researchers for decades. This study explored the interaction between maternal education and childhood malaria infection. Cross-sectional survey data from three African countries were used. Descriptive analysis and multivariate logistic regression models were completed in line with identified correlates. Marginal effects and Oaxaca decomposition analysis on maternal education and childhood malaria infection were also estimated. Children with mothers whose education level was beyond primary school were 4.7% less likely to be malaria-positive ($P < 0.001$). The Oaxaca decomposition analysis exhibited an 8% gap in childhood malaria infection for educated and uneducated mothers. Over 60% of the gap was explained by differences in household wealth (26%), household place of domicile (21%), malaria transmission intensities (14%), and media exposure (12%). All other correlates accounted for only 27%. The full adjusted model showed a robust and significant relationship between maternal education and childhood malaria infection.

INTRODUCTION

For many years, researchers have explored the relationship between maternal education and childhood health, including access to preventive and treatment services.[1–4] Findings from these studies have played key roles in informing policy discourses, especially those relating to investment in education and health.[5,6] The potential societal benefits realized by investing in women's education are best described through the indirect benefits that educated mothers enjoy as the socioeconomic status of their household improves.[7–9] Furthermore, maternal education has also been shown to have a significant relationship to child survival, even after controlling for family characteristics.[10–12] Given high childhood malaria susceptibility and deaths, better understanding of the linkages between maternal education and childhood malaria infection is important.[13] As the world strives to achieve United Nations millennium development goal (MDG) 4 to reduce child mortality, there is an urgent need to understand how maternal education relates to childhood malaria infection as well as access to and use of both preventive and treatment services.

A number of studies have described the relationship between maternal education and childhood immunization, nutritional status, and mortality rates.[5,14,15] However, the relationship between maternal education and malaria, a leading cause of child mortality in Africa, has not garnered adequate research interest.[16,17] Interventions to reduce the burden of malaria in both pregnant women and children ages less than 5 years old (children under 5 years of age) have primarily focused on vector control through use of insecticide-treated nets (ITNs), malaria case management, and intermittent preventive treatment during pregnancy (IPTp). Although there has been a substantial increase in the scale up of ITNs, the use of ITNs has often fallen short of the expectations.[18–20] Multiple factors, including perceived malaria risks, demographics, and other intrahousehold socioeconomics, have all been associated with the low use of ITNs in communities where malaria prevalence is high.[21–23] Nevertheless, there are not many studies that have specifically explored the role of maternal education in the use of these effective preventive interventions.[24] Such studies have the potential to help understand the optimal ways to mitigate the burden of childhood malaria infections, especially in sub-Saharan Africa, where the burden of malaria is highest. Therefore, a better understanding of these relationships is crucial to achieving at least five of eight MDGs. These include reducing childhood mortality, halving global extreme poverty, achieving universal primary education, promoting sex equality, and empowering women as well as achieving substantial improvements in maternal health.[25]

In this study, we investigated the relationship between maternal education and childhood malaria infection rates in settings with relatively high malaria transmission. The aims of the study were to, first, outline the important correlates of maternal education and childhood malaria infections and second, explore the statistical relationships between maternal education and childhood malaria infection using the outlined framework of correlates. We used nationally representative cross-sectional malaria indicator survey data from Angola, Tanzania, and Uganda. Data were collected in 2006 and 2007/08 for Angola and Tanzania respectively, and 2009 for Uganda. Because the literature on the causal relationship between education and health is relatively well-established,[12,26–28] this study did not delve into establishing these causal relationships. The analysis was undertaken with the assumption that malaria prevention and treatment choices are affected by the level of knowledge that individuals possess about the disease. The study focused on exploring past evidences about malaria etiology, prevention, and control.[29,30] Ultimately, the goal of this study is to elucidate these relationships and help inform the malaria control debate on better strategies to sustainably reduce the burden of the disease, especially among those most vulnerable. In the subsequent section, we describe the possible logical relationships between maternal education and childhood malaria infections.

Delineating the potential correlates. The causal pathway through which maternal education impacts child health in developing countries has been described in multiple ways.[5,15,31] A multicountry analysis looking at the effect of maternal education on child survival rates by age-specific segments concluded that child survival rates by mother's education levels

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were substantially higher among those children ages 1–5 years than those children in the neonatal and post-neonatal periods.[14] In the same study, it was estimated that a 1-year increment in maternal education could lead to as high as 10% decline in children under 5 years old mortality rates. Based on the outlined linkages and given the magnitude of malaria burden in children under 5 years old living in malaria-endemic countries, it is critically important to explore these relationships.

Improved knowledge encompassing child health. Previous studies have documented that maternal education improves health-related knowledge and increases their receptiveness to health messages.[32–34] Regardless of whether the specific health messages are covered in all school curricula, the overarching goal of education helps most women become more receptive to good health messages funneled through different sources, including the health infrastructure, mass media, and other social networks.[35] Mothers with poor knowledge about the causes of malaria are less likely to recognize malaria symptoms or take proper and prompt actions when their children became sick. A study in Indonesia showed that educated women had greater awareness of correct immunization schedules, which resulted in higher use of childhood vaccines.[9] This finding suggests that educated mothers may be better equipped to protect their children from illness than uneducated mothers. Educated mothers are also more equipped with problem-solving skills and confidence in dealing with the challenges of taking care of a sick child than mothers without formal education. For instance, a mother who has gone through vocational training may be better prepared to troubleshoot hanging a mosquito net in her bedroom than one who never had a chance to attend formal school. A study from India argued that "little learning" in primary schools was beneficial, because girls learned to accord teachers with great authority and went on to bestow similar authority on health practitioners; as a result, they carefully followed prescribed treatment schedules when they became mothers.[11] In the Philippines, a study showed that, with each additional 1 year of maternal education, there was increased probability for using preventive services by 4% during any month in the first 1 year of a child's life.[8,36] Additionally, studies have also warned that, given the fact that school quality may vary widely across communities or countries for that matter, years of schooling alone may not provide an adequate measure of impact of education on people's lives, including their children's health outcomes.[37]

