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Behavioural and socio-economic risk factors and pathways associated with malaria in children in Ghana: A mediation analysis

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M.Sc. Health Sciences

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Abstract

Background: Malaria remains a major threat to public health and a leading cause of morbidity and mortality especially among children under 5 years old in Ghana. In 2019, approximately 40.000 children in Ghana died from malaria. While a relationship between sustainable development and malaria control has long been recognised, the implementation of structural interventions is restricted by a limited understanding of the causal pathways between poverty and malaria.

Objectives: This study contributes to addressing this gap by investigating (i) relevant socio-economic factors at the household-level, (ii) constructing a Ghana-specific household wealth index (HWI), and (iii) exploring potential behavioural and socio-economic factors mediating the effect of socio-economic positioning (SEP) on reported malaria fever events in children under the age of 5 in Ghana.

Methods: Data analyses are based on Ghana Malaria Indicator Survey (GMIS) household and individual-level data from 2019 provided by the DHS program. Principal Component Analysis (PCA) was conducted to develop an asset-based HWI. Mediation analysis was used to explore the potential mediators (i.e. treatment-seeking, bed net use, educational attainment, housing conditions) and to assess the relative contribution of their effect.

Results: A higher educational attainment (EA) of mothers and living in improved housing jointly mediate 18 % of the association between SEP and malaria fever events, which is in line with previous evidence on housing improvements. The EA and visiting formal prenatal care provider mediate 20 % of the total effect, also when having a poor socio-economic position. No strong mediation between SEP and malaria fever events was found by EA and use of LLINs in this study (7.5 %).

Conclusion: The findings suggest that current biomedical and behavioural malaria control efforts could be strengthened by investments at the structural levels, such as increased (female) education, targeted improvements in housing and integration of informal health care. Future research should focus on further investigating the complex pathways between poverty and malaria, which can inform more holistic, multisectoral strategies for sustainable malaria control.

Keywords: Malaria, behavioural and socio-economic factors, mediation analysis, household wealth index, child health, Ghana

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ACT	Artemisinin-based combination therapy
aOR	Adjusted odds ratio
CAPI	Computer assisted personal interview
(G)DHS	(Ghana) Demographic Health Survey
DRC	Democratic Republic of Congo
GMIS	Ghana malaria indicator survey
HBR	Human biting rates
HBV	Hepatitis B virus
HCF	Health care facility
HIC	High-income country
HWI(1-5)	Household wealth index (quintile 1-5)
IPT-SP	Intermittent-preventive treatment with sulfadoxine-pyrimethamine
IRR	Incidence rate ratio
ITN	Insecticide treated mosquito bed net
LLIN	Long-lasting insecticidal nets
LMIC	Low- and middle-income country (can also be refered to as countries of the global south)
MA	Mediation analysis
NHIS	National health insurance system
OR	Odds ratio
PCA	Principal component analysis
PCR	Polymerase chain reaction
RDT	Rapid diagnostic test
RWI	Rural household wealth index
SD	Standard deviation
SEP	Socio-economic position
SES	Socio-economic status
UWI	Urban household wealth index
WASH	Water, sanitation and hygiene
WHO	World Health Organisation

1 Introduction

Malaria remains a major public health challenge in Sub-Saharan Africa (SSA), particularly also in Ghana. According to the World Malaria Report 2020, Ghana is among the ten countries with the highest number of malaria cases and deaths. An estimated 30.4 million Ghanaian people were at risk of malaria infection in 2019, with 6.7 million confirmed cases and 11.161 estimated deaths (WHO, 2020). According to UNICEF, it is estimated, that 40.168 children under the age of five have died from malaria in Ghana in 2019 (Severe Malaria Observatory, 2021).

There are manifold efforts from the government to control the burden malaria has on the Ghanaian population. To eradicate malaria, multi-level efforts are aiming at improving the prevention, diagnosis and treatment of malaria, as well as surveillance, monitoring and evaluation of trends in malaria-related morbidity and mortality. One effective way of preventing malaria is the distribution of long-lasting insecticidal bed nets (LLIN), the spread of indoor-residual spraying and intermittent-preventive treatment (Awine et al., 2017; CCM Ghana, 2020b; World Health Organization, 2020). As resistances to treatment and insecticides are on the rise, future control efforts need to include a broader spectrum of interventions, including those that relate to the socio-economic development of populations (Tusting et al., 2013).

While a connection between poverty and malaria has long been recognised, it is challenging to understand the direction and magnitude of this correlation (Castro and Fisher, 2012; Somi et al., 2007; Teklehaimanot and Mejia, 2008). Most probable, there is a bi-directional association (McCarthy FD, Wolf H, Wu Y, 2000). While studies in a range of settings have shown that malaria contributes to the impoverishment of households and individuals there is also evidence of a ‘reverse causality’ between poverty and malaria. For example, a number of studies in African settings have shown that the odds of malaria infection are on average doubled in children with the lowest socio-economic position (SEP) (as measured by household wealth index (HWI) scores, parents’ educational status, or occupation), compared with children with the highest SEP within the same community (Krefis et al., 2010; Tusting et al., 2013). In Ghana, higher odds of malaria infection were found among less educated individuals, of lower socio-economic position, and with lower use of insecticide treated nets (ITNs) in

endemic areas (Anabire et al., 2019; Klinkenberg et al., 2006; Ricotta et al., 2019). The mechanisms through which wealth can protect against malaria include better access to health care, long-lasting insecticidal nets (LLINs) use, treatment-seeking behaviour, housing and neighbourhood environmental quality, and nutrition (Barat et al., 2004; Caulfield et al., 2004; Fobil et al., 2011; Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016). Yet few studies have systematically investigated the relative contribution of the different pathways between household-level poverty and malaria to shed light on how inadequate living conditions can affect the risk of malaria and to what extent this effect may be mediated by risk factors on a causal pathway (Chuma et al., 2006; Degarege et al., 2019; Fobil et al., 2010; Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016). In other words, the question to ask is no longer whether poverty is associated with malaria, but why it is so. This can have important implications for the design and implementation of interventions to strengthen the global response to malaria (Awine et al., 2017).

1.1 Research aim and objectives

Building on a small but growing body of literature that seeks to clarify the mechanisms through which poverty affects malaria (e.g. Degarege et al., 2019; Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016), this research project aims to investigate potential mediators on the pathway between household-level poverty and malaria approximated by fever events in children in Ghana drawing on the Ghana MIS survey data from 2019 (Ghana Statistical Service (GSS), Ghana Health Service (GHS), and ICF, 2017).

The primary research question is ‘What are the pathways through which socio-economic position is associated with malaria fever events in children under the age of 5?’

More specifically, the objectives are:

1) to describe and identify relevant socio-economic factors at the household-level
2) to derive a Ghana-specific household wealth index (HWI)
3) to explore the potential mediators (e.g. treatment seeking, bed net use, housing conditions and educational attainment of mothers) of the effect of SEP on reported fever events in children under the age of 5.

1.2 Structural arrangements

This thesis consists of 7 chapters. Chapter 1 provides an introduction to the research rationale and study aim, followed by a theoretical background in chapter 2, where current research gaps are being introduced, and an overview of key literature relating to malaria epidemiology, with a particular focus on socio-economic factors and malaria in Ghana is given. In Chapter 3 the conceptual framework for the relationship between household SEP, mother's educational attainment, and malaria in Ashanti, Ghana, will be explained. Building on this, the methodological approach to data analyses using principal component analysis and mediation analysis of data from the Ghana Malaria Indicator Survey 2019 (GMIS2019) will be described in Chapter 4. This will be followed by Chapter 5, in which the results relating to study population characteristics and mediators of the effect of socio-economic position on reported fever events in children will be presented and critically discussed with considerations of study strengths and limitations in Chapter 6. The thesis will close in chapter 7 with concluding remarks.

2 Background

The following chapter reports on the theoretical background as the basis of the conducted analyses. After providing a brief overview of malaria in general, and in Ghana in particular, theoretical and research perspectives on the relationship between malaria and poverty are being reviewed, comprising a short reflection on the current socio-economic and epidemiological situation of malaria in Ghana, followed by a description of national poverty and deprivation and the long recognised bi-directional correlation between the disease and poverty. In addition, the strengths and limitations of the current literature are discussed and implications for methodology and malaria interventions are assessed, stressing the gap of causal relations between the SEP, mediating factors and malaria, quantified by different approaches, like reported fever and the need for evaluations of relative contributions of risk factors towards the odds of malaria infection. The literature discussed below is intended to be exemplary rather than exhaustive.

2.1 Characteristics of malaria

Malaria is a vector-borne acute febrile disease that is caused by the parasite *Plasmodium spec.* transmitted through the bite of female *Anopheles* mosquitoes. *P. falciparum and P. vivax* are the most prevalent species among the five species pathogenic for humans, with *P. falciparum* being responsible for approximately 75 % of malaria cases in Africa. Transmission depends on the parasite, the vector, the human host and environmental and climatic factors. Transmission occurs mostly in places close to *Anopheles* breeding sites and their aquatic habitats and is subject to seasonal fluctuations, with high transmission rates during rainy season (WHO, 2021). The parasite life cycle includes cyclical infection of humans and female *Anopheles* mosquitoes. If an infected *Anopheles* takes a blood meal in a human individual, it transmits *Plasmodium spec*. to the human (Figure 1) (CDC, 2021).

An infected individual usually develops symptoms within 10 to 15 days after infection. Symptoms include fever, headache, chills, sweats, headaches, nausea, vomiting, body aches and/or malaise and in severe cases can lead to death, if not treated within 24 hours. In children, severe malaria can cause- among others - severe anaemia, respiratory distress, metabolic acidosis or cerebral malaria, while adults can be affected with multi-organ failures. Parasite detection is done by

microscopy or rapid diagnostic tests (RDT) and the timely malaria diagnosis of suspected cases, not solely based on symptoms, is crucial before they receive treatment, such as artemisinin-based combination therapy (ACT). Once the illness is overcome, people can develop partial immunity, which can lead to asymptomatic infections and relapses after years.

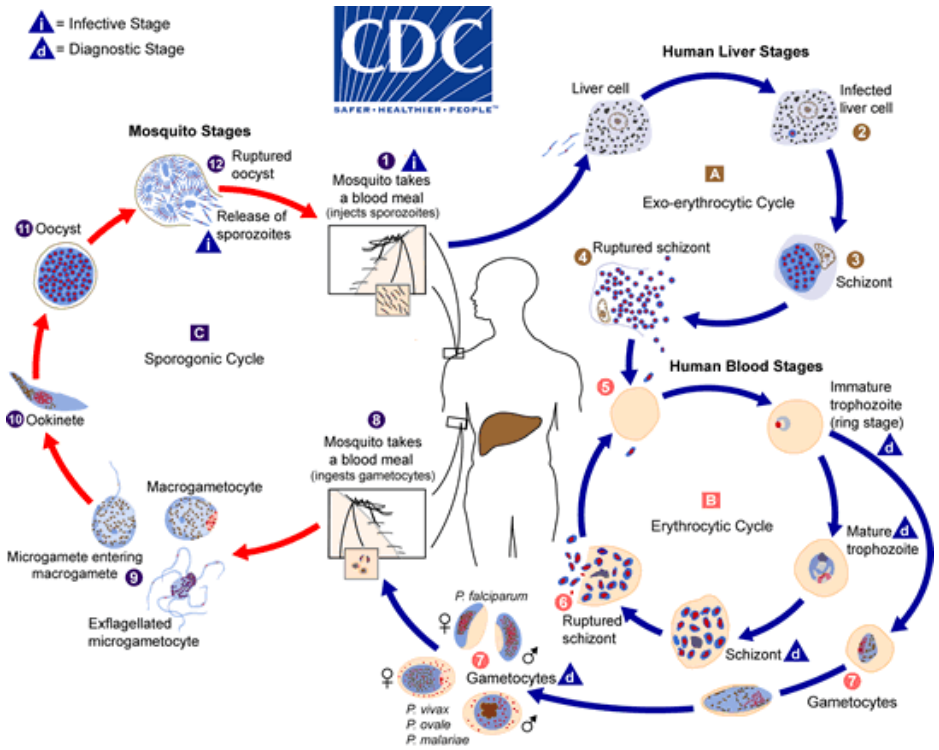

Figure 1: Anopheles mosquito life cycle (Source: CDC, 2021)

Population groups particularly vulnerable to malaria infection, include infants and children below the age of 5, pregnant women, immune-compromised individuals, such as people living with HIV/AIDS, and non-immune people traveling to endemic regions. Malaria can be prevented through vector control measures, like the usage of ITNs and indoor residual spraying. Further, anti-malarial drugs can be administered to vulnerable groups in the form of chemoprophylaxis for suppression of the blood stage for traveller, intermittent preventive treatment (IPT) with sulfadoxine-pyrimethamine (SP) for pregnant women after the first trimester and monthly intake of amodiaquine and SP for children under the age of five living in SSA in high transmission season, as recommended by WHO (Rehman et al., 2019; WHO, 2021).

Although malaria is easy to prevent and successfully treatable, it is still a major problem, especially among socio-economically disadvantaged people living in rural areas in endemic regions, where there is limited access to health care facilities and effective treatment (CDC, 2021).

2.2 Malaria burden in Ghana

2.2.1 Epidemiology of malaria in Africa and Ghana

Ghana is a lower middle-income country with 30.2 million inhabitants and an estimated average life expectancy of 68.4 years for females and 62.6 years for males as of 2017. The child mortality rate is 55.5 per 1 000 children under 5 years in Ghana (World Bank Group, 2020).

According to the 'World Malaria Report 2020' by the WHO, in 2019 approximately 229 million cases of malaria occurred in 87 malaria endemic countries and 409 000 persons are estimated to have died from malaria, 94 % of all cases and deaths occurred in the WHO African Region. While the WHO African Region has managed to reduce its incidence rate of malaria cases by 137.6 / 1 000 population at risk and the mortality rate by 80.8 since 2000 (World Health Organization, 2020, 18-23), children under the age of five and pregnant women in SSA remain among the most vulnerable groups at risk of malaria accounting for 67 % of all malaria deaths. More than 25 million pregnant women in SSA are at risk of malaria infection and 11 % of all newborn deaths are due to malaria during pregnancy.

The Global Burden of Disease (GBD) study confirms that as of 2019 malaria continues to account for one of the highest burden of diseases in Ghana, and a predominant cause of death. Data suggest that especially pregnant women and children under the age of 5 are at higher risk of infection and more severe malaria disease progression (Institute for Health Metrics and Evaluation, 2021).

During rainy seasons, mosquito breeding and the risk of malaria transmission is high. Malaria is endemic and persistent in all regions of Ghana with seasonal variations in malaria transmission in the northern regions. From July to October, 50 % - 59 % of clinical malaria cases arise in the Savannah regions: Northern, Upper East, Upper West regions (Severe Malaria Observatory, 2021). Malaria season in Ghana has its peak between September and November but transmission occurs throughout the year.

While the prevalence of malaria infection and death has decreased in all ten regions of Ghana between 2002 and 2016 (Figure 2), primarily due to malaria control programs, Ghana remains malaria endemic, which means its entire population is at risk of malaria infection. In 2016 39% of all outpatient cases were suspected to be malaria cases, in pregnant women they were accounted for one third of all outpatients (CCM Ghana, 2020a).

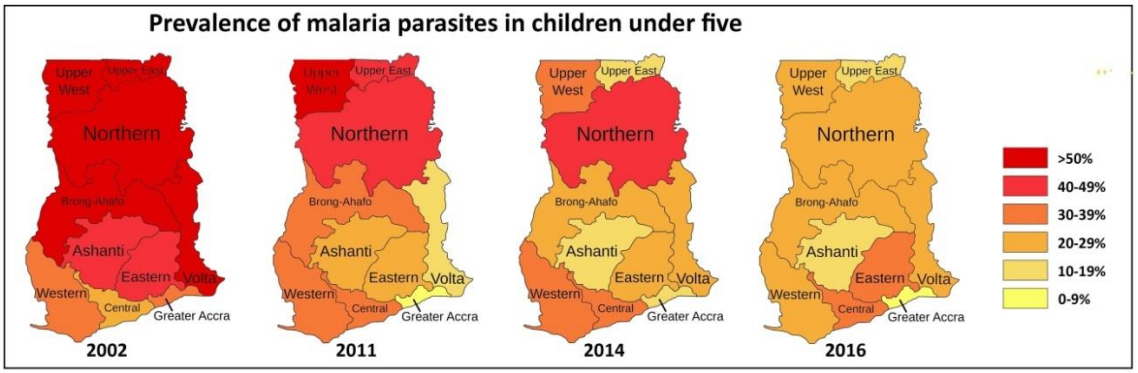

Figure 2: Prevalence of malaria parasites in children under five years in Ghana 2002-2016 (CCM Ghana, 2020a)

2.2.2 Malaria control efforts in Ghana

Malaria control efforts in Ghana began in the 1950s and are continuing up until now. Examples are the “Malaria Control Unit” or “Roll Back Malaria” (RBM) which aim to improve malaria disease control, availability and access to treatment, as well as the prevention of premature deaths due to malaria (Castro and Fisher, 2012; CCM Ghana, 2020a). The target of the National Malaria Strategic Plan was to reduce malaria-related morbidity and mortality by 75% by 2020 through prevention, diagnosis, treatment, surveillance, monitoring and evaluation (Awine et al., 2017) (Figure 3). The objectives on individual interventions were among others to provide universal access to and utilisation of at least one ITN for 85% of children under-five and pregnant, at least three doses of appropriate IPT-SP for pregnant women/ infants and raised awareness or recognition of early malaria symptoms of caretakers so that up to 90 % of children under five can receive appropriate ACT in 24 hours after disease onset (CCM Ghana, 2020b; World Health Organization, 2020).

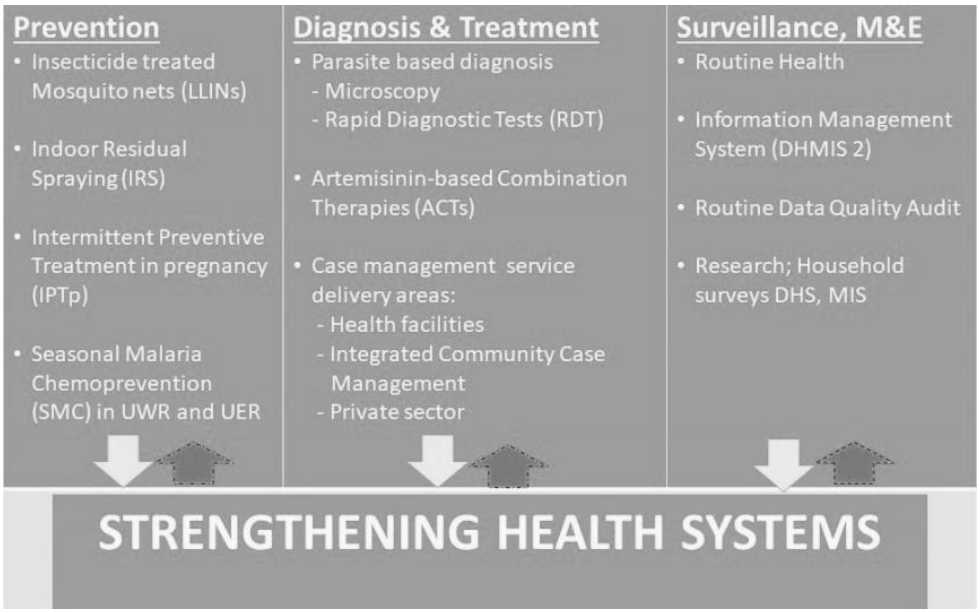

Figure 3: Strategy for 'National Malaria Control Programme' Ghana until 2020 (CCM Ghana, 2020b)

Challenges in the fight against malaria include emerging insecticide and drug resistances, which hinder emergency responses and elimination strategies WHO, 2021. As the burden of disease and mortality in Ghana still remains high, providing individuals with access to protective measures does not seem to be a realistic stand-alone target for sustainable long-term interventions. The interventions in place have already proven effective by themselves, as individuals are aware of existing mitigation strategies, such as vector-control measures and preventive tools, but strategies lack success within the population (Institute for Health Metrics and Evaluation, 2021; Severe Malaria Observatory, 2021), as they do not reach the especially vulnerable populations and are focussing mainly on lowering the severe progression of malaria and less on reducing socio-economic barriers on a structural level towards health care access, prevention and curative services and commodities (Barat et al., 2004). There is the question, how and to what extent malaria could be sustainably reduced on a national level, by taking socio-economic, community and structural factors more into account (Castro and Fisher, 2012). If there is a link between malaria and poverty, it could be of rising interest for populations and public policy maker, to intervene on a higher, more structural level with sufficient multisectoral interventions reaching vulnerable individuals (Tusting et al., 2013; WHO, 2020). Long-term strategies to tackle malaria at its source should focus on reducing inequities in health coverage. This can be

achieved overall by strengthening of the public and informal health sector, improved strategic investments in malaria control, and increased coverage towards universal access to malaria treatment and prevention interventions (Awine et al., 2017; CCM Ghana, 2020b; Littrell et al., 2013; Tusting et al., 2013). Multi-disciplinary policies may improve the economic starting points within the realities of vulnerable groups through structural improvements of educational and livelihood-opportunities (e.g. raised salaries and continued payment of such during illness), and improvements of infrastructure in urban and rural dwellings, (Barat et al., 2004; Chuma et al., 2006). Through a better educational system and more financial inputs towards sustainable development, the socio-economic barrier towards health care services could be lowered (Awine et al., 2017; Degarege et al., 2019). As many countries are suffering from weak health systems, the WHO has established manuals to assist those countries in need of a timely and effective malaria response. For instance, a pilot program for the roll-out of the first vaccine against malaria is integrated in the Ghanaian, Kenyan and Malawian immunization programs. Further efforts are made by the countries and the WHO towards elimination of malaria worldwide and the disruption of transmission, such as the 'High Burden high impact' initiative in Burkina Faso, Ghana, Niger and Nigeria, which started in 2019 aiming for evidence-based national strategic plans and funding requests (WHO, 2020).

2.3 Poverty and deprivation of Ghanaian children

Ghana has been the first country in SSA to achieve the Millennium Development Goal to reduce extreme poverty by 2015 by a rate decrease from 37.6 % to 8.2 % between 1991 and 2017. Overall the incidence of poverty dropped from 52.6 % to 23.4 %. However, the absolute number of people living in poverty is estimated to have increased by 400,000 people. The majority of the poorer Ghanaian population live in rural regions of Ghana, where there is a poverty rate of 39.5 % in 2017 compared to 7.8 % in urban dwellers (NDPC, 2020, p. 11).

According to the World Bank there is an inequality of wealth in Ghana, with a Gini Index of 43.5 in 2016 (World Bank Group, 2021b). In 2020 Ghana experienced the first recession due to the COVID-19 pandemic after a decade of continuous economic growth. Strong economic sectors include agriculture, manufacturing, and tradable services. It is suspected, that the current COVID-19 pandemic, as

well as the Ebola outbreak in Guinea in 2020 have posed additional risks for population health and poverty reduction in Ghana (World Bank Group, 2021a).

It is important to note that different definitions of poverty exist. While a common perception is, that poverty is the mere expression of monetary deprivation, it should more adequately be recognized as a multidimensional concept, which includes the absence or lack of access to basic services, water, sanitation and hygiene (WASH), good health, education and information, livelihood opportunities, and environmental hazards (NDPC, 2020).

Children in Ghana are particularly exposed to poverty and deprivation. According to a study by Unicef, drawing on 'Ghana multiple indicator cluster survey (MICS) 2017-2018' and 'Ghana living standard survey (GLSS) 2016-2017' data, it is estimated, that three out of four children in Ghana are still facing deprivation in at least three of the dimensions of poverty as defined above, with children under the age of 5 being most affected (82.9 % of children 0-4 years). Children living in rural areas are significantly higher affected by multidimensional poverty compared to urban settings (81.5 % against 62.5 %). The target 1.2.2 of the UN Sustainable Development Goals (SDGs) is to reduce this rate of multidimensional poverty by half until 2030 (from 73.4 % to 36.7 %). Inversely, there is an association between low educational attainment of mothers or households and a higher multidimensional poverty in all age groups. Most people in Ghana who experience deprivation are doing so in terms of dimensions, such as sanitation, housing, learning, and protection dimensions (NDPC, 2020). It is therefore crucial to assess this deprivation in relation to health outcomes.

2.4 Malaria and socio-economic development

There is a link of malaria infection between the level of poverty and socio-economic risk factors in SSA at the national level (e.g. Gallup and Sachs, 2001; Sachs and Malaney, 2002). In SSA malaria is a disease that is much more prevalent among poorer populations and can conversely contribute to increased poverty (e.g McCarthy FD, Wolf H, Wu Y, 2000). In countries where health systems are less strong, patients often have to pay out of pocket for transportation, consultation, treatment and medicine against malaria (Castillo-Riquelme et al., 2008; Castro and Fisher, 2012; Somi et al., 2007; Teklehaimanot

and Mejia, 2008). When the next health facility is far away from the dwelling, many have to disrupt their daily work and by this miss out on income, which can results in increased impoverishment. Due to this financial barrier, poorer individuals are having limited access to health care and are struggling to pay health expenditures and thus resort in alternative ways of saving money and receiving treatment. (Chuma et al., 2006) For example, re-purposing medicine and sharing them with friends and family who have similar symptoms poses a higher risk for drug resistances. Especially patients from rural areas have restricted access to health care, but are more prone to malaria infection (Teklehaimanot and Mejia, 2008). In 2012 in high infection areas of Ghana, such as forest zones, transmission rates are 269 in rural areas and 13.5 in urban areas respectively. In the poorest households, with 52 % the infection rate is much higher compared to richest households, with an infection rate of 3 %. A higher rate is also seen in non-literate mothers (43%) compared to secondary or higher educated mothers (5%) (Severe Malaria Observatory, 2021). Looking at the high rates of deprivation and poverty among children in Ghana and the higher rates of malaria infection in less educated mothers, children are particularly vulnerable to infection with strong symptoms and severe progression of malaria, indicating a need to assess poverty as a potential risk for children under 5 years from a causal perspective (WHO, 2020).

2.5 Literature background

A comprehensive literature search within the research databases ‘Pubmed’ and ‘Web of Sciences’ was conducted with the aim of indentifying relevant research gaps. Existing evidence on the relationship between SEP and malaria in SSA was reviewed. The search aimed further to review the utilisation of pathway analysis in research for investigating the association of SEP, education and associated risk factors, as proposed by Degarege et al (2019). The systematic review by Degarege et al (2019) suggests that the odds of infection with *plasmodium* parasites are increased, when living in poorer quality of housing (OR 2.13, 95% CI 1.56–3.23, I2 = 27.7), being uneducated (OR 1.36, 95% CI 1.19–1.54, I2 = 72.4.0%), being occupied as farmers (OR 1.48, 95% CI 1.11–1.85, I2 = 0.0%) [p<0.01 for all], or having decreasing income (OR 1.02, 95% CI 1.01–1.03, tau2<0.001) or wealth index (OR 1.25, 95% CI 1.18–1.35, tau2 = 0.028) [p<0.001 both] among children under five and individuals living in SSA (Degarege et al.,

2019). The present search strategy was based on the one used by Degarege et al. and included terms in relation to SEP, such as housing, occupation, income, wealth and education, malaria and related proxies, such as parasitaemia, and fever events, as well as mediation and pathway analysis as the method of analysis (Table 1). To evaluate mediation analysis in epidemiological studies, an additional non-systematic search was done to investigate the method itself and studies using mediation analysis for a diverse range of topics.

The database search resulted in 3,264 publications after removal of duplicates. After title and abstract screening, 164 titles remained for full-text eligibilty, many of which are reporting potential mediators, as the exposure of malaria. To provide an overview on the socio-economic factors associated with malaria, 15 studies were selected to illustrate a number of associations between poverty, possible mediators, and malaria risk. Four additional publications on mediation analysis were included in the review to determine whether this analytical method is a distinct, reliable and valid approach to assess mediating effects on the occurrence of health outcomes, and different factors confounding this effect.

The identified suitable publications were published between 2006 and 2019 and most studies are measuring malaria by parasiteamia or human biting rate.

A large number of studies exist that have investigated the association of socio-economic factors and malaria infection in SSA, but the majority does not account for a broad spectrum of risk factors simultaneously. In the conducted literature search, the systematic review could be found again (Degarege et al., 2019). Further, only few studies are collecting longitudinal data, such as Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al. (2016) in Uganda, while most studies are cross-sectional surveys among households, individuals in their communities or in health care facilities e.g. in Tanzania, Ghana and DRC. Even fewer studies are focusing on the malaria risk explicitly of children under the age of five. Studies using mediation analysis are scarce. Two examples are Tusting et al. (2016) who did a pathway analysis of the housing type and food security between the SEP and malaria, and Ma et al. (2017) who are analysing the causal relationship between education and wealth as mediators towards malaria prevalence. However, the majority of evidence is based on multivariate logistic regression

analyses, focusing only on single effects of each variable, such as SEP, education, or prenatal care visits on malaria outcomes or from SEP-variables on the expected mediators as outcomes (Anabire et al., 2019; Homenauth et al., 2017; Klinkenberg et al., 2006; Ma et al., 2017; Somi et al., 2007; Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016).