Family formation patterns. Studies have shown that birth order, maternal age at birth, and birth interval length were important factors contributing to improved child health.[2,31,38] Education enhances the tendency for women to delay childbearing and avoid high-risk childbearing when younger.[39] Educated mothers also tend to avoid early marriages, which accord them time to grow and mature as they prepare to deal with marriage and childbearing challenges. Such early preparations prepare mothers to deal better with childhood illnesses.[39] In the malaria-endemic world, better spaced birth intervals have the potential to enable mothers to attend to their young children's health needs. For instance, the ability to provide bed nets to an entire family may be hampered when a family expands too quickly.

Economic empowerment. Gender oriented economic restrictions can be an obstacle in enhancing women's abilities to deal with the health challenges of their young children. Even in circumstances where women are empowered to decide where and when to seek care and how to protect their children from infections, such empowerment is reliant on financial independence. Studies have shown the direct relationship between maternal education and decision-making autonomy as well as health service use.[40,41] Educated women may also enjoy more autonomy in making independent decisions and socioeconomic mobility in their decision-making about their children's health service use.[42,43] Maternal education not only improves the ability to make autonomous decisions but comes with increased sense of economic security to facilitate execution of these decisions. Educated mothers have been shown to earn more than those with less education, and their incomes improve household welfare.[44–47] Furthermore, income earned by educated mothers has also been found to increase child care expenditures as their incomes increases, whereas higher male income does not necessarily translate in the same way.[47] Educated mothers are also more likely to live in communities with better healthcare access and better infrastructure, including water and sanitation services.[5,6] Therefore, for an effective childhood malaria control, intervention maternal education would be an important component, because it empowers mothers both financially and mentally.

Improved social networking. In addition to formal education, schools provide a venue for students to learn necessary social and communication skills. Educated mothers may have broader social networks that provide knowledge on improving child health, health-seeking behavior, and preventive techniques. A study from Gambia reported that peer influence among mothers in rural areas was important in their use of antenatal care services.[3] Maternal education has the potential to help mothers organize themselves and advocate for their children's health including voicing support for various malaria control programs like subsidize or free ITNs. In rural Tanzania, social marketing was, at one time, a bedrock strategy for bed-net distribution. Women of at least primary education level were central to the success of this bed-net distribution strategy. Ownership and use of ITNs improved substantially through social marketing, where comedians and musicians helped spread accurate messages about malaria infection. Malaria prevention messages were also disseminated at public health rallies, which were disproportionately attended by educated mothers and as such better, allowed them to benefit from the health education messages.[48]

Given these outlined pathways, a better understanding of these relationships will enhance malaria control efforts through implementation of more holistic programs that focus on not only understanding the behavior of malaria vectors and the disease epidemiology but also, relating malaria control to other non-health factors, like education, for effective and more sustainable malaria control programs.

DATA AND METHODS

Malaria indicator survey data. In this study, nationally representative cross-sectional malaria indicator survey (MIS) data from Angola, Tanzania, and Uganda were used. A two-stage cluster sampling technique with heavy reliance on each country's national census cluster sampling approach was used. The first stage involved selecting sample points or clusters from a list of enumerated areas covered in the national population census for each of the three countries. These clusters were drawn from the stratified regions. In total, 475 clusters

were selected in Tanzania, 170 clusters were selected in Uganda, and 120 clusters were selected in Angola. The second stage involved selection of households from a compiled list made for each of the selected clusters. A systematic sampling of households from these clusters was undertaken to determine which households would be visited for an interview. Approximately 25 households were selected from each cluster in Angola, 16–18 households were selected from each cluster in Tanzania, and 28 households were selected from each cluster in Uganda. Therefore, 2,500 households were selected in Angola, 8,400 households were selected in Tanzania, and 4,400 households were selected in Uganda. The household and individual samples selected were generally comparable across all three countries. Using the sample selection, standardized household questionnaires and individual questionnaires directed at women of childbearing age were completed to document household and individual demographics and women's knowledge of malaria prevention and treatment.

Study setting and data collection. The three countries were selected because of their varied malaria epidemiology, data availability, and also, for the fact that these were the first cohort of countries in sub-Saharan Africa chosen by the US Government to receive substantial President's Malaria Initiative (PMI) resources. The PMI was launched in 2005 with the goal to reduce malaria mortality by 50% in the 19 African countries with highest malaria risk burden.[49] Data were collected during the period from 2006 to 2009, covering a total of over 10,000 households sampled from the three countries. Data collection was aimed to occur during high malaria transmission season, which also happened to be during the rain seasons in these countries. Unfortunately, because of infrastructure and logistic challenges, data collection continued even after the high malaria transmission season had ended in some of the countries. The surveys collected information on both years of education and literacy levels for household heads and all women of reproductive age (15–49 years old) participating in the interviews. Additionally, the survey collected information on key malaria indicators, including childhood malaria infection rates, history of fever and care-seeking, household ownership, and use of ITNs by children under 5 years of age during the night before the survey was done.