Table 1: Search term for literature search of databases

Database	**Medline and Web of Science**
Outcome	malaria OR plasmodium OR fever
Intervention/ Exposure	socioeconomic status OR socioeconomic position OR income OR wealth OR poverty OR equity OR house* OR employment* OR occupation* OR education*
Type of analysis	mediator OR mediation OR Path*
Population	sub saharan africa OR sub-saharan africa OR ssa OR angola OR benin OR botswana OR burkina faso OR burundi OR cameroon OR cabo verde OR cape verde OR central african republic OR chad OR comoros OR democratic republic of congo OR congo OR cote d'ivoire OR djibouti OR equatorial guinea OR eritrea OR eswatini OR swaziland OR ethiopia OR gabon OR the gambia OR ghana OR guinea OR guinea-bissau OR kenya OR lesotho OR liberia OR madagascar OR malawi OR mali OR mauritania OR mauritius OR mayotte OR mozambique OR namibia OR niger OR nigeria OR réunion OR rwanda OR sao tome and principe OR senegal OR seychelles OR sierra leone OR somalia OR south africa OR south sudan OR sudan OR swaziland OR tanzania OR togo OR uganda OR zambia OR zimbabwe
Time	2000- 2020 (publication year)

2.5.1 Malaria and poverty

In SSA one systematic literature review was found (Degarege et al., 2019), as well as the household-level children's cohort-study in a high-transmission region of Uganda by Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al. (2016), the household-level study in Tanzania by Somi et al. (2007), the health-facility based study by Homenauth et al. (2017), who evaluated different compositions of wealth indices and their connection to malaria, and the study in Ghana by Anabire et al. (2019) which is collecting data from pregnant women at their first prenatal care visit as well as Giardina et al. (2012) who were looking at cross-sectional data from the Senegal MIS2008/09. All of these showed that a higher HWI or financial status is protective against the odds of (mono-)infection with malaria parasites such as *P. falciparum,* indicating a lowered risk of malaria (Degarege et al.: OR 1.25, 95% CI 1.18–1.35, tau2 = 0.028, p<0.001); (Homenauth et al.: 85% , OR=0.15; 95% CI 0.07-0.34); (Anabire et al.: AOR = 0.52, 95% CI = 0.36-0.74, p<0.001), parasitaemia (Giardina et al: very poor quintile: OR = 0.77, 95% BCI = 0.57–1.03; least poor: OR = 0.09, 95% BCI = 0.01–0.26) and human biting

rates (Tusting et al.: IRR 0.71, 95 % CI 0.54–0.93, p = 0.01), but not with clinical malaria incidence (Tusting et al.: aIRR 0.69, 95 % CI 0.53–0.91, p = 0.008). These studies are using wealth indices constructed by principal component analysis (PCA) comprising ownership of assets, food security, housing materials and/ or infrastructural features, but are mostly lacking a perspective on mediating factors between wealth and malaria, with the exception of Tusting et al. The conceptual framework by Tusting et al. is providing, on one hand, an almost comprehensive overview of pathways and interacting socio-economic, environmental, and behavioural influences that are leading risk factors for malaria, as well as the bi-directionality of malaria that is leading back to poverty. The educational attainment of children's caregiver, on the other hand, was not evaluated as a pre-condition for the mediating factors (Anabire et al., 2019; Degarege et al., 2019; Homenauth et al., 2017; Somi et al., 2007; Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016). Some studies could nevertheless not demonstrate the association between household and individual wealth and malaria, which may be caused by the choice of wealth index composition and classification, but also due to the epidemiology and disease characteristics of malaria. For example Guerra et al. used the type of housing as the basis of SEP, which might lack a comprehensive depiction of the actual wealth (Guerra et al., 2018).

2.5.2 Malaria and education

Studies, such as Anabire et al. and Ma et al., are evaluating the influence of parental education on malaria indicate, that a higher educational attainment protects against malaria in parents, pregnant women and children, as well as Degarege et al. (OR 1.36, 95% CI 1.19–1.54, I2 = 72.4.0%). Anabire et al. looked at formal education of pregnant women and their risk of mono-infection with *P. falciparum* (AOR = 0.48, 95% CI = 0.32-0.71, p<0.001) and co-infection with *HBV* (AOR = 0.27, 95% CI = 0.11-0.67, p = 0.005). Ma et al. have found a possible causal relationship between maternal education and malaria predicted through bed net use, higher household wealth, greater social networking, family structure, and possibly lower HIV rates by a putative pathway analysis of cross-sectional data from DRC, suggesting a higher protective effect of education than a biomedical malaria vaccine (Anabire et al., 2019; Degarege et al., 2019; Ma et al., 2017).

2.5.3 Malaria and behavioural risk factors

The Ethiopian DHS data under investigation by Ayalneh et al. were used to produce evidence that household wealth, measured by PCA and educational status of fathers (but not mothers) are determining inequalities towards health care seeking for fever in children (three higher HWI-quintiles against poorest households: AOR = 2.46 (1.57–3.86)), AOR = 1.83 (1.33–2.52)), and (AOR = 1.47 (1.07–2.01)). This study does not take malaria infection into account directly, but might indicate a potential influence of health care seeking as a mediator between wealth and malaria (Ayalneh et al., 2017).

In Ghana, Ricotta et al. (2019) find a decrease in bed net use when wealth is increasing, within households that had access to bed nets (OR 2.5, 95% CrI 1.5–4.2), taking GDHS2014 and GMIS2016 data into account, while Deressa researched the effect of LLIN ownership on malaria at the household and individual levels in Ethiopia and found that malaria awareness, educational attainment, occupation or housing conditions are associated with LLIN ownership, and SEP was not associated with malaria infection. A study in Senegal by Giardina et al. (2012) showed that having ITNs in households and living in urban areas is protective against parasitaemia (86 % lowered odds), as well as Tusting et al. who proved in their multi-national analysis, that ITN use reduces the odds of malaria infection compared to non-use (microscopy: aOR = 0.84, 95%CI = 0.79–0.90, $p< 0.001$; RDT: aOR = 0.85, 95%CI = 0.80–0.90, $p< 0.001$). These findings suggest that education and malaria awareness are particularly important factors associated with increased bed net use. However, existing studies are lacking a deeper focus on pathways, that are connecting these risk factors with actual malaria infection (Deressa, 2017; Giardina et al., 2012; Ricotta et al., 2019; Tusting et al., 2017).

2.5.4 Malaria and housing

The type of housing material and housing condition has a direct influence on malaria prevalence as suggested by Tusting et al. (2017) within their multi-national analysis of surveys, Klinkenberg et al. (2006) within a cross-sectional study in Ghana, El-Sadr et al in a cross-sectional study in Ethiopia, Rek et al. as well as Snyman et al. within cohort studies in children in Uganda. The studies are suggesting a positive impact of modern housing materials, sanitation facilities,

closed eaves and indoor residual spraying on a reduced risk of malaria infection and parasite prevalence (Tusting et al.: microscopy: aOR = 0.91, 95%CI = 0.85–0.97, p = 0.003; RDT: aOR = 0.86, 95%CI = 0.80–0.92, p< 0.001), (Rek et al.: aOR = 0.43, 95%CI = 0.24–0.77, p = 0.004), (Snyman et al.: IRR = 0.54, p = 0.001) and (El-Sadr et al.: IRR = 3.49; 95%CI = 1.78–6.81). Guerra et al. analysed housing as a proxy for SEP and could not find an association between SEP tertiles and malaria infection or parasitaemia (El-Sadr et al., 2009; Guerra et al., 2018; Klinkenberg et al., 2006; Rek et al., 2018; Snyman et al., 2015; Tusting et al., 2017).

2.5.5 Evidence on mediation analysis in health research

Through Mediation Analysis (MA), it is possible to research the directions in which several factors can impact health outcomes, like malaria and to what extent they can fit into the model, and be accounted for as explanatory variables between an exposure and an outcome. To evaluate multiple perspectives of the relationships and to describe, determine, and test probable causal relationships, mediation analysis is an effective tool. Detecting intermediate effects is an important tool when trying to explain the mechanisms of causal effects between independent and dependent variables. But one must keep in mind the risk of false conclusions and explanations. When applying mediation analysis, it is important to have knowledge of the statistical approach and theoretical criteria, embedded in a broader framework about experiences, assumptions, needs, and the researcher's overall point of view (Agler and Boeck, 2017).

Broadly speaking from this literature search, within sociological, epidemiological and health research mediation analyses are used to provide insights into pathways of socio-economic inequities, and the proportion of impact by associated factors with diseases and health care access (Amegah et al., 2013; DeBeaudrap et al., 2019; Jones et al., 2018; Kanters et al., 2013). Amegah et al. (2013) demonstrate using causal pathway analysis, that malaria infection, poor nutrition and indoor air pollution in Cape Coast and Ghana mediate large proportions of the effects of socio-economic deprivation on low birth weight, and a low (RR: 4.57; 95% CI: 1.67–12.49) and middle SEP (RR: 3.78; 95% CI: 1.39–10.27) was associated with higher risk of low birth weight. Jones et al. (2018) use mediation analysis but did not find an association between ownership of livestock and child aneamia by

animal source food consumption in Ghana, even though a positive association was found between owning chicken and aneamia in children. Further, Ricotta et al. (2015) show in a study in Tanzania, that mediation analysis is a valid tool to measure the positive effect of social and behaviour change (i.e. bed net ideation) between community change agents or messaging, and household universal coverage. DeBeaudrap et al. (2019) use mediation analysis to show that education and restricted lifetime work mediate a large proportion of the association between disability and lowered use of HIV testing and of family planning. Kanters et al. (2013) used mediation analysis to measure the effect of gender on the time to death of HIV-infected Ugandans, which was mediated through 43% by initial CD4-count.

The here mentioned studies use different approaches of MA and provide evidence, that there is a wide field of application of it and that there is a general need for researchers focussing on the study of causal relations. Additionally, there is the need to test for assumptions of associations between exposure, mediator and outcome. Up to now, many epidemiological studies do not report on the methodology and testing of assumptions and interacting confounder in the best qualitative ways (Liu et al., 2016). The studies here, have all used multilevel regression models and single-mediator analysis only, indicating a further need to look at joint mediation effects for a more comprehensive understanding of the concepts of different risk factors influencing one outcome. The strength of using multiple mediation over single mediation are evaluated by MacKinnon et al., who state, that the multiple mediator, as an extension of single-mediation models might provide more accurate evaluations of the mediating effects (MacKinnon et al., 2007). Through joint mediation, it is accounted for possible mediator-mediator-interactions, as well as adjusted for added confounder (Vansteelandt and Daniel, 2017). It can even provide additions to previous evidence, when no mediating effects are found. (MacKinnon et al., 2007). A deeper insight into mediation analysis is provided within chapter 4.2.3 on the principles of mediation analysis.

Concluding, this chapter aimed at providing an overview of the associations related between wealth, education and occupation, housing conditions, LLINs, health care seeking and malaria in SSA. There is a large amount of publications from the past 20 years, and this chapter tried to depict on the evidence relevant for

this study, and can therefore not be a detailed description of all factors associated with malaria risk. It nevertheless becomes clear, that a connection between the mentioned factors is unevitably present. As the mentioned studies demonstrate, there is an association between malaria and SEP in either direction. It becomes clear, as suggested by most studies, that an improvement of SEP can reduce the malaria burden within populations and show the association of different risk factors, either as interlinked factors or separate predictors. Further, the measurement of SEP at household or individual level and a consensus on how it is quantified is still unclear. However, due to the complexity of the relationships towards malaria, evidence can still be contradictory, depending on the focus and their implications of impact. A higher SEP can, on the one hand, be seen as a positive impact against malaria infection, because i.e. of a higher prevalence of owned bed nets, but this could be explained by a higher income or knowledge and the financial means to buy bed nets. On the other hand, bed nets are often spread for free within campaigns, and can't be linked with financial means. Whereas those means imply also better access to health care or prevention and the studies highlight the importance of improving housing, ITN use, residual spraying and educational starting points as effective malaria control interventions.

Yet the lack of joint analyses of all factors combined and described in a comprehensive conceptual framework, to evaluate the impact each risk factor provides on the overall risk to be infected with malaria, especially within children under the age of five, and in populations from Ghana, becomes more visible. As shown by several publications on other diseases, as well as the apparent linkages between wealth and malaria risk, mediation analysis can add to available evidence and provide deeper knowledge on pathways between household wealth and the individual risk of malaria infection.

3 Conceptual Framework for the relationship between household socio-economic position (SEP), mother's education, and malaria in Ashanti, Ghana

In this thesis, the association between SEP and malaria infection, reported through fever events, and its pathways explaining this possible association are under investigation. A conceptual framework is developed to describe the hypothesised indirect effects from household-level poverty to malaria outcomes through different behavioural and socio-economic factors as possible mediators (Figure 4).

While it is recognized, that there is a bi-directional link between malaria and poverty (Somi et al., 2007; Teklehaimanot and Mejia, 2008), this study focuses on the direction from poverty, as poorer populations might face a higher risk for the development of malaria, as explained within chapter 2.5 'Literature Background'. And although there is a wide spectrum of factors influencing the association between poverty and risk for malaria infection (highlighted in grey), within the conceptual framework this study focuses on a selection of factors, based on available data within the GMIS2019, which is suggestive of potential pathways. Building on existing conceptual frameworks, such as Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al. (2016) and congruent literature, the here developed conceptual framework depicts the hypothesis, that the association between SEP at the household level, educational attainment at the individual level and risk of malaria infection in children in Ghana, is mediated by factors, such as poor housing quality, health care seeking and usage of LLIN or indoor-residual spraying.

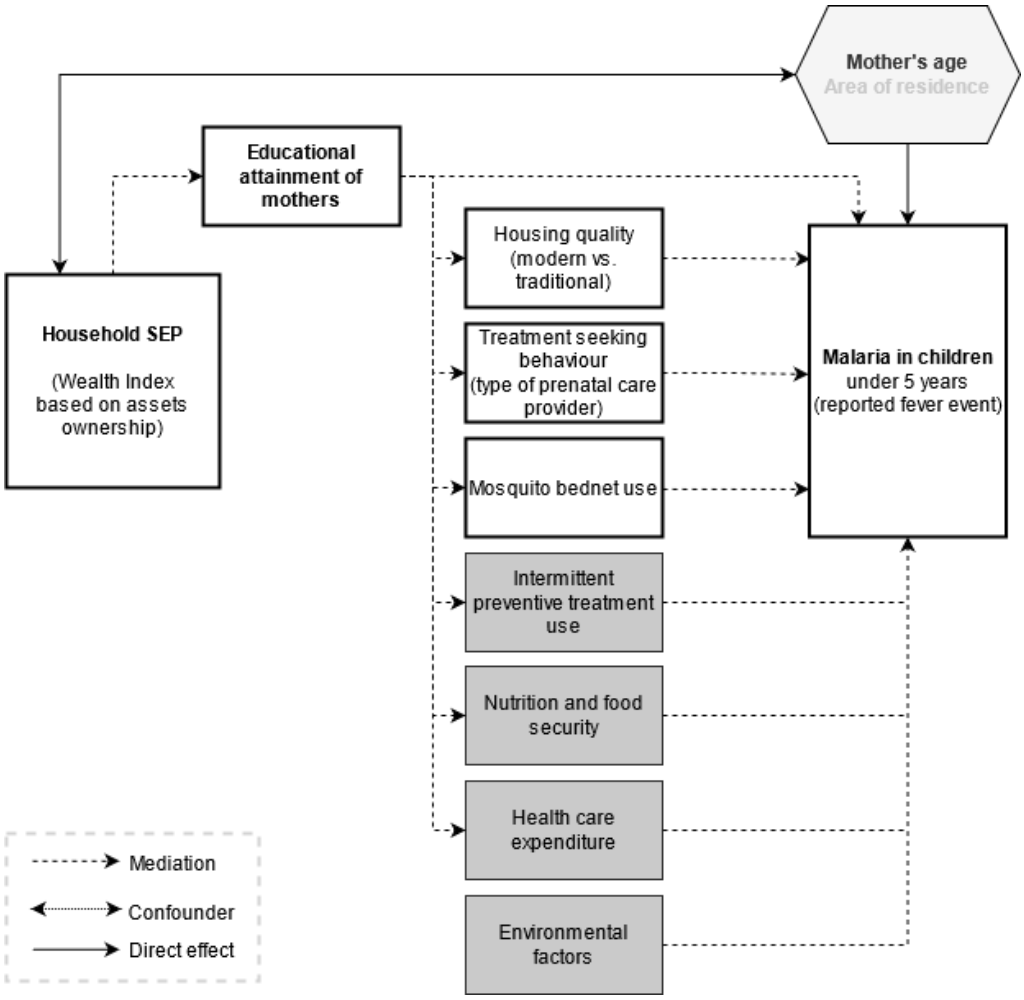

Figure 4: Conceptual framework of the association between SEP and Malaria
The conceptual framework tries to depict a comprehensive picture of the association between household SEP and malaria fever events in children u5 in Ghana. Possible additional mediators, shaded in grey, are not provided within GMIS2019-data or are already part of the HWI (source: own figure, adapted from Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016)

3.1 Household wealth as a measurement of socio-economic position

3.1.1 Definition of socio-economic position

According to the American psychological association (APA), the socio-economic status (SES) describes the social class or standing of a group or an individual, measured by combining education, income and occupation. Focussing research on SES can disclose inequities of access to resources and problems to privilege, power and control (American Psychological Association, 2020).