Ethical clearance. The survey obtained Institutional Review Board approval from respective institutions in each of the three countries and was executed by local research agencies with technical assistance from ICF Macro—MEASURE DHS. Data collection was made possible through financial assistance provided by the US International Development Agency (USAID) through the PMI. Detailed information on sampling, questionnaires, and survey implementation, including the survey reports, can be freely accessed at www.malariasurveys.org.

Outcome variables and variable definitions. The main outcome variable of interest was childhood malaria infection rates. Independent variables included maternal education and all related correlates as described in Table 1.

Estimation strategy. Using the anticipated pathways through which maternal education relates to child health, multiple logistic regression models were estimated to look at the relationship between maternal education and childhood malaria infections. The analytical techniques were based on a study that looked at the relationship between maternal education and child immunizations in India.[50] We started with a base model regressing malaria infection rates on maternal education plus other basic demographic controls. We then incrementally added each of the four pathways hypothesized to mediate the relationship between maternal education and childhood malaria infection rates. Furthermore, we included the sampling cluster fixed effects to hold constant any unobserved community-level heterogeneities. The goal of the analysis was to find out the extent to which the magnitude of the education coefficients would diminish/increase after the

TABLE 1
Variables of interest

Category	Variable name	Variable description
(1) Outcome variable		
i	Childhood malaria infection	A dichotomous variable (1/0) exhibiting a rapid diagnostic test malaria infection confirmation in a child within a surveyed household
(2) Independent variables		
i	Maternal education level	Indication of the highest level of education attained by a mother of a child in a surveyed household. Education level is coded into three categories: (1) no formal education, (2) primary education only, and (3) any secondary or college education.
ii	Child health knowledge	Five indicators used to capture maternal knowledge on their children's health: (1) correct knowledge on malaria-transmitting vectors, (2) prompt access and treatment of childhood febrile illnesses, (3) reported use of intermittent preventive treatments during pregnancy by mothers, (4) reported ownership of any mosquito net within the household, and (5) child birth spacing measured by the number of children born by a woman within the last 5 years.
iii	Economic empowerment	Women's economic empowerment measured by the household wealth quintiles (developed by Filmer and Pritchett[70]) coded in ascending order from one to five.
iv	Family formation pattern	Captured by use of two proxies. (1) Household size in terms of the total number of people living under one roof. (2) Total number of children under 5 years old born to a single mother within the household.
v	Social networking	Ownership of mobile phones by mothers was used as a proxy for enhanced social networking.[65,71,72]
(3) Other controls		
i	Country-level effects	Country-level fixed effects to account for macroeconomic differences.
ii	Regional-level effects	Regional-level fixed effects to account for variations in malaria transmission intensity across regions, even within countries.
iii	Individual-level effects	Household wealth score, sex, age, and education level of the household head.[73]

introduction of each of the hypothesized pathways. Our final full model included all hypothesized pathways as shown:

$$m_{ijk} = \underbrace{ME_{ik}\beta_0}_{\text{Base Model+C}} + \underbrace{CK_{ijk}\beta_1}_{\text{Pathway1}} + \underbrace{PF_{ijk}\beta_2}_{\text{Pathway2}} + \underbrace{E_{ijk}\beta_3}_{\text{Pathway3}} + \underbrace{SN_{ijk}\beta_4}_{\text{Pathway4}} + \underbrace{c_{ijk}x_{1,\ldots,n}}_{C} + \mu_{ijk} \quad (1)$$

In equation 1, m_{ijk} represents childhood malaria infection rates, ME_{ijk} stands for maternal education level, CK_{ijk} represents knowledge about childhood health, PF_{ijk} represents family formation patterns, E_{ijk} stands for economic empowerment, SN_{ijk} represents social network, c_{ijk} represents all other controls, and μ_{ijk} represents the standard errors. The subscript ijk represents individual i in household j and regional primary sampling unit k. After generating the odd ratios, we further estimated the marginal effects on the probabilities of maternal education relating to childhood malaria infections. The estimated marginal effects enabled us to succinctly determine and report the direction of these relationships in Results.

Blinder–Oaxaca decomposition. Additionally, we used the Blinder–Oaxaca decomposition technique to better understand how childhood malaria infections may be explained by inequalities in maternal education rather than other contributing factors, such as level of media exposure, household wealth, differences in malaria transmission intensity, differences in household heads' education levels, and places of domicile. The technique allows for a division of observed average malaria infection rates between educated mothers and uneducated mothers into both explained and unexplained portions, such as described in the economic and social literature, especially sex wage differences studies.[51–53] In this study, the technique provides an objective means of disentangling the effects of true impact of maternal education versus other justified differences. Because the study's primary outcome variable is binary, with coefficients from the logistic regression model, the coefficients cannot be used directly in standard Blinder–Oaxaca decomposition equations. We adopt the Blinder–Oaxaca decomposition extension technique for the logit and probit models described in past studies.[54] Non-linear decomposition techniques can be useful in identifying the causes of sex, racial, geographical, or other categorical differences, like malaria infections in binary outcomes in which logit and probit models are used. Therefore, assuming that a relationship exists between child i's malaria infection rate (m_i) and some determinants of childhood malaria infections, X_i (X_i being a place of domicile, malaria transmission intensity, household income or wealth, bed-net availability, etc.). The decomposition for a non-linear equation such as, $m_i = f(x_i < \hat{\beta})$ can be written as $m_i = F(x, \hat{\beta})$,

$$m_i^{edu} - m_i^{noned} = \left[\sum_{i=1}^{N^{edu}} \frac{F\left(x_i^{edu}\hat{\beta}^{edu}\right)}{N^{edu}} - \sum_{i=1}^{N^{noedu}} \frac{F\left(x_i^{noedu}\hat{\beta}^{edu}\right)}{N^{noedu}}\right] + \left[\sum_{i=1}^{N^{noedu}} \frac{F\left(x_i^{noedu}\hat{\beta}^{edu}\right)}{N^{noedu}} - \sum_{i=1}^{N^{noedu}} \frac{F\left(x_i^{noedu}\hat{\beta}^{noedu}\right)}{N^{noedu}}\right] \quad (2)$$

In equation 2, N refers to the sample size for educated and non-educated mothers. This alternative decomposition expression is used, because the mean of the outcome variable (in our case, childhood malaria infection rates) does not necessarily equal the mean of independent variables coefficients. In equation 2, the first term in brackets represents the part of the malaria infections gap that is caused by differences in maternal education level, whereas the second term represents the part caused by differences in the group processes determining levels of outcome variable m_i for childhood malaria infections. The second term also captures the portion of the malaria infections gap that is caused by group differences in immeasurable or unobserved endowments. These differences in childhood malaria infections would result if all children who varied only in their other characteristics not related to their mothers' education levels were cared for by mothers of same education level, which is what we also call the unexplained differences in malaria infections by maternal education. Using similar previous studies applying decomposition technique, this study does not focus on the unexplained portion of the gap because of the difficulties in interpreting such results.[55–57]

Statistical analysis tools. Data were requested from the ICF Macro offices headquartered in Calverton, MD. Data files were received in STATA format, and all analyses were completed using STATA, version 11 (Stata Corp., College Station, TX). Survey adjustment commands for data weighting were used to ensure that the results were truly representative of each country's national survey samples. Descriptive statistics were obtained by use of simple tab, mean, and table STATA commands.

RESULTS

In total, 1,390 (82%) women interviewed in Angola, 5,975 (79%) women interviewed in Tanzania, and 2,997 (75%) women interviewed in Uganda were eligible for answering survey questions on childhood malaria infections, prevention, and treatment practices. Of all eligible women interviewed, Angola had the largest proportion of women without formal education (39%) followed by Uganda (21%), and in Tanzania, only 9% of women reported having no formal education (Figure 1).

Childhood malaria infection was most prevalent among women reporting no formal education across all three countries. In Angola, childhood malaria burden among women without any formal education was 38% compared with 26% among women with more than just primary education. In Tanzania and Uganda, childhood malaria infections were highest among women reporting no formal education: 24% and 44%, respectively. Childhood malaria infection rates reported among women with only primary education were also high for both Tanzania and Uganda. The difference between having primary education and not having any formal education in terms of malaria infection rates among children under 5 years old was not statistically significant in either Tanzania or Uganda. However, there were 11% and 35% differences in childhood malaria infection rates for mothers reporting as having acquired education beyond primary level compared with those without primary education in Tanzania and Uganda, respectively. For the case of Angola, having some primary education was associated with a 10% reduction in childhood malaria infection prevalence. The difference in childhood malaria infection prevalence reported by those

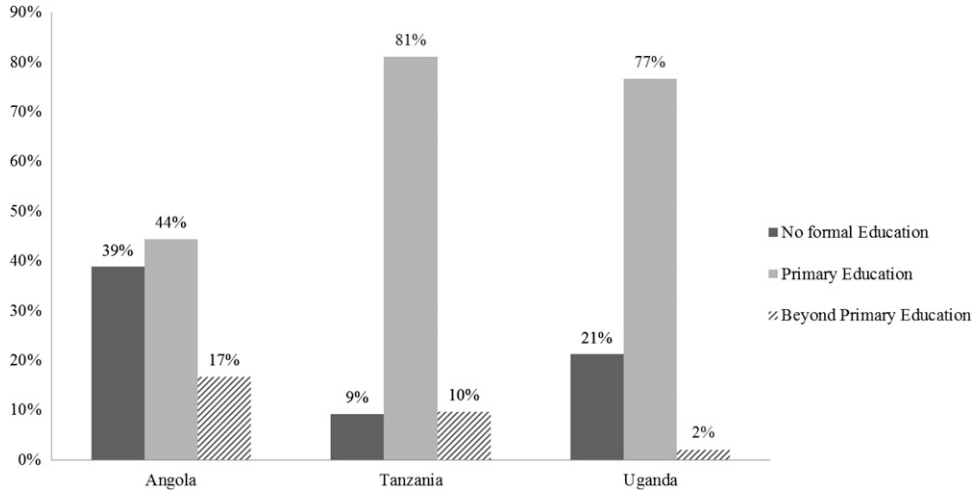

FIGURE 1. Distribution of maternal education levels by country of origin.

with an education level beyond the primary level and those with only primary education was only 2% (Figure 2).

We computed the probability for children having malaria infection based on their mothers' education at 95% confidence intervals. In each of the three countries, the probabilities for children being malaria-infected were highest if their mothers had reported no formal education. Meanwhile, children of mothers reporting to have post-primary education exhibited the lowest probabilities of being infected with malaria parasites: 26% in Angola, 13% in Tanzania, and only 9% in Uganda compared with 38%, 24%, and 44% in children whose mothers had no formal education in Angola, Tanzania, and Uganda, respectively (Figure 3).