Krieger et al. define the SEP as a concept of social class positions of individuals measured on a resource-based and prestige-based level. It can be used on an individual, household, neighbourhood or community level and measured in different time spans of life. The SEP is measured based on the availability of

resources, e.g. materialistic and social assets, expressed through wealth, income or educational level. ‘Poverty’ or ‘deprivation’ are describing words for the inadequacy of resources. On the prestige-based level, the SEP is a status or rank on a social hierarchy, estimated by access and consumption of goods, services, knowledge linked to occupation, prestige, income and education. *SEP* is not interchangeable with the term *social class*, which describes social relationships, but used to define several components of economic and social well-being related to class position. Unlike the term *SES*, the SEP does not describe an index based on a ranked status of (economic) hierarchies or prestige that confuses the status with actual resources, but is rather an orientation of where individuals or population groups are located based on economic and social well-being (Krieger et al., 1997, pp. 345–348).

In this document the phrase SEP will be used for further description and analyses, as it is covering a holistic description of long-term wealth and social inequities of individuals living in LMIC. The SEP will be used here to reveal mechanisms between SEP and Malaria outcomes.

3.1.2 Measuring monetary vs. asset-based SEP in LMIC

In contrast to high-income countries (HIC), measuring the socio-economic position and wealth inequalities of people in low- and middle-income countries (LMIC) by monetary wealth can be more difficult or complicated for area based or ecological measures, like gross domestic product (GDP). For individual or household-levels in HIC, besides the health status of a person, physicians usually can evaluate social class, wealth and working conditions as determinants of health. That practice is rooted in a long-established history of research. Besides that, some researchers focusing their work on LMIC tend to assume a generally low SEP and therefore have not prioritized research on existing inequalities in health in LMIC. However, it is known, that disadvantaged living and working conditions and social class are reasons for less coverage to preventive measures and health interventions and therefore related to poorer status of health, lower life expectancy, low nutritional status and higher incidence of infectious diseases (Howe et al., 2012). It is thus essential to quantify the individual, social, behavioural and economic factors within societies, the SEP, for usage in epidemiological studies and public health measures in LMIC. The SEP can be

seen in epidemiological studies as a confounder, but also as a predictor for health inequalities. Major factors describing the SEP are occupation and income, the educational attainment, as knowledge-based assets of individuals or their parents. But also asset-based measures can describe the household-wealth in LMIC, when economic data are not available or reliable (Filmer and Pritchett, 2001). For instance, the Demographic and Health Surveys (DHS) are not collecting data on income or household consumption expenditure, but are collecting data on ownership of a range of assets that have a potential indirect impact on health. These assets are on the one hand durable assets, like owning a car, refrigerator and television; material of dwelling floor and roof and main cooking fuel as household characteristics; persons per sleeping room, ownership of agricultural land and domestic servant, and on the other hand access to basic services, such as electricity supply, source of drinking water and sanitation facilities (DHS Program, 2020). All of the beforehand mentioned properties are often being used for describing a cumulative living standard of a household within a wealth index. This living standard is seen as a long-term economic position between wealthier and poorer households, because experiencing sudden changes in this ownership, or reallocation of financial means would not automatically mean a rapid change of living situation, like children dropping out of school (Filmer and Pritchett, 2001; Howe et al., 2012, p. 872). And using a household-level measurement of wealth is giving more information on the actual SEP and is useful to account for the living standards of all household members and not only of the member providing for the household, because unemployed member or children might have a low individual SEP, but higher living standards, due to the occupation of their partners or parents (Krieger et al., 1997). One must further add that a wealth index (WI) can only refer to poorer or wealthier households or individuals, but never refer to absolute poverty or wealth (Hjelm et al., 2017).

These assets as unweighted composites of wealth would not be suitable to provide sufficient information on the socio-economic position, because their different variable scales would provide a vast amount of information and variation among households. Their significance for wealth is also differing between countries and regions. Owning e.g. a watch or a refrigerator would be considered a usual asset in Europe, and thus would not indicate poverty or wealth, but in other

countries, e.g in SSA, owning these assets can suggest a higher wealth position. Hence a data reduction technique, such as principle component analysis can function to summarize and standardize the meaning of assets in an index serving as a proxy for wealth or poverty (Filmer and Pritchett, 2001; Vyas and Kumaranayake, 2006). This has been shown in previous work to be a useful 'empirical and logistical alternative to consumption' in the context of malaria research (Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016, p. 650). The DHS is providing gold standard datasets for studies and analyses of SEP in connection to health outcomes.

3.2 Women's education and malaria in children

In addition to living conditions and health behaviour, education is strongly linked to income and occupation and therefore naturally connected to the SEP. It is hypothesized that a higher educational attainment of women and mothers, measured through years of formal education attended, literacy or other qualifications, is linked to a reduced risk for malaria infection of their children, because they are more likely of having a higher income and therefore are able to afford higher expenses for preventive actions and transportation to health care facilities and by this have better access to health care services (Ma et al., 2017). Through education, knowledge and attitudes can also serve as protective factors for malaria infection of vulnerable groups. Since education is linked to wealth, but might also has a direct effect on health, the level of maternal educational attainment can be detached from the SEP and treated as a preconnected mediator to other pathways linked to malaria (Howe et al., 2012, p. 872).

3.3 Treatment seeking and malaria in children

As previously mentioned, higher educated women are possibly more likely to seek help and receive timely treatment for diseases and pregnancies, because of greater health awareness and financial means to do so. Malaria infection and severe progression of the mothers and their unborn infants could effectively be prevented by prenatal care visits and antimalarial treatment during the pregnancy, but there is a lack of knowledge and capacities to seeking help (Ayalneh et al., 2017; Njama et al., 2003). Further, wealthier individuals are more likely to seek health care in public facilities, which is expected of being a higher quality provision of malaria care (Onwujekwe et al., 2011). Evaluating the effect of general health

care and prenatal treatment seeking and preventive medication and comparing different health care provider can be of great value to understand through which interventions malaria infections could be prevented in the future (Littrell et al., 2013; WHO, 2016, 2019)

3.4 Insecticide treated mosquito bed net use and malaria in children

ITN are effective interventions to protect children from bites of anopheles mosquitos and therefore indirectly prevent malaria infection. The ownership of LLIN's is on the one hand more likely within richer households, and on the other hand is frequently distributed as part of malaria awareness campaigns to all interested population groups. But the mere ownership of LLINs does not automatically reflect on the actual use of the LLINs and therefore should not be solely looked at when researching preventive measures against malaria. It is suspected, that a higher SEP, by higher educational attainment has a positive effect on the utilisation of LLINs and the genuine protective effect against mosquitos, already when two household member are using these bed nets. (Deressa, 2017; Giardina et al., 2012; Ricotta et al., 2019; Tusting et al., 2017). Parents providing bed nets to be used especially by their children alone or with just one other person are providing effective protection against malaria in their children, while too many people using one net seems not be be as protective (Tamari et al., 2019). Further, LLINs have been shown to reduce under-five mortality from Malaria by 18.8% in Ghana, in combination with indoor residual spraying even by 55% (Min et al., 2020).

3.5 Housing condition and malaria in children

Whether people live in traditional or modern houses can be an indicator of wealth or SEP, since wealthier people are more likely to afford and live in modern houses. But the quality of the housing condition the individuals live in can have an even higher influence on being exposed to the vectors entering the dwelling, and therefore pose a risk factor for malaria infection (Guerra et al., 2018; Klinkenberg et al., 2006; Rek et al., 2018; Snyman et al., 2015; Tusting et al., 2017; Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016). Modern houses are defined as those with improved materials for walls, roof and floors and made up by rudimentary or finished materials, making it difficult for mosquitos to find their way into the houses. Traditional houses are constructed with unimproved materials,

mainly from natural or rudimentary resources, like stick walls and straw roofs, and are not built air-tight or sealed. Mosquitos, that are spilling over the parasite to humans have a higher chance to enter the houses and rest within the construction materials, when they are of natural source (Beavogui et al., 2020; Florey and Taylor, 2016).

3.6 Malaria outcome: fever event in last two weeks

In available publications, malaria infection is often and in a most reliable way measured by diagnosing such through blood tests, e.g. PCR or RDTs and parasite count by microscopy (Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016). The human biting rate (HBR) and the prevalence of mosquitos within dwellings or compounds on a household or community level can also be used as a proxy for the probability to be infected with malaria, but are only indirect proxies of malaria prevalence. In Ghana, one of the most common causes of fever in children under 5 years of age is considered to be malaria infection. And even though it is only a proxy for malaria prevalence, collecting data on (self-) reported fever events is often more feasible than collecting blood and data on HBR, because it requires less infrastructural and financial means. Therefore reported fever events are frequently used as a proxy for malaria prevalence by malaria indicator surveys across SSA and Asia, which has proven to be an informative proxy for malaria (Florey and Taylor, 2016; WHO, 2020).

4 Methods

In this chapter, the data source will first be described in section 4.1, followed by an explanation of the principles of PCA for HHWI-construction. Details of the mediation analysis will be provided in sections 4.2.2 and 4.2.3.

4.1 The data source

To answer the research question the ‘2019 Ghana Malaria Indicator Survey’ data (GMIS 2019) were used to conduct the analyses.

4.1.1 About the MIS

The Malaria Indicator Surveys (MIS) are part of the global efforts to fight malaria through the ‘Roll Back Malaria’ program by its ‘Monitoring and Evaluation Working Group’ (MERG). The MIS data are sampled in correspondence to high malaria transmission seasons of the respective countries or regions on representative respondents on household level. The surveys’ content is derived from the ‘Demographic Health Surveys’ (DHS) and the ‘Multiple Indicator Cluster Surveys’ (MICS). The MIS data collection within the four questionnaires (Household, Woman’s, Biomarker and Fieldworker) is based on established malaria indicators and includes questions about preventive measures, such as household ownership of ITNs, intermittent preventive treatment during pregnancy, and malarial fever events in children. The MIS also collect further information on characteristics of the household members, such as women’s educational attainment and literacy, health insurance coverage, and household assets like electricity, indoor plumbing facilities, ownership of radios, vehicles, cooking fuel types etc. Thirdly, it features Computer Assisted Personal Interview (CAPI) survey types, fieldworker characteristics, GPS/georeferenced, health insurance data, anaemia testing results, malaria microscopy and RDT results and reports on social marketing strategies.

The Ghana Malaria Indicator Survey of 2019 was the second of its kind in Ghana. It was improved and adapted from the first GMIS, which was conducted in 2016. The surveys in Ghana are implemented by the Ghana Statistical Service (GSS), the Ghana National Malaria Control Programme (NMCP) and the National Public Health and Reference Laboratory (NPHRL) of the Ghana Health Service (GHS). Funding for the GMIS2019, as part of the DHS Programm, was provided by the

USAID; the Global Fund to Fight AIDS, Tuberculosis and Malaria; and the Government of Ghana. The work is conducted in collaboration with technical assistance by ICF. With each MIS, the contributing institutions publish a final report, in this case, the 'Ghana Malaria Indicator Survey 2019 Final Report' (GSS and ICF, 2020).

4.1.2 Sampling strategy and sample size

The DHS GMIS uses two-stage probability samples (random selection of known and nonzero probabilities) drawn from existing sampling frames, that are stratified for homogenous groupings, by the 10 geographic regions and for urban/rural areas in these regions. Households are selected through the allocation of samples of the stratum, and per cluster, 30 households are selected. The final number of sampling clusters is therefore defined by the amount of households, the primary sampling units (PSU), such as census enumeration areas (EAS) that are selected with probability proportional to size (PPS) (Croft, Trevor N., Aileen M. J. Marshall, Courtney K. Allen, et al., 2018, p. 48; GSS and ICF, 2020).

For the cross-sectional GMIS 2019 between the months September and November of 2019 6,002 households were selected, of which 5,833 were occupied at the time of the fieldwork and 5,799 households were then successfully interviewed among the occupied (99% response rate). From among these household, 5,246 eligible women were identified and 5,181 individual, female respondents were successfully interviewed for the survey (99 % response rate). The heads of the household provided answers to the household questionnaire, while when eligible women/mothers of the same households were available, were responding to the woman's questionnaire including questions about the individual women's and if applicable the children's anthropometric, behavioural and health information. Mothers answered questions for a total of 3004 children under the age of 5 (Table 2).

The answers of the questionnaires are provided by the DHS in a household dataset, a woman's individual dataset and a children's dataset and variables are named by recoding according to questionnaire, number of question and sub-answer categories. Questions stating multiple categorical answers are provided as dichotomous variables each ('yes', 'no').

Each household is allocated to a household ID number, and each woman and child of the household receives an individual ID number consisting of the household ID plus two digits for the individual's line number in the household questionnaire. These individual ID numbers are used for identification in the woman's individual and children's dataset.

Table 2: Results of the household and individual interview sampling
Number of households, number of interviews, and response rates, according to residence (unweighted), Ghana MIS 2019

Result	Residence		Total
	Urban	Rural	
Household interviews			
Households selected	2,912	3,090	6,002
Households occupied	2,822	3,011	5,833
Households interviewed	2,801	2,998	5,799
Household response rate[1]	99.3	99.6	99.4
Interviews with women age 15-49			
Number of eligible women	2,468	2,778	5,246
Number of eligible women interviewed	2,440	2,741	5,181
Eligible women response rate[2]	98.9	98.7	98.8

[1] Households interviewed/households occupied
[2] Respondents interviewed/eligible respondents

4.1.3 Household-level data

Household-level data are being generated by means of a household questionnaire (Annex A). The questionnaire is divided into five sections, beginning with the household schedule. It contains information on each household resident, their demographic information, relationship to the head of the household, and an eligibility check for the woman's questionnaires (women between 15 and 49 years) and the children's questionnaire (children under the age of five). Section two on 'Household characteristics' is focusing on questions concerning the ownership of household assets, such as the source and type of drinking water, type and sharing of toilet facility, the type of cooking fuel, number of rooms used for sleeping, the ownership of livestock and agricultural land, having a bank account, electricity and the ownership of household amenities, such as radios, TV's, telephones, household appliances, furniture and means of transportation. Regarding preventive measures against malaria infections, questions of the third section 'mosquito nets' include if the interior walls of the dwelling got sprayed against

mosquitos, and if they were sprayed by government worker, private companies, NGO's or others. Moreover it is asked, how many mosquito nets the household owns and who of the household members slept under the respective bed nets the night before the interview. The main material of the floor, roof and walls of the dwelling are noted down as observations by the interviewer in section four 'additional household characteristics'. The last section of the interview comprises space for comments about the interview, on specific questions and any other comments, noted by the interviewer after the interview, and observations by the supervisor.