Logistic regression analyses were conducted on pooled data from the three countries. We further estimated the marginal effects to determine the direction of the relationships between variables. Base model 1, which explores the relationship between maternal education and childhood malaria infection rates, indicated that children belonging to women with some primary education had a lower chance of being malaria-positive by 4.2% ($P < 0.01$). Meanwhile, education beyond primary school was significantly associated with about an 8% reduction in malaria prevalence among children under 5 years old ($P < 0.001$). Other important variables with significant positive or negative impact on the relationship between maternal education and childhood malaria infection rates were place of domicile, media exposure, and regional malaria transmission intensity. Education level and sex of the household head exhibited a negative relationship with malaria infection rate, but the coefficients were not statistically significant (Table 2).

In model 2, we included mothers' knowledge on child health while controlling for household-, regional-, and country-specific factors and explored how maternal education variables would change. The output results indicated that protection from childhood malaria infections by mothers with primary education only declined by 1–3.3% and remained statistically significant ($P < 0.01$) at the percent level. The model revealed that secondary education provided about 9% protection against childhood malaria infections ($P < 0.001$). Children living in rural areas were more likely to test malaria-positive by about 5% ($P < 0.05$) compared with those

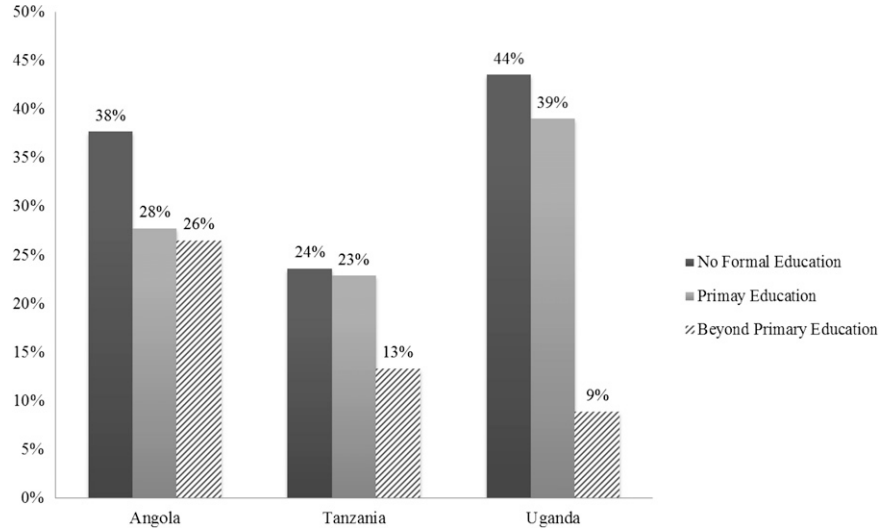

FIGURE 2. Maternal education and childhood malaria infection rates.

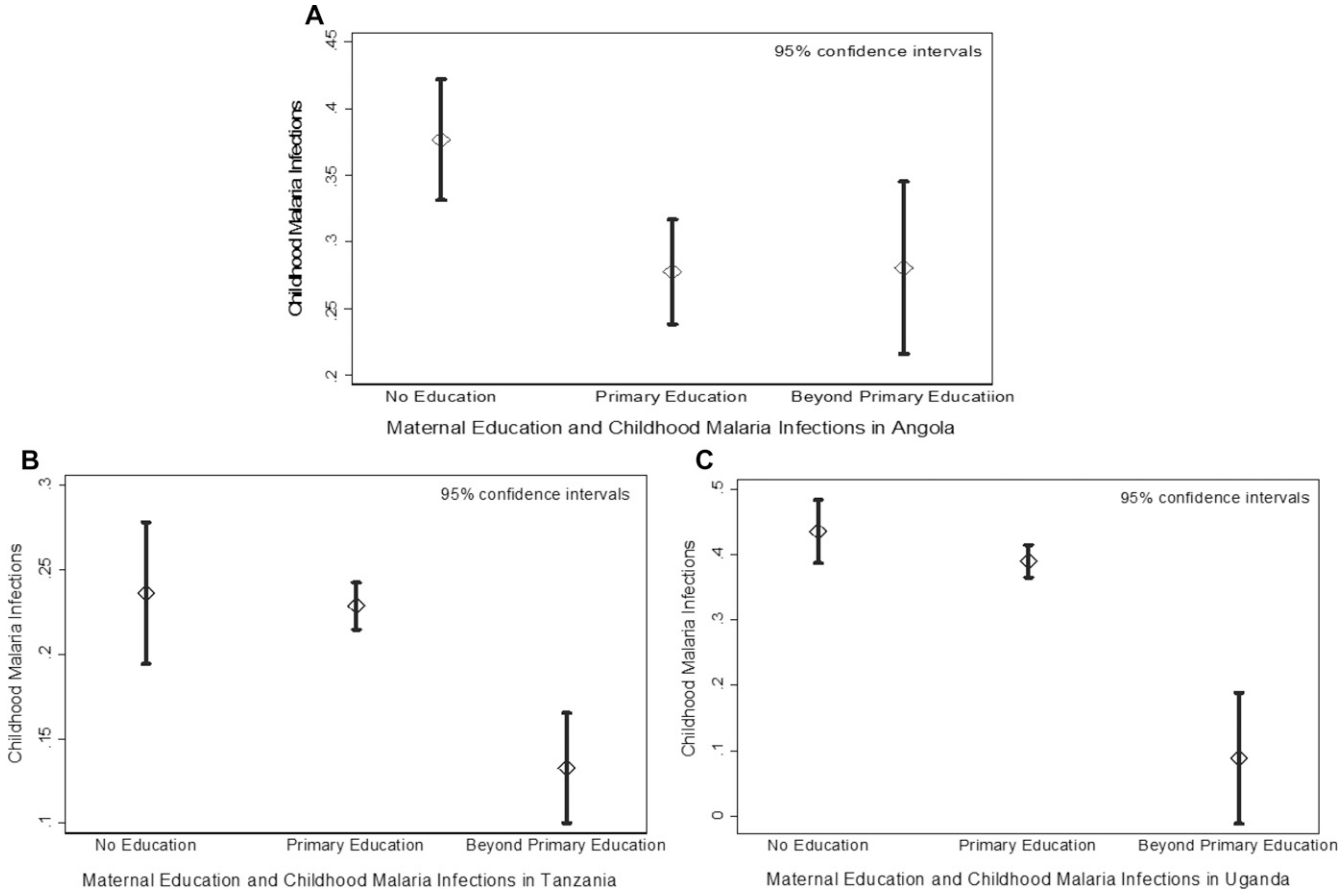

FIGURE 3. Maternal education and childhood.

residing in urban settings. Meanwhile, media exposure and regional malaria transmission intensity continued to be statistically significant when related to malaria childhood malaria infection rates. Although malaria knowledge did not show a positive relationship to childhood malaria infection protection, use of intermittent prevention treatment during pregnancy, antenatal service use, and ownership and use of mosquito nets all exhibited the expected negative statistical relationship with malaria infection rates in children under the age of 5 years.

Furthermore, we estimated another model (model 3) looking at the impact of maternal education on childhood malaria infection through the family formation pathway. The contribution of maternal education in reducing childhood malaria infection remained steady at 3.7% ($P < 0.05$) less malaria infection prevalence for children of mothers reporting at least primary education and around 9.3% ($P < 0.001$) less malaria for children of mothers reporting education level beyond primary school. Household size and total number of children ages less than 5 years were associated with marginal increases in childhood malaria infection rates by 0.7% ($P < 0.05$) and 1.6% ($P < 0.01$), respectively. Other important covariates with significant impact on malaria infection rates were media exposure, regional malaria transmission intensity, and whether the household lived in a rural or urban domicile.

In two additional models (models 4 and 5), we explored the economic empowerment and social capital pathways and their relationships to childhood malaria infection given the varying education levels of their mothers. Household wealth was strongly associated with childhood malaria infection. Wealth seemed to be the single most important cause for reduction in childhood malaria prevalence. Children in top wealth quintile households were 18% ($P < 0.001$) less likely to be malaria-infected compared with children in the second lowest wealth quintile. Maternal education remained consistently influential in reducing childhood malaria infection by 3.4% if a mother had some primary education and 5% to almost 7% if a mother reported an education level beyond primary school. For social networking, cell phone ownership was associated with 8.4% ($P < 0.001$) reductions in childhood malaria infections. Media exposure and regional malaria transmission intensity also exhibited significant relationships to childhood malaria infections, which are shown in Table 2.

Finally, we estimated an adjusted full model that included all four maternal education pathways envisioned to impact childhood malaria infections. Overall, maternal education maintained a modest but significant negative relationship with childhood malaria infection prevalence, although the coefficients were less robust than in the individual models. Some primary school education was associated with 3.2% reduction in childhood malaria infection ($P < 0.01$), whereas secondary school education and beyond was associated with almost 5% reduction in childhood malaria infection rates ($P < 0.001$). We also included the interaction terms between maternal education and other pathways. The results are not shown in Table 2, but there was a positive and significant

TABLE 2
The relative childhood malaria infection risks by mothers' education levels in Angola, Tanzania, and Uganda

Malaria infections (N = 6,170)	Basic model (model 1)	Knowledge on child health (model 2)	Family formation pattern (model 3)	Economic empowerment (model 4)	Social capital (model 5)	Full model (model 6)
Maternal education						
PS	–0.042* (0.065)	0.033* (0.016)	–0.037* (0.016)	–0.034* (0.016)	–0.026 (0.016)	–0.032* (0.018)
Beyond PS	–0.084† (0.000)	–0.092† (0.021)	–0.093† (0.020)	–0.050* (0.024)	–0.068‡ (0.023)	–0.047‡ (0.021)
Age (years)	0.003 (0.006)	0.002 (0.002)	–0.001 (0.002)	–0.001 (0.003)	–0.003 (0.005)	–0.001 (0.005)
Sex of household head	–0.018 (0.000)	–0.018 (0.014)	–0.010 (0.014)	–0.021 (0.014)	–0.026* (0.015)	–0.014 (0.015)
Household head with PS education	–0.003 (0.013)	–0.002 (0.014)	–0.002 (0.014)	–0.019 (0.014)	–0.011 (0.014)	–0.024 (0.021)
Household head education beyond PS	–0.004 (0.033)	0.007 (0.035)	0.010 (0.035)	–0.018 (0.042)	–0.012 (0.037)	–0.009‡ (0.004)
Rural domicile	0.060‡ (0.020)	0.053* (0.021)	0.059‡ (0.021)	0.034 (0.022)	0.066‡ (0.021)	0.024* (0.013)
Limited media exposure	–0.014 (0.013)	–0.011 (0.014)	–0.011 (0.014)	–0.016 (0.014)	–0.011 (0.014)	–0.016 (0.014)
High media exposure	–0.032* (0.015)	–0.043† (0.016)	–0.044‡ (0.016)	–0.049‡ (0.016)	–0.037* (0.016)	–0.028* (0.130)
High malaria transmission	0.083‡ (0.028)	0.080‡ (0.029)	0.078‡ (0.028)	0.12† (0.029)	0.08‡ (0.029)	0.093† (0.028)
Knowledge on child health						
Malaria knowledge		0.001 (0.017)				–0.013‡ (0.003)
IPTp use		–0.010* (0.005)				–0.010* (0.005)
ITN ownership and use		–0.0.056‡ (0.021)				–0.076‡ (0.022)
Birth spacing		0.038* (0.016)				0.045‡ (0.016)
ANC use		–0.034‡ (0.0144)				–0.029* (0.014)
Family formation pattern						
Household size			0.007‡ (0.002)			0.009† (0.002)
Number of children < 5 years old			0.016* (0.006)			0.010 (0.006)
Total children born			0.003 (0.002)			0.003* (0.002)
Economic empowerment						
Poor				–0.022 (0.016)		–0.019 (0.017)
Less poor				–0.041* (0.017)		–0.033* (0.018)
Middle				–0.105† (0.016)		–0.065† (0.018)
Rich				–0.182† (0.018)		–0.123† (0.019)
Social capital						
Cell phone use					–0.084† (0.013)	–0.030‡ (0.015)
Household controls	No	Yes	Yes	Yes	Yes	Yes
Cluster-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