4.1.4 Individual-level data

Data at the level of the individual are collected by means of a woman's questionnaire (Annex B). Data are collected on respondents' background characteristics, such as the date of birth and age, the highest level of education, religious and ethnic affiliation, registration to health insurance and whether it is known, that malaria care is covered under the NHIS.

In section 2 'reproduction' the woman's questionnaire includes data on the number of births women had, whether the children are alive and what day each of them was born, where they live, and if the women is currently pregnant. Subsequent questions in section 3 concerning their last pregnancy include if and where antenatal care was sought at. The intermittent preventive treatment seeking is asked for by noting down the month of pregnancy in which antenatal care was sought first, where and how many times within this pregnancy ANC and SP/Fansidar was taken to prevent malaria infection. Section four 'fever in children' concerns fever events and their diagnosis for each child under the age of 5 (born in 2014-2019). Initially it is asked, if the child was enrolled in a program providing preventive malaria medicine in 2017 or 2018. Then it is probed, whether the child had a fever in the last two weeks and to recall the result of a possible blood test for malaria or other diseases. It is additionally asked if and when after illness onset the caretaker sought advice or treatment for this fever and where and why this was done. Further questions include, if drugs were taken against the disease (antimalarial, antibiotic, others) or why they have not been taken. In section five, the 'social behaviour change and communication' is covered, including questions on knowledge towards malaria messages, their sources with content about

protective measures and attitudes, and whether the respondent came across certain messages in the past six months and how they react in case a child has a fever. The questionnaire concludes with comments about the interview, specific questions and others and supervisors observations (DHS Program, 2020; GSS and ICF, 2020).

4.2 Data analyses

Prior to the statistical analyses, an extensive literature search was done to determine the need for research on pathways associated with SEP at the household level and malaria in children. On the basis of the results of this literature search (Chapter 2 Sections 2.5.1 to 2.5.4) a conceptual framework was developed (Chapter 3). Following the development of the conceptual framework, data provided by the GMIS2019 were used for a descriptive analysis of the household-level characteristics and the data on the individual-level characteristics. The household-level data were then used to construct a wealth index based on ownership of household assets. The HWI was used to determine the SEP of children in the dataset and was included within the individual level data to form the basis of the subsequent explorative mediation analysis on the different pathways as described within the conceptual framework. All statistical analyses were computed with the statistical data software '*R-Studio*' version 4.0.2 (R Foundation for Statistical Computing).

4.2.1 Descriptive analysis

The characteristics of the households and women included in the survey are described with absolute frequencies and proportions of categorical variables for the total populations; and stratified by urban and rural residency (e.g. the number and proportion of each source of drinking water and type of toilet facility) of the household level data; or the WI of the individual level data (e.g. type of residency, educational attainment and fever presence). Means and standard deviations were calculated for the continuous variables in case of a normal distribution, such as age of the child and their mothers, and median, minimum and maximum values were calculated for variables, such as for household sizes.

4.2.2 Principles of Principal Component Analysis

PCA is a data reduction technique, which measures correlations between assets or indicators to generate a set of uncorrelated principal components resulting in a composite score. The concept was introduced by the DHS Program at the end of the 1990s and is often reported as an asset index or wealth index (Croft, Trevor N., Aileen M. J. Marshall, Courtney K. Allen, et al., 2018, p. 36). The wealth index as a measurement of SEP is now widely established in public health research in LMIC (Homenauth et al., 2017; Howe et al., 2012, p. 874; Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016).

There is no consent on a best practice approach, by which variables are selected for the calculation of a wealth index (Montgomery et al., 2000). With the help of PCA, the impact of the ownership of assets and household infrastructural features provided by a household questionnaire can be summarized into a HWI with a low risk of reporting bias. The calculation is dependent on the research objective and the assets' association to the underlying health outcome, as well as factors specific for the area under investigation, but a broad range of literature is providing sufficient information for orientation (Homenauth et al., 2017; McKenzie DJ, 2003; Tremblay et al., 2015; Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016). With each item evaluated for the HWI, the representation of wealth is more specific and therefore a broader inclusion of variables is recommended (Rutstein and Johnson, 2004; Vyas and Kumaranayake, 2006).

The constructed HWI is based on assets features, which are given equal weights or scores produced by correlation matrix of variables, to standardize for the units of different variables. The produced factor loadings add up, and a higher eigenvalue reflects on a higher variation in the total explained data. A positive factor loading is indicating a wealthier position in the respective areas, a negative factor loading indicates a poorer position (Krefis et al., 2010; Vyas and Kumaranayake, 2006).

The first principal component serves as the data for the HIW, as this is describing the largest proportion of variation of the indicator variables (Howe et al., 2012, p. 873; Vyas and Kumaranayake, 2006). When many indicators correlate with each other, this means a strong contribution to the same principle component (Hayden, 2018). Including additional principal components in multiple-regression

analyses would not be of informative additions for the prediction of the HWI, because they are correlated with consumption expenditure. Since the aim is to produce a single measure of SEP, using the first principal component is suitable for an asset-based wealth index, even if this explains a low proportion of variance in the indicator variables (Krieger et al., 1997).

As the SEP cannot be generalized from populations of rural living areas to urban living areas and vice versa, in terms of the ownership of livestock and agricultural land and its meaning for the wealth of a household, the present analysis was done for each area separately. The number of chicken for example may suggest being a poor household in an urban setting, while the same amount of chicken in a rural area might indicate a wealthier household compared to households without chicken (Rutstein, 2020, p. 5). Therefore, the PCA includes the calculation of an urban specific HWI, a rural specific HWI and a national (common) HWI that are combined into one final composite HWI to map the households HWI's for national comparability (Figure 5). With a linear regression model of the urban and rural score mapped on the national score respectively, they are combined into the final composite score.

The final composite score is then categorised into quintiles, by using 20% cut-off-points on the scale defining the lowest, second, middle, fourth and highest HWI-category.

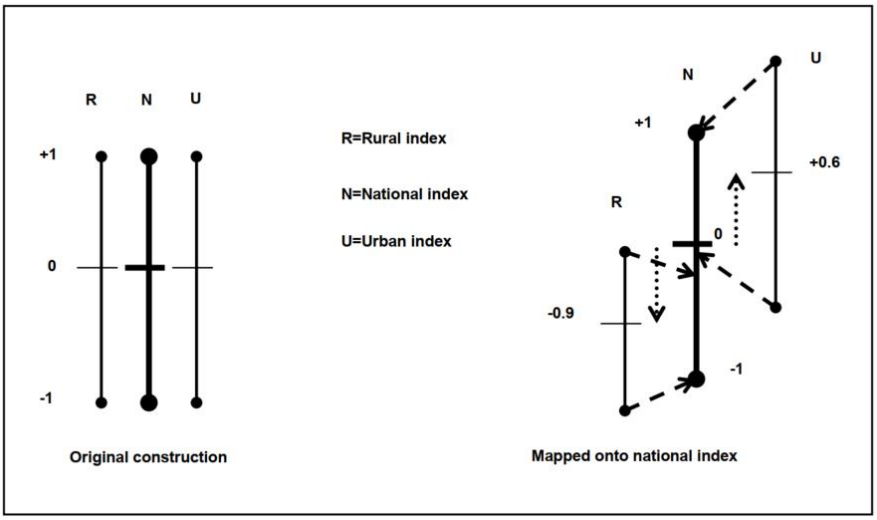

Figure 5: Mapping of urban and rural indices onto national index
to create a composite index to account for different economic meanings of agricultural land and livestock ownership (Source: Rutstein, 2008, p. 16)

4.2.2.1 Conduct of the PCA for this study

For the analysis within this study, the ‘household recode file’ of the GMIS2019 serves as the data source, which is loaded into ‘R’. The PCA is calculated and variables are coded according to Rutstein (2020), the command used is ‘princomp()’ which is a generic R function and the first principle component is returned by the ‘score’ function of princomp().

It is suspected, that the living situation, housing characteristics and educational attainment are influencing the outcome of malaria, while being also explained through the position on the HWI scale. These factors therefore are also posing risks for malaria outcomes on their own and are not included as components of the HWI-composition.

The present HWI provided within the GMIS2019-Data is derived also from housing materials, therefore a new HWI is to be constructed. This new HWI excludes housing variables from the PCA. Components of the PCA are identified in the dataset and exported into a new dataset for evaluation of relevant indicator variables. These indicators are to a certain degree reflecting the economic long-term position of households (Vyas and Kumaranayake, 2006).

The assets ownership variables are provided as dichotomous variables and are not needed to be recoded. To be able to use the indicators in the PCA all categorical variables, the household characteristics (type of cooking fuel, source of drinking water, source of non-drinking water and type of toilet facility) are dummy coded into separate dichotomous variables for each answer option, with 0 for ‘no’ if this indicator type does not apply to the household, and with 1 for ‘yes’ if it applies. The answer category ‘others’ is treated like an indicator, while ‘don’t know’ or missing values are treated as no answers or missing (‘NA’). A list of all indicator variables can be found within Annex D.

The national HWI consists of only the variables which are comparable between urban and rural households, resulting in the exclusion of the variables for ‘amount of agricultural land’ and the ‘number of livestock owned’. For the region-specific HWI’s, the dataset is divided in two subsets by the ‘type of place of residency’ (urban or rural), and for each, the HWI is calculated from all assets, to account for different meanings of wealth in urban and rural settings. The linear regression is

used to combine the HWI's and this composite wealth index is ranked on a continuous score, which is divided into quintiles that range from HWI category 1 ('lowest' or 'poorest') to 5 ('highest' or 'least poor'). Each household score is then assigned to the children below the age of five of the respective households and further used for the individual-level dataset subsequently (GSS and ICF, 2020). A detailed supplementing description of the data preparation for the HWI-construction and the 'R'-syntax is attached in Annex C and D.

4.2.3 Principles of mediation analysis

A mediation model is aiming to explain associations with the outcome that are indirectly linked to an exposure, and directly to mediators. Here, causal mediation analysis will be used to explore the potential mediators (e.g. treatment seeking, bed net use, educational attainment[1], housing conditions) of the effect of socio-economic position on malaria incidence to approximate closer to causality of associations (Rochon et al., 2014; Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016).

The advantage of mediation analysis over standard unconnected regression models is, that no specific statistical model with specific assumptions is needed to be developed, but rather a defined model of three linear regressions for direct, indirect and total effects (Agler and Boeck, 2017).

MA is often reported as such, or as (causal) pathway analysis. It is a statistical method that can estimate causal pathways of the (natural) indirect effect (or mediated effect; =a*b) of an independent variable (IV) on the dependent variable (DV) (Cashin et al., 2020, p. 1; Ricotta et al., 2015). This indirect effect is explained through endogenous factors, the mediators. When using multiple mediation analyses, the (natural) direct effect (=c') of an exposure (X) on the outcome (Y), not mediated by other mediators (M), can be defined as $E(Y_{aM1a^*M2a^*} - Y_{a^*M1a^*M2a^*})$ and is controlled for the mediating variables. The indirect effect via two mediators is defined as $E(Y_{aM1aM2a} - Y_{aM1a^*M2a^*})$, and is the product of estimates from the exposure on the mediator(s) and the mediator(s) on the outcome controlled for the exposure and confounder. The sum of the direct effect and the indirect effect produce the total effect (=c). Therefore, through mediation

[1] Can be both a risk factor and potential mediator.

analysis, it can be explained and described how and to what degree the total effect of the relationship between the exogenous variables (IV and DV) accounts for the DV and to what extent this effect is impacted by other factors. The proportion mediated can then be achieved by dividing the indirect effect by the total effect (Figure 6) (Ricotta et al., 2015; Vansteelandt and Daniel, 2017).

When having a mediation hypothesis and an exploratory driven analysis with the focus to evaluate the indirect effects (=a*b) of mediation, it is not required for the total effect (=c) between the exposure and the outcome variable to be present, since it is irrelevant to the question whether or not there is an indirect effect present, explaining the intermediate effects themselves (Agler and Boeck, 2017, p. 5).

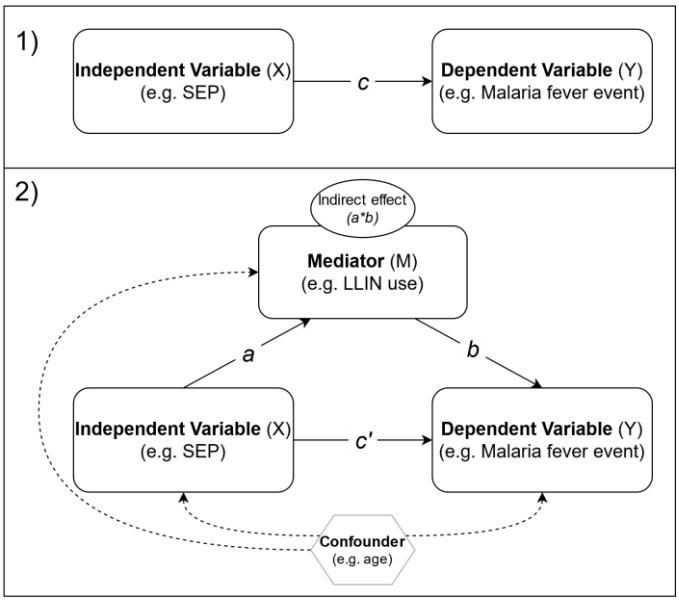

Figure 6: Effects of mediation analysis in a causal directed acyclic graph with confounder (source: own figure, adapted from (MacKinnon et al., 2007, p. 595))
(1) c = total effect of X on Y without considering M. (2) a = linear regressional effect of X on M; b = linear regressional effect of M on X; a*b = indirect effect of X on Y through M is calculated by logistic regression, c' = direct effect of X on Y

The mediation analysis is done in five steps, starting with a first model containing the first interconnected mediator educational attainment (EA) as a single mediator and age as a confounder. The explanatory variables are introduced into natural effect models, which are conditional mean models, (neMod1) through an imputation of counterfactual outcomes to yield the natural direct effect (NDE) and a natural indirect effect (NIE) by bootstrapping standard errors (Vansteelandt and

Vanderweele, 2012). Multiple ‘en bloc’ mediation models are conducted according to Vansteelandt et al. by the combination of EA with one other mediator per natural effect model and a last mediation concludes by introducing all mediators and confounder in the joint model. This has the advantage over single mediation that it provides effect decomposition methods to account for all factors simultaneously, rather than separately. The joint mediated effect yields more detailed information than the sum of individual mediated effects, because the mediators might influence each other, but also when they are not related, they might still ‘interact on the additive scale in the effect they produce on the outcome’ (Vansteelandt et al., 2017, p. 17).