β-Coefficients with robust standard errors in parenthesis are indicated by footnotes. ANC = antenatal care services; PS = primary school.
*$P < 0.05$.
†$P < 0.001$.
‡$P < 0.01$.

relationship between maternal education and mothers' knowledge about malaria disease, their use of IPTp and bed nets, and their use of antenatal care services. However, maternal education was not positively associated with birth spacing, total number of children born, or number of children under the age of 5 years living in a given household. Meanwhile, maternal education was also positively associated with the level of household wealth, whereby mothers belonging to poorest households were up to 35% less likely to be as well-educated as those in wealthier households ($P < 0.001$).

We also used the non-linear Oaxaca decomposition technique to identify the causes of maternal education differences in childhood malaria infection. There was a gap in malaria infection rates between children of educated mothers and those with mothers without education ranging from 19.6% in model 1 to almost 8% in the final adjusted full model (model 6). In executing the technique, we focused on the final model (model 6). Of particular interest was whether (and the extent to which) group differences in the most likely causes, including household head education level, household wealth, place of domicile, level of media exposure, and differences in regional malaria transmission intensity, contribute to variations in childhood malaria infections because of their maternal education disparities. Table 2 reports the findings on individual contributions from maternal education-level differences given the suspected causes of malaria infections at household level. Overall, our full adjusted model reports a 7.8% gap in childhood malaria infection rates because of maternal education-level disparities. With malaria being closely associated to poverty, the final adjusted model reports household wealth as the largest factor explaining the childhood malaria infection gap of 3.2% because of mothers' education disparity. Residing in a rural place, regional malaria transmission intensity, and level of media exposure were some of the important factors explaining the gap between high malaria infections in children under 5 years old for educated and uneducated mothers. Overall, all variables included in the model explain almost 61% of the 7.8% gap in the full adjusted model as shown on Table 2 (Table 3).

DISCUSSION

The goal of this study was to explore the statistical relationship between maternal education and childhood malaria infection. Our analysis relied on MIS data from the first cohort of malaria-endemic countries supported by the US PMI funding. Using multiple logistic regression models, our results showed that maternal education had a significantly strong relationship with childhood malaria infection rates. The results also showed that background variables, such as place of residence and demographic and other household characteristics, were important in explaining the relationship between maternal education and childhood malaria infection.

TABLE 3
Important correlates and their relative risk to childhood malaria infections in the Oaxaca decomposition analysis

Oaxaca decomposition variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Infection rates for children of educated mothers	0.247*	0.263*	0.269*	0.278*	0.286*	0.291*
Infection rates for children of uneducated mothers	0.443*	0.422*	0.405*	0.381*	0.377*	0.369*
Educated/uneducated gap	0.196 (61.8%)	0.159 (60.4%)	0.136 (59.6%)	0.103 (45.5%)	0.091 (45%)	0.078 (39.2%)
Contributions from maternal education differences explained by						
Household head education	0.008†	0.008†	0.007	0.007	0.007	0.007
Household wealth	NA	NA	NA	0.043*	0.036*	0.032*
Rural domicile	0.042‡	0.037‡	0.035*	0.031*	0.029*	0.026*
Media exposure	0.033†	0.028‡	0.024*	0.020*	0.017*	0.015‡
Malaria regional endemicity	0.038‡	0.031*	0.026*	0.022‡	0.021*	0.018*
All included variables	0.121 (38.2%)	0.104 (39.6%)	0.092 (40.4%)	0.123 (54.5%)	0.11 (55%)	0.121 (60.8%)

β-Coefficients with robust standard errors in parenthesis are indicated by footnotes. NA = not applicable.
* $P < 0.001$.
† $P < 0.05$.
‡ $P < 0.01$.

Even after controlling for these background characteristics, children of educated mothers were found to be less likely to have malaria infection than those of mothers with lower education levels. These results corroborate with other previous studies which have also found strong statistical association between child health and survivorship in terms of improved nutritional status and increased immunization uptakes and maternal education levels.[50,58]