The MA provides a summary of the natural effect models and the effect decomposition to evaluate the effects of the different pathways. The effect sizes are used to calculate the proportion mediated (PM) through the models and odds ratios are informing on the risk differences (Feingold et al., 2019; MacKinnon et al., 2007). A subsequent analysis of variance (ANOVA) is then conducted for an overall assessment of the natural effect models and a joint comparison of all HWI quintiles. (Steen et al., 2017; VanderWeele and Vansteelandt, 2014)

4.2.3.1 Conduct of the mediation analysis of pathways between SEP and fever incidence

The multiple mediator analysis is conducted with the package developed for ‘R’ ‘Medflex: An R Package for Flexible Mediation Analysis using Natural Effect Models’ from CRAN with an imputation-based approach on the outcome model (=counterfactual approach) (Steen et al., 2017). The advantages of ‘medflex’ compared to other mediation packages in R, such as ‘mediation’ by Tingley et al. (2014) include, that it offers all required functionalities and can be used for multiple mediations with categorical exposures and can deal with a larger class of parametric models, as well as using bootstrapping for non-parametric calculation of standard errors. The usage of natural effect models provides an analysis fit for nested counterfactuals of the outcome (Steen et al., 2017). For this analysis, binary logistic regression is used to evaluate the correlation between the ordinal exposure variable HWI, calculated previously, the dichotomous outcome variable fever incidence and the binary or discrete mediators within the natural effect model (Valeri and Vanderweele, 2013; Vanderweele, 2010).

The variable indexing the incidence of malaria will be approximated by the report of fever incidence in the last 2 weeks before the interview and thus function as a proxy variable for clinical malaria incidence. The variable is provided in the dataset as a categorical variable with ‘no’ being the reference category, ‘yes’ and ‘don’t know’ the expressions. All subjects reporting ‘don’t know’ will be set as a missing variable to avoid false interpretation and to create a dichotomous outcome variable.

The mediators under investigation are (1) educational attainment, measured by completion of school levels (categorical); (2) healthcare seeking behaviour reported by the type of prenatal care provider visited (categorical), (3) use of LLIN’s in the household measured by the amount of children sleeping under it the night before the survey (categorical) (4) type of housing material of the floor, roof and walls (dichotomous) which were prepared within the dataset and subsequently entered into the mediation model.

The variable ‘age of respondent in years’ is used in the model to adjust for the age of mothers as a confounding factor between the mediators and the outcome. Since the age of mothers or female caretakers is influencing the risk for malaria infection, SEP and the educational attainment tend to increase with age. The variable is provided in the dataset as a continuous variable from 15 to 49 years of age and not recoded into age categories, to avoid loss of information.

Since in this analysis, only females were respondents of the interviews, the risk factor or confounder of gender can be neglected. Further, the gender of children is not expected to be a confounding factor for the infection with malaria in children under the age of five, and therefore not factored into the MA as a confounder (GSS and ICF, 2020).

Since the interviews for the GMIS2019 took place during one high malaria transmission season (within 8 weeks from september to november 2019), seasonality could not be adjusted for (GSS and ICF, 2020).

5 Results

The results of the analyses will be described in detail in the following. The descripitive analysis comprises the distribution of assets among households at the household level and the sample characterstics. The weights assigned to the household assets by PCA and the HWI composition is described afterwards. The chapter concludes with a description of the association between wealth and fever events, measured in a regression model and by natural effect models, and the effect decomposition and proportions mediated of the mediation analysis are reported.

5.1 Study population characterstics

5.1.1 Description of household level information

The sample underlying the PCA includes n = 5,799 households, of which 48.3 % are situated in urban areas, while 51.7 % are located in rural settings. On average, the households consist of 4.04 (median = 4; IQR = 2 – 6, max = 38) de jure member, with an average household size of 3.52 (median = 3, IQR = 2 – 5; max = 38) in urban areas and 4.53 (median = 4, IQR = 2 – 6, max = 20) in rural areas. The HWI was derived from different household assets. In the following, these assets are reported by their distribution between the households looked at in total and separately by urban and rural residency (Table 3).

Source of drinking water

Piped water into the house does not seem to be a common source for drinking water in Ghana. Most urban households use sachet water and public tabs/standpipe (85 %), and 42 % of rural households use tube wells or boreholes and also sachet water for drinking water and 24 % are using piped water as their source of drinking water. 5 % of all households are using surface water for drinking.

Type of toilet facility

49 % of the urban households are using pit toilet latrines, of which 895 households are using ventilated (improved) pit latrines. 44 % of households in urban areas are using flush toilet and most of them use flush toilets with septic tanks. In the rural regions, 60 % of households use pit toilet latrines (40 % households with slab) and 5 % use flush toilets, while 33 % of rural households are having no toilet facilities,

but practicing open defecation (bush/field). 61 % of all households are sharing their toilet facilities with other households.

Type of cooking fuel

The majority of all households use wood, charcoal or LPG as their main cooking fuel. With 68 % wood is the most common type of cooking fuel in rural households and LPG is only used within 8 % of rural households. While with 47 % charcoal is the most common cooking fuel in urban households, wood is only used in 13 % of urban households.

Number of rooms used for sleeping

3,093 of all households are using one sleeping room for all household members (56 % urban vs. 44 % rural), 25 % use two sleeping rooms (46 % urban vs. 54 % rural), 12 % use three sleeping rooms (33 % urban vs. 67 % rural) and 9 % use four or more rooms for sleeping (31 % urban vs. 69 % rural).

Ownership of livestock or agricultural land

Of all households, 23 % of urban households and 68 % of rural households own land usable for agriculture, making up for 46 % of all households owning agricultural land. 21 % of urban households and 59 % of rural households own livestock, herds or farm animals.

Ownership of household assets

A large proportion of households have electricity in their homes, of which 58 % live in urban areas. Nearly 2 % of all households, mostly in urban areas, have an electric generator or invertor in their homes. 54 % of all households own a radio, 57 % a TV, 57 % a refrigerator and 8.5 % a freezer. 39 households have a landline-telephone and 497 a mobile. A watch is owned by 51 % of households. Further, almost 2 % own a camera and 17 % have a video/DVD/VCD device, nearly 2 % of households own a washing machine and 15 % of all households have a sewing machine in their homes. 100 households own an animal-drawn cart, 62 households own a boat with a motor, 41 without a motor. 28 % of households own a bicycle, 17 % a motorcycle or scooter, 7 % of all households own a car or truck. The larger majority of households own a bed, a table and/or a chair. 25 % of all households own a cabinet or cupboard. 44 % of 5799 households have a bank account.

Table 3: Distribution and factor loadings of assets across households of MIS2019 in Ghana

Household Characteristics	Type of place of residence				Total		Factor loadings	
	Urban		Rural				Urban	Rural
	n	%	n	%	n	%		
Total	2,801	48.3	2,998	51.7	5,799	100		
Source of drinking water								
PIPED WATER								
Piped into dwelling	115	81.56	26	18.44	141	2.43	0.082	0.060
Piped to yard/plot	257	81.59	58	18.41	315	5.43	0.009	0.060
Piped to neighbor	246	70.49	103	29.51	349	6.02	-0.070	0.040
Public tap/standpipe	407	43.53	528	56.47	935	16.12	-0.151	0.013
TUBE WELL WATER								
Tube well or borehole	213	14.74	1,232	85.26	1,445	24.92	-0.091	-0.169
DUG WELL								
Protected well	104	42.11	143	57.89	247	4.26	-0.061	0.009
Unprotected well	37	26.06	105	73.94	142	2.45	-0.059	-0.028
WATER FROM SPRING								
Protected spring	-	-	5	100.00	5	0.09		
Unprotected spring	2	3.85	50	96.15	52	0.90	-0.014	-0.011
SURFACE WATER River/dam/lake/ponds/ stream/canal/ irrigation channel	7	2.39	286	97.61	293	5.05	-0.026	-0.067
RAINWATER	21	28.77	52	71.23	73	1.26	-0.039	0.015
TANKER TRUCK	4	17.39	19	82.61	23	0.40	-0.013	0.033
CART WITH SMALL TANK	1	33.33	2	66.67	3	0.05		
BOTTLED WATER	45	84.91	8	15.09	53	0.91	0.076	0.063
SACHET WATER	1,342	77.89	381	22.11	1,723	29.71	0.185	0.220
Type of toilet facility								
FLUSH TOILET								
Flush to piped sewer system	64	86.49	10	13.51	74	1.28	0.047	0.043
Flush to septic tank	981	90.25	106	9.75	1,087	18.74	0.226	0.162
Flush to pit latrine	132	78.57	36	21.43	168	2.90	-0.018	0.033
Flush to somewhere else	20	86.96	3	13.04	23	0.40	-0.012	0.030
Flush, don't know where	13	86.67	2	13.33	15	0.26	-0.001	0.009
Flush, bio-digester (biofil)	10	76.92	3	23.08	13	0.22	0.009	0.020
PIT TOILET LATRINE								
Ventilated Improved Pit latrine (VIP)	895	58.23	642	41.77	1,537	26.50	-0.080	0.142
Pit latrine with slab	301	29.54	718	70.46	1,019	17.57	-0.080	-0.006
Pit latrine without slab/open pit	171	28.74	424	71.26	595	10.26	-0.088	-0.015
NO FACILITY								
No facility/bush/field	202	16.69	1,008	83.31	1,210	20.87	-0.103	-0.188
COMPOSTING TOILET	9	90.00	1	10.00	10	0.17	-0.005	0.007
BUCKET TOILET	1	50.00	1	50.00	2	0.03	-0.001	-0.007
HANGING TOILET/LATRINE	1	2.22	44	97.78	45	0.78	-0.007	0.004
OTHER	1	100.00	-	-	1	0.02		

Cont. Table 3: Distribution and factor loadings of assets across households of MIS2019 in Ghana

Household Characteristics		Type of place of residence				Total		Factor loadings	
		Urban		Rural				Urban	Rural
		n	%	n	%	n	%		
Share toilet with other households	No	525	50.77	509	49.23	1,034	17.83	-0.125	0.140
	Yes	2,074	58.34	1,481	41.66	3,555	61.30		
Type of cooking fuel									
Electricity		15	57.69	11	42.31	26	0.45	0.012	0.012
LPG		946	78.83	254	21.17	1,200	20.69	0.287	0.233
Natural gas		1	50.00	1	50.00	2	0.03		
Biogas		1	50.00	1	50.00	2	0.03		
Kerosene		2	100.00	-	-	2	0.03		
Cooking gel		2	50.00	2	50.00	4	0.07		
Charcoal		1,317	70.62	548	29.38	1,865	32.16	-0.135	0.148
Wood		378	15.57	2,050	84.43	2,428	41.87	-0.174	-0.257
Straw/shrubs/grass		1	1.72	57	98.28	58	1.00	-0.015	-0.059
Agricultural crop residue		1	50.00	1	50.00	2	0.03		
Animal dung						0	0		
No food cooked in household		136	65.07	73	34.93	209	3.60	-0.042	0.027
Other		1	100.00			1	0.02		
Number of rooms used for sleeping	1	1,727	55.84	1,366	44.16	3,093	53.34	-0.084	-0.025
	2	678	46.00	796	54.00	1,474	25.42		
	3	232	32.68	478	67.32	710	12.24		
	4-24	164	32.42	358	68.58	522	9.00		
Owns livestock, herds or farm animals	No	2,205	64.10	1,235	35.90	3,440	59.32	-0.019	-0.029
	Yes	596	25.26	1,763	74.74	2,359	40.68		
Owns land usable for agriculture	No	2,154	69.69	937	30.31	3,091	53.30	-0.096	-0.181
	Yes	647	23.89	2,061	76.11	2,708	46.70		
Has electricity	No	194	15.32	1,072	84.68	1,266	21.83	0.175	0.240
	Yes	2,607	57.51	1,926	42.49	4,533	78.17		
Has radio	No	1,139	42.80	1,522	57.20	2,661	45.89	0.170	0.113
	Yes	1,662	52.96	1,476	47.04	3,138	54.11		
Has television	No	652	26.77	1,784	73.23	2,436	42.01	0.240	0.272
	Yes	2,149	63.90	1,214	36.10	3,363	57.99		
Has refrigerator	No	1,500	37.36	2,515	62.64	4,015	69.24	0.284	0.261
	Yes	1,301	72.93	483	27.07	1,784	30.76		
Has bicycle	No	2,253	53.59	1,951	46.41	4,204	72.50	-0.020	-0.123
	Yes	548	34.36	1,047	65.64	1,595	27.50		
Has motorcycle/ scooter	No	2,412	50.20	2,393	49.80	4,805	82.86	0.026	-0.014
	Yes	389	39.13	605	60.87	994	17.14		
Has car/truck	No	2,476	46.14	2,890	53.86	5,366	92.53	0.208	0.107
	Yes	325	75.06	108	24.94	433	7.47		
Has telephone (land-line)	No	2,771	48.11	2,989	51.89	5,760	99.33	0.071	0.028
	Yes	30	76.92	9	23.08	39	0.67		

Cont. Table 3: Distribution and factor loadings of assets across households of MIS2019 in Ghana

Household Characteristics		Type of place of residence				Total		Factor loadings	
		Urban		Rural				Urban	Rural
		n	%	n	%	n	%		
Has mobile telephone	No	120	24.14	377	75.86	497	8.57	0.129	0.118
	Yes	2,681	50.57	2,621	49.43	5,302	91.43		
Has watch	No	1,026	36.32	1,799	63.68	2,825	48.72	0.204	0.217
	Yes	1,775	59.68	1,199	40.32	2,974	51.28		
Has animal-drawn cart	No	2,790	48.96	2,909	51.04	5,699	98.28	-0.029	-0.058
	Yes	11	11.00	89	89.00	100	1.72		
Has boat with a motor	No	2,782	48.49	2,955	51.51	5,737	98.93	-0.015	-0.004
	Yes	19	30.65	43	69.35	62	1.07		
Boat without a motor	No	2,791	48.47	2,967	51.53	5,758	99.29	-0.002	-0.003
	Yes	10	24.39	31	75.61	41	0.71		
Has a computer	No	2,211	44.00	2,814	56.00	5,025	86.65	0.231	0.177
	Yes	590	76.23	184	23.77	774	13.35		
Has bank account	No	1,173	36.58	2,034	63.42	3,207	55.30	0.231	0.211
	Yes	1,628	62.81	964	37.19	2,592	44.70		
Has Freezer	No	2,433	45.85	2,873	54.15	5,306	91.50	0.181	0.164
	Yes	368	74.65	125	25.35	493	8.50		
Electric generator/ invertor	No	2,736	47.99	2,965	52.01	5,701	98.31	0.116	0.064
	Yes	65	66.33	33	33.67	98	1.69		
Washing machine	No	2,715	47.67	2,980	52.33	5,695	98.21	0.167	0.100
	Yes	86	82.69	18	17.31	104	1.79		
Camera	No	2,730	47.84	2,977	52.16	5,707	98.41	0.109	0.080
	Yes	71	77.17	21	22.83	92	1.59		
Video/DVD/VCD	No	2,180	45.55	2,606	54.45	4,786	82.53	0.156	0.178
	Yes	621	61.30	392	38.70	1,013	17.47		
Sewing machine	No	2,323	46.90	2,630	53.10	4,953	85.41	0.042	0.056
	Yes	478	56.50	368	43.50	846	14.59		
Bed	No	587	33.11	1,186	66.89	1,773	30.57	0.196	0.216
	Yes	2,214	54.99	1,812	45.01	4,026	69.43		
Table	No	344	36.13	608	63.87	952	16.42	0.135	0.159
	Yes	2,457	50.69	2,390	49.31	4,847	83.58		
Chair	No	217	33.70	427	66.30	644	11.11	0.127	0.137
	Yes	2,584	50.13	2,571	49.87	5,155	88.89		
Cabinet/ cupboard	No	1,781	41.05	2,558	58.95	4,339	74.82	0.239	0.194
	Yes	1,020	69.86	440	30.14	1,460	25.18		

5.1.2 Sample description of individual-level information

The sample includes n = 3,004 children between 1 and 59 months of age with a mean age of 28.53 months (±17.29) or 2.38 years, of which 49.6 % (or 1,491) are female (Table 4).