This is the first study to specifically explore the correlates between maternal education and childhood malaria infections in such detail. Our study analytical approach to build the model describing these relationships incrementally was particularly novel in delineating the relationship between maternal education and childhood malaria infection rates in sub-Saharan Africa. Using this approach, which was first used to understand the relationship between maternal education and child immunization in India, it was possible to disentangle the most important correlates that influence these intricate relationships.[50] In this study, two important pathways on human capital, also referred to as health knowledge and cultural capital or communication skills, were found to be most important in explaining how maternal education influenced childhood immunization rates in India. In our study, health knowledge, economic empowerment, and social networks were the most important paths through which maternal education determined childhood malaria infections. Other studies in African settings have also yielded similar conclusions. A study in Kenya found that women reporting some higher level of education were more likely to own and use bed nets obtained from retail sector outlets than those without any formal education.[59] Nevertheless, a study in Ghana investigating a school-based participatory health education intervention for malaria showed no changes in malaria parasite prevalence between the intervention and the control groups, but malaria knowledge was significantly higher in the intervention group.[60] Education can, therefore, play an important role in malaria control efforts. Education has the potential to increase household incomes as women find better-paying jobs, and it also improves women's knowledge of the best ways to protect themselves and their children from various diseases, including malaria. Apart from knowledge and increased income, it also empowers women socially, because it increases their intrahousehold bargaining power and their stake in deciding how household resources should be used.[61] Perhaps it should not be a surprise that some researchers are fascinated with the causal relationships between malaria and poverty, because they believe that better understanding of these dual relationships may unlock the secrets to effective and sustainable global malaria control efforts.[62–64]

Cell phone ownership, which we used as a proxy for social networking, was also found to be a significant determinant of childhood malaria infection. One may argue that a cell phone would be a poor proxy, because it also represents the financial position of the owner. However, increasing use of cell phones has opened up new opportunities for improving child health by providing relevant health information on availability of drugs, ITN distribution campaigns, and appropriate treatment of children's illnesses directly to subscribers. Cell phones are increasingly being integrated into public health programs as tools for monitoring disease outbreaks, surveillance, and public health promotions across sub-Saharan Africa.[65,66] Although education may accelerate the desire to own and use cell phones because of increased confidence to use modern technology, it also enhances social networks and information-sharing as well as use of various health services.[14,67]

Findings from this study imply that, to successfully and sustainably control malaria, maternal education should be brought to the forefront. Successful prevention and treatment strategies should not only focus on overcoming the physical and financial barriers inhibiting access to effective malaria control strategies, but there should also be efforts to incorporate other non-health sector aspects, like improving formal education with a particular focus on women and girls across all malaria-endemic countries. Measures to improve educational opportunities for women stand not only to benefit these women but the entire malaria control effort across countries. Malaria researchers and policymakers should look beyond purely vertical malaria control efforts that focus on clinical and epidemiological trends alone to integrating broader socioeconomic, anthropologic, and educational issues. A synergy of investments in clinical malaria control and prevention tools on one hand and improvement of school enrollment and curriculum at both primary and secondary schools on the other hand will have farther reaching impact than simple focus on malaria epidemiology alone. Such a broader policy agenda aimed at addressing structural and sociocultural bottlenecks, including improved access to quality education, will likely yield the greatest returns on investments, and some

studies have argued for the sector-wide approach to solving health problems.[68,69]

Study limitations. First, the analysis used cross-sectional data to only explore the association between maternal education and childhood malaria infections and could not ascribe any causal effects. The existence of confounding factors, which are difficult to control given the nature of cross-sectional data, inhibits the capacity to perform any additional sophisticated analysis. As a result of these limitations, the analysis had to devise various proxy variables, like mobile phones for social networking, which may not fully capture the many aspects of social networking in African communities. Although future study is necessary, this study succeeded in the use of these variables and shows that they play a key role in determining the relationship between maternal education and childhood malaria infections.

Second, the study used survey data from three countries that had just been selected to receive substantial PMI support for malaria control. The MIS data were regarded as the baseline survey to help map out PMI interventions across the three countries. One may argue that these results will be better understood if the same analysis is performed in the follow-up survey data after substantial PMI malaria control investments were made.

Third, one may argue that there is huge diversity in the quality of education across the three countries and that it would be unfair to attempt to use this information to understand how maternal education relates to childhood malaria infections. Education curricula also do not teach any specifics related to malaria control, and therefore, the study conclusions could be an overreach. We argue that the level of exposure that students receive from formal education in classrooms is especially important for improving public health. Even in situations where there is huge diversity and the curricula are different across countries, there are still many indirect benefits these students receive by being in the classrooms and having an opportunity to relate with their peers. Education is both formal and informal. People who attend school are often treated and perceived differently within communities. They are often highly regarded and often seen as achievers, which may further increase their self-confidence and motivation. Perhaps an interesting question might be to explore how societal preferential treatment of educated mothers may play a key role in benefiting such women as they struggle to ensure that their children are offered the best health and nutritional services available. One may look at whether societal preferential treatment enjoyed by educated mothers plays any role in improving their children's health relative to the skills acquired through existing education systems.

Conclusion. This study explored the relationship between maternal education and childhood malaria infection in three sub-Saharan Africa countries. Four important causal pathways by which maternal education may impact childhood malaria infections were described and statistically explored. The magnitude of the coefficients in the final full adjusted model was 4.7% for those reporting education levels beyond primary school compared with 8.4% in the base model. The Oaxaca decomposition technique showed that there was an 8% unexplained gap in childhood malaria infections between educated and uneducated mothers. In the fully adjusted model, 61% of this gap was explained by differences in education level of the household head, household wealth, place of domicile, level of media exposure, and regional malaria transmission intensity.

The findings suggest that malaria control efforts should be informed by broader issues than simple malaria epidemiology. Investments in malaria control should be mindful of broad socioeconomic, cultural, and educational issues for countries to reduce malaria burden not just in children under 5 years old but across people of all age groups. Although understanding the epidemiology of malaria remains key for better malaria policy design and implementation, malaria control efforts should embrace a broader and more holistic agenda, tackling issues relating to socioeconomic, cultural, and education-level improvements.

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