The 3,004 mothers or caretaker of these children, serving as respondents of the interviews, were on average 29.86 years old (±6.89), with an age range from 15 to 49 years. The households of these children were on average 6.3 member large (median = 5, IQR = 4 - 7, max = 38).

In total, 27.5 % of mothers have no educational attainment, 16.4 % and 5.1 % have an in-(complete) primary level of highest education respectively, while with 36.9 % most women have attended, but not completed secondary educational level and 9.2 % have completed such. 4.9 % of mothers interviewed reported obtaining a higher level of education as secondary level.

When looking at the place of residency, the majority of children is situated in rural regions of Ghana (61.1 %) compared to 38.9 % in urban areas.

Of n = 3,004 children, 30.1 % live in houses made of traditional construction materials in contrast to 69.9 % in houses with modern construction materials.

13.6 % of all mothers reported, that no bed nets were present in the household the night before the interview. 21.7 % (n = 617) of mothers reported, that none of their children slept under a mosquito bed net the night before the interview, even though one was available. 53.5 % of respondents stated, that all children slept under a bed net the night before, compared to 11.9 % where only some children slept under the bed net the night before.

2,308 mothers were seeking treatment during their last pregnancy. The majority (96.9 %) were visiting formal health personnel (doctor, nurse/midwife or community health officer/nurse) for at least one prenatal care visit. 16 women or 0.7 % went to other informal health care provider (traditional birth attendant, community/village health worker or traditional health practitioner) for prenatal care visits, while 2.4 % were not seeking prenatal care during their last pregnancy at all.

From 2,928 children (NA=76 providing no answer), the majority of children reported no fever event within the last two weeks prior to the interview (n=1,980),

whereas 31.7 % of children reported having had a fever in the last two weeks. Of those 929 children, that had a fever in the last two weeks, 354 (38 %) answered, that a malaria blood test was taken. 56 children had a negative malaria blood test, 232 children (65 %) tested positive for malaria, 20 children tested positive for another illness and 46 respondents did not recall or did not know the result.

Table 4: Characteristics of study participants of MIS2019 in Ghana

Characteristics of children		Total		HWI quintile									
		n	%	Lowest		Second		Middle		Fourth		Highest	
				n	%	n	%	n	%	n	%	n	%
Total		3004	100.0	656	21.8	620	20.6	579	19.3	586	19.5	563	18.7
Mean age child in months		28.53 (±17.29)		27.86 (±17.22)		28.79 (±17.3)		28.37 (±16.79)		29.44 (±17.57)		28.23 (±17.58)	
Mean age mothers in years		29.86 (±6.89)		29.62 (±7.21)		29.73 (±6.85)		30.09 (±6.71)		30.56 (±6.9)		29.29 (±6.66)	
Sex of child (n =3004)	Female	1,491	49.6	328	22.0	308	20.7	293	19.7	304	20.4	258	17.3
	Male	1,513	50.4	328	21.7	312	20.6	286	18.9	282	18.6	305	20.2
Type of place of residence (n = 3004)	Urban	1,170	38.9	173	14.8	213	18.2	241	20.6	299	25.6	244	20.9
	Rural	1,834	61.1	483	26.3	407	22.2	338	18.4	287	15.7	319	17.4
Educational attainment of caretaker (n = 3004) [a)]	No education	826	27.5	217	26.3	179	21.7	169	20.5	141	17.1	120	14.5
	Incomplete primary	493	16.4	129	26.2	105	21.3	93	18.9	80	16.2	86	17.4
	Complete primary	153	5.1	30	19.6	32	20.9	40	26.1	29	19.0	22	14.4
	Incomplete secondary	1,109	36.9	205	18.5	218	19.7	207	18.7	244	22.0	235	21.2
	Complete secondary	277	9.2	44	15.9	63	22.7	43	15.5	57	20.6	70	25.3
	Higher	146	4.9	31	21.2	23	15.8	27	18.5	35	24.0	30	20.6
Type of housing construction (n=3004) [b)]	Traditional	904	30.1	261	28.9	216	23.9	159	17.6	140	15.5	128	14.2
	Modern	2,100	69.9	395	18.8	404	19.2	420	20.0	446	21.2	435	20.7
Children under 5 slept under mosquito bed net last night (n = 2916)	No net in household	396	13.6	82	20.7	103	26.0	75	18.9	64	16.2	72	18.2
	No	617	21.2	120	19.5	112	18.2	115	18.6	151	24.5	119	19.3
	Some children	348	11.9	71	20.4	66	19.0	64	18.4	86	24.7	61	17.5
	All children	1,555	53.3	365	23.5	315	20.3	313	20.1	269	17.3	293	18.8
Type of prenatal care provider (n=2308) [c)]	None	55	2.4	16	29.1	18	32.7	3	5.5	6	10.9	12	21.8
	Other person	16	0.7	2	12.5	3	18.8	6	37.5	2	12.5	3	18.8
	Health personnel	2,237	96.9	484	21.6	441	19.7	448	20.0	447	20.0	417	18.6
Had fever in last two weeks (n = 2928)	No	1,980	67.6	448	22.6	398	20.1	384	19.4	369	18.6	381	19.2
	Yes	929	31.7	195	21.0	196	21.1	174	18.7	202	21.7	162	17.4
	Don't know	19	0.6	1	5.3	7	36.8	4	21.1	4	21.1	3	15.8

a) primary =primary school; secondary = Junior secondary school (JSS); Junior high school (JHS); Senior secondary school (SSS), Senior high school (SHS)

b) modern housing = improved floor, wall and roof; traditional housing = unimproved floor, wall and roof

c) other person= traditional birth attendant, community/ village health worker, traditional health practitioner; health personnel (skilled person) = doctor, nurse, midwife, community health officer/ nurse

5.2 PCA – Household Wealth Index

The indicator assets ‘source of non-drinking water’, and some types of cooking fuels, drinking-water sources and toilet-types were excluded from the analysis due to a standard deviation below 0.5, indicating no variation between households.

The first principal component (PC1) of the urban HWI (UWI) explains 7.18 %, and the PC1 explains 7.19 % of the overall variability of the rural HWI (RWI) in the assets variables. The highest weights of UWI are set for using LPG as cooking fuel (0.287), owning a refrigerator (0.284), television (0.240), computer (0.231), bank account (0.231), and a cabinet/cupboard (0.239). For the RWI owning a television (0.272), a refrigerator (0.261), a watch (0.217) and using electricity (0.240), sachet water for drinking (0.220) and LPG as cooking fuel (0.233) are given the highest weights (Table 3).

Since the calculation of HWI was done by creating quintiles, the households within the five WI-groups are equally distributed and each category is made up by 1160 households (one by 1159).

5.2.1 Individual sample characteristics by HWI

The following chapter is providing a description of the children’s characteristics that are used within the mediation analysis and are separately reported for each HWI quintile (Table 4).

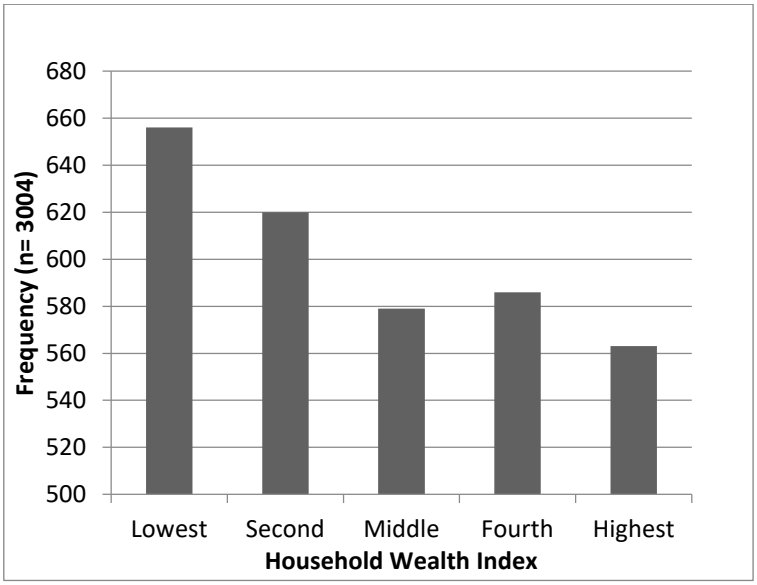

Figure 7: Frequency of children across HWI categories

Within the sampling group of children under the age of five, 21.8 % of 3004 children of interest are identified as being very poor (being situated in the lowest HWI quintile). 20.6 % of children fall into the second lowest HWI and 19.3 % in the middle HWI. Within the fourth HWI-category 19.5 % of children are situated, while 563 children or 18.7 % of children are falling into the least poor (or highest) HWI (Figure 7).

While in urban areas, the proportion of children increases with each category of HWI until the fourth HWI (25.6 %), the percentage of children from rural areas decreases with each category until the fourth HWI (15.7 %). Within the highest HWI quintile, there are 20.9 % of all children from urban areas and 17.4 % of the children from rural areas (Figure 8).

Educational attainment

Within women that have obtained no education, 26.3 % are in the lowest HWI quintile and the percentage of women within each quintile lowers with each category to 14.5 % in the highest HWI quintile. When mothers have incomplete primary education, 26.2 % (or 129 women) are counted in the lowest wealth quintile, 21.3 % in the second lowest, 18.9 % in the middle category, 16.2 % (n=80) in the fourth and 17.4 % in the highest wealth quintile. When women have completed primary education, most of them belong to the middle HWI quintile (26.1 %), while least of them have a highest SEP (14.4 %). With incomplete secondary educational attainment, out of 1,109 mothers, the biggest category is the fourth HWI with 22.0 % or 244 of mothers, while least of them are having a lowest SEP with 18.5 % (n=205). From 277 mothers that completed secondary education, 25.3 % have a highest SEP, while 15.9 % have a lowest SEP, and 15.5 % a middle SEP. Having a higher educational attainment results in 24.0 % being in the fourth HWI-quintile, while, with 15.8 % least women are in the second lowest HWI-quintile (Figure 9).

Housing construction

The number of children living in traditional housing decreases with increasing SEP. 69.9 % of all children live in modern houses and the proportion increases with increasing SEP from 18.8 % in HWI1 to 21.2 % in HWI4 and 20.7 % in HWI5 (Figure 10).

Mosquito bed net use

When children did not sleep under a bed net, 37.7 % of those are counted within lowest and second HWI-quintiles while 46.7 % of the children without bed nets in the household are in the respective HWI-quintiles. While 39.4 % of respondents of 'some children slept under the bed net' are found within the two lowest HWI groups, the response that 'all children slept under a bed net' was given in 43.8 % of children that are in the two lower HWI-quintiles (Figure 11).

Treatment seeking behaviour

21.6 % of mothers going to health personnel are located in the lowest HWI quintile, while 19.7 % are in the second, 20 % in the third and fourth respectively and 18.8 % in the highest HWI quintile. Other personnel was visited by only 16 mothers, of which 12.5 % are located in the lowest HWI quintile, 18.8 % in the second, 37.5 % in the third HWI quintile, 12.5 % in the fourth and 18.8 % in the highest HWI quintile as well. When no prenatal care was sought, 29.1 % were in the lowest HWI quintile, 32.7 % in the second, 5.5 % in the third, 10.9 % in the fourth and 21.8 % in the highest HWI quintile (Figure 12).

Fever incidence

Within the HWI-quintiles, those with a fever are located by 21.0 % in the lowest quintile, 21.1 % in the second, 18.7 % in the middle, 21.7 % in the fourth and 17.4 % in the highest quintile. Compared to those without a fever, 22.6 % are in the lowest HWI, 20.1 % in the second HWI, 19.4 % in the middle, 18.6 % in the fourth and 19.2 % in the highest HWI (Figure 13).

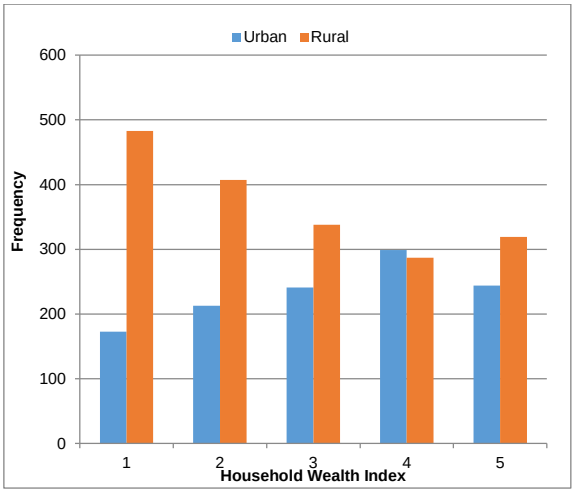

Figure 8: Frequency of individuals in HWI by type of residence

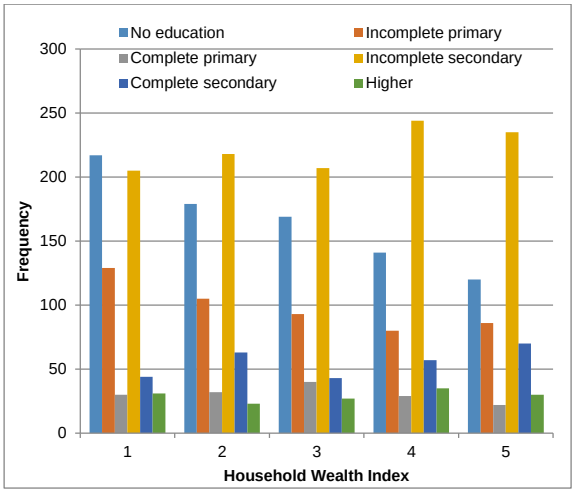

Figure 11: Frequency of individuals in HWI by level of educational attainment

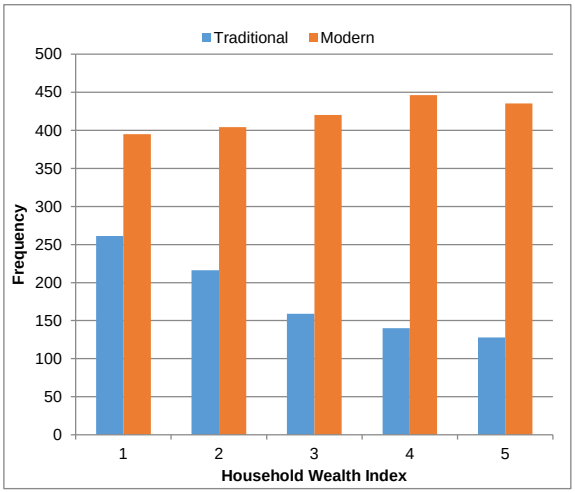

Figure 9: Frequency of individuals in HWI by type of housing

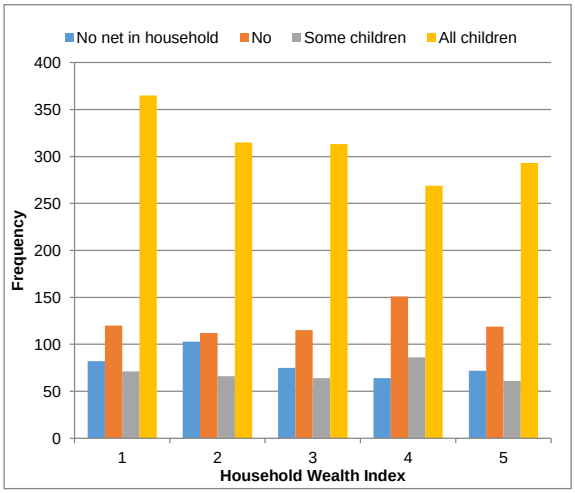

Figure 12: Frequency of individuals in HWI by bed net usage

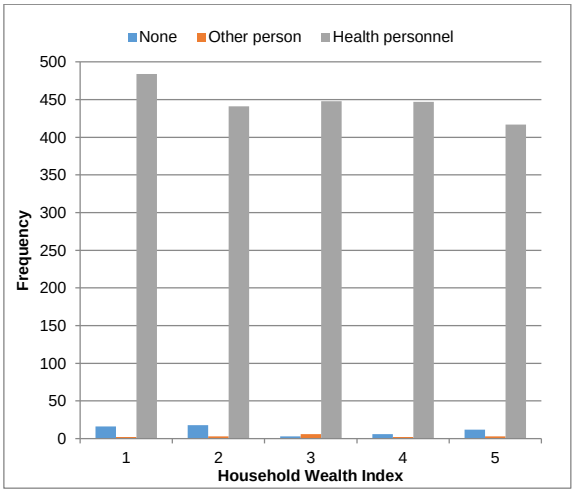

Figure 10: Frequency of individuals in HWI by type of health care provider

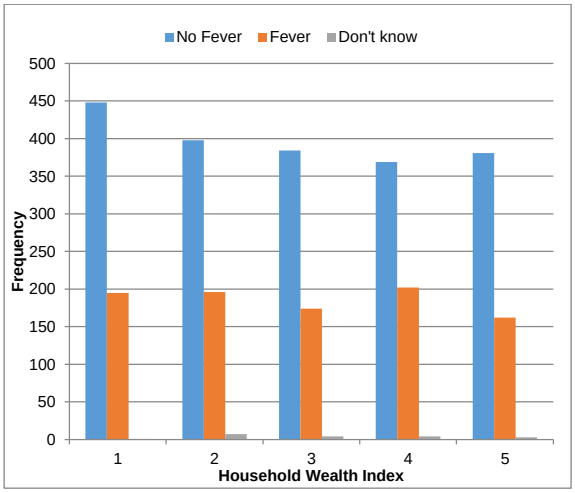

Figure 13: Frequency of individuals in HWI by presence of fever even

5.3 Mediation Analysis

This chapter summarises the results for the conduct of the exploratory mediation analysis. First the result of the preceding logistic regression for the association between the HWI and fever events is reported. Following this, the results from the different natural effect models are given by effect decomposition of the mediators under investigation.

5.3.1 Effect of HWI on fever event – binary logistic regression

In a preceding binary logistic regression analysis no association between the SEP categories and fever incidence ($X^2(4)=5.396$) was found, while being an individual in HWI quintile 4 is associated with higher odds of having a fever (OR = 1.2, 95%CI = 1.00-1.62).

5.3.2 Effect decomposition of natural effect models with mediators

A causal multiple mediation analysis was conducted to evaluate the hypothesised natural indirect effects of pathways between the relationship of SEP on fever and 5 sequential natural effect models (neModel) were conducted.

Table 5: Effect decomposition of natural effect model for sequential mediation analyses

neModel No. (mediator)		NDE [a]	NIE [a]	TE [a]	PM [a]
1) Educational Attainment (EA)	Estimate	0.144	-0.017	0.127	- 0.134
	OR (95%CI)	1.16 (0.90 - 1.48)	0.98 (0.96 - 1.00)		
	[b] χ^2 *(p)*	6.40 (0.17)	8.84 (0.07)		
2) EA + type of housing	Estimate	0.151	-0.023	0.127	-0.181
	OR (95%CI)	1.16 (0.91 - 1.48)	0.98 (0.96 - 0.998)		
	[b] χ^2 *(p)*	7.54 (0.11)	12.12 (0.02)		
3) EA + LLIN use last night	Estimate	0.164	-0.011	0.153	-0.075
	OR (95%CI)	1.18 (0.92 - 1.50)	0.99 (0.97 - 1.01)		
	[b] χ^2 *(p)*	6.46 (0.17)	8.10 (0.09)		
4) EA + type of prenatal care provider	Estimate	0.139	-0.023	0.117	-0.200
	OR (95%CI)	1.15 (0.86 - 1.51)	0.98 (0.95 - 1.00)		
	[b] χ^2 *(p)*	4.44 (0.35)	8.99 (0.06)		
5) EA + type of housing + LLIN use + type of prenatal care provider	Estimate	0.171	-0.024	0.147	-0.163
	OR (95%CI)	1.19 (0.89 - 1.57)	0.98 (0.95 - 1.01)		
	[b] χ^2 *(p)*	4.78 (0.31)	4.13 (0.09)		

Effect decomposition on the scale of the linear predictor with standard errors based on the non-parametric bootstrap conditional on: V012 with x* = 1, x = 2; OR = odds ratios, 95%CI = 95 % Confidence Interval

a) **NDE = Natural Direct Effect; NIE = Natural Indirect Effect through mediator(s); TE = Total Effect, PM = proportion mediated, all models adjusted for covariate 'mother's age in years'**

b) **ANOVA: Wald's Chi square test; df=4 for differences of NDE odds and NIE odds between HWI-quintiles**

Looking at the indirect effect of the neModel1, it can be said, that the odds of children having a fever would be lowered by 2 % (Natural Indirect Effect, NIE= - 0.017; OR=0.98; 95%CI=0.96-1.00) given a low SEP, if the educational attainment of mothers would be changed to the level of EA seen in the SEP of one unit higher. Regarding the distribution of educational attainment levels among different HWI quintiles, this means having to change the EA to a higher level. The difference between odds of the indirect effect is estimated at $\chi^2(4) = 8.84$ ($p = 0.07$) between the five HWI categories The effect decomposition suggests a natural direct effect estimate (NDE, or risk difference) of 0.144 (OR=1.16; 95%CI=0.90-1.48) of SEP on fever via educational attainment. The potential protection through educational attainment is explaining 13.4 % of the total effect mediated (TE = 0.127; OR=1.14).

The results of neMod2 suggest, that the NDE of SEP on fever incidence shows a risk difference of 0.151 (OR=1.16*;* 95%CI=0.91-1.48), when looking at the mediation of EA and housing type combined. The analysis suggests, that living in modern houses, while having a higher educational level and a higher socio-economic position is associated with a lowered risk of fever (OR= 0.98, 95%CI = 0.96 - 0.998). 18.1 % of this total effect (TE = 0.127; OR=1.14) is explained through changes in educational attainment and housing type, with education being the main factor for the risk difference (13 %). The explained indirect effect is not very large, but there is still a risk difference between the levels of wealth with a Wald's $\chi^2(4) = 12.12$ ($p = 0.02$*).

Children of low SEPs have 1 % lowered odds (NIE = -0.011; OR = 0.99; 95%CI = 0.97 – 1.01) of developing a fever, through the indirect effect of the educational attainment of the caretaker would increase to that seen in caretaker of children of higher SEP, and if also changing the use of LLIN from not using LLIN's to more children sleeping under an LLIN as given in higher SEPs (neMod3). It is further estimated that SEP has an NDE of 0.164 (OR = 1.18; 95%CI = 0.92 – 1.5) on fever when the mediators are added to the model. Between the HWI levels measured in the ANOVA, the difference of NIE odds is estimated at $\chi^2(4)$=8.10, ($p = 0.09$). The TE is estimated at 0.153 (OR=1.17) and 7.5% of the total effect is mediated through EA and bed net use combined.

The result of neModel4 indicates that the odds of children having a fever would be also lowered by 2 % (NIE = -0.023; OR=0.98; 95%CI=0.95-1.00) given a low SEP, if the educational attainment of mothers and the type of prenatal care provider would be changed to the level of EA and provider seen in the SEP of one unit higher. The ANOVA suggests no differences of NIE odds between HWI categories ($\chi^2 = 8.99$ ($p = 0.06$)). The mediation through EA and type of prenatal care provider has an NDE estimate of 0.139 (OR=1.15; 95%CI=0.86-1.51). The protection through educational attainment and provider is explaining 20.00 % of the total effect (TE = 0.117; OR=1.13).

In the final neMod5, all four mediators were added to the calculation of a multiple mediation. The result of neModel5 indicates that the odds of children having a fever is lowered by 2 % (NIE = -0.024; OR=0.98; 95%CI=0.95-1.01) given a low SEP, if the educational attainment of mothers, the type of housing, the use of LLINs and the type of prenatal care provider would be changed to the level of the respective mediators as seen in the SEP of one unit higher. Further no difference of odds of NIE between the different HWI quintiles ($\chi^2 = 8.13$ ($p = 0.09$) could be shown. The NDE is estimated at 0.171 (OR=1.19; 95%CI=0.89-1.57). The protection through all mediators combined is explaining 16.3 % of the total effect (TE = 0.147; OR=1.17).

Further, a difference of odds of the covariate age of mothers could be shown across the different HWI categories in neMod1 to neMod3.

To summarise, the effects indirectly shown through the educational attainment, with and without the type of housing material or the type of prenatal care provider, seem to protect against a high risk of malaria fever events in children. When improving the SEP from poorer to wealthier, educational attainment, housing and prenatal care providers are mediating the total effect of the SEP towards fever events by a range from 13 to 20 %. No clearly protective indirect association could be shown for the relation of LLIN between the SEP and fever events.

6 Discussion

6.1 Summary of main findings

This study set out to investigate the pathways through which socio-economic position is associated with malaria fever events in children under the age of 5 in Ghana. A conceptual framework for mediation analysis, which is reported in chapter 3, was developed based primarily on findings from Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., which were identified through a screening of relevant literature (chapter 2.5). The study was guided by three objectives. The first objective, which pertained to the description of the socio-economic characteristics of the study population was addressed by doing a descriptive analysis of Ghana DHS data and the findings of which are presented in chapter 5, section 5.1. Secondly, a Ghana-specific HWI was derived using PCA, which is described in chapter 5, Section 5.2. For the third objective of exploring the potential mediators of the effect of socio-economic position on reported fever events in children under the age five by means of a pathway/mediation analysis, which is reported in chapter 5, section 5.3. In the subsequent sections of this chapter, the findings of this study are discussed and possible implications drawn for future malaria control strategies and further research into the relationship between poverty and malaria.

6.2 Study population characteristics

From the descriptive analysis of households, it can be disclosed, that there are slightly more households located in rural areas, rather than urban areas, and the households in urban areas are on average smaller by one person than the average household in rural settings. The differences in household numbers can be explained by the sampling strategy, and are within normal ranges of differences (GSS and ICF, 2020).

The distribution of many assets shows large inequalities between urban and rural dwellings, suggesting the need for improvements of infrastructure and livelihood opportunities especially among rural areas. A detailed discussion of these assets is provided together with their weight calculated by the PCA within the next sub-chapter.

The incidence of fever in children under 5 years of age in the present dataset is nearly one third of the 929 children, of which 65 % fever are associated with malaria infection and 13 % not recalling the result, while the remaining having other infections. It can be therefore assumed, that malaria is the major cause of infection for the fevers in the remaining children as well, where no malaria blood test was conducted. This compares to a similar rate of infection of national surveillance data for children under the age of 5, where malaria incidence was higher in rural areas and lower in the capital region and urban settings (CCM Ghana, 2020b; WHO, 2020). The data verify that approximating for malaria through reported fever events in this study is a suitable instrument to account for the missing malaria testing information for the total study population.

6.3 Socio-economic position and household wealth index

The HWI in this study was constructed using principal component analysis by validated instructions of Rutstein (2020). Within publications explaining the wealth index composition, there is no comprehensive explanation on why some variables, like ownership of agricultural land and livestock, are specifically considered as explaining higher wealth. The choice of indicators was based on previous research by the DHS Program. The composition of indicators for assets ownership, livestock and agricultural land ownership, number of household member per sleeping room (overcrowding) and type of residency are reflecting long-term wealth more closely, because quantifying SEP only by ‘standard expenditure measures underestimate[s] the difference between rural and urban households’ welfare by not adequately adjusting real incomes for the implicit price differences for the services provided by infrastructure’ (Filmer and Pritchett, 2001, p. 120), implying the asset-based HWI as being a suitable tool to measure national wealth between different regions (Montgomery et al., 2000; Rutstein and Johnson, 2004; Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016). Nevertheless, it should be also taken into consideration, that some of the indicators of wealth can also be linked to a higher risk of infection themselves, such as owning livestock, which can serve as mosquito feeding sites and therefore interpreted with caution (Bulterys et al., 2009). The housing construction material were, unlike within the DHS-HWI, not included in the calculation of the HWI of this study, because housing construction is suspected to play an important role for the acquisition of

malaria parasites, which are discussed in chapter 6, section 6.4 (Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016). Therefore, it was necessary to leave this factor out of the calculation of the HWI to prevent bias or confounding to potentially evaluate its role as a mediating factor for the development of malaria. This therefore resulted in a pure economic index of wealth without impacts of education, knowledge or other contributors on income and expenditures (Rutstein and Johnson, 2004). The HWI was derived from a regression of a national HWI and the UWI/ RWI respectively to receive a composite HWI for whole Ghana and to account for differences in the factor loadings for urban and rural households.

Looking at the HWI of this study, it can be said, that it is equally distributed between households from urban and rural living areas but there are major differences in assets ownership between the rural and urban population. Assets that are commonly connected to richer households in SSA were also given higher weights within the PCA for the available dataset in Ghana, and thus it can be said, that the first PC predicts the SEP status and inequities in an effective and less biased way (Tusting et al. 2016b; Filmer und Pritchett 2001). Even though, the PC1 reflects only 7 % of the overall variability of the variables, this is still reflecting the most variation and therefore is suitable as the basis for the HWI's. Literature on a threshold of the proportion sufficient to explain wealth by PC1 is scarce, and one publication found by the literature search, reports that the variation of original data was between 12 % and 27 % (Vyas und Kumaranayake 2006). Generally, a low percentage can be explained by the number of variables or the complexity of correlations between indicating variables.

There are assets that are considered indicating higher household wealth, when owned by rural households, but indicating lower wealth when owned by urban households. Such indicators include ownership of agricultural land and livestock, as living in cities and having a lot of livestock is considered as being poorer. Agricultural land and livestock might reflect not only on private sources for sustenance, but also on occupation and economical chances to provide for the household members. Populations of rural areas are thus more likely to own agricultural land and livestock in a broader extent, as this is one of the major livelihood opportunities and a way of saving financial means by self-sustenance in rural areas (Rutstein, 2008). Having access to electricity, improved toilet facilities

and piped water is more prevalent in urban areas, and thus should be looked at with caution, as this might not be an indicator of wealth in itself, but more on restrained availability and access of infrastructure in rural areas in general, which might have an impact on health on their own.

Further, one might suppose that larger households have more income, because more persons can have an occupation and thus a higher SEP, which would mean, that the rural households, with higher average household sizes, have a higher wealth. But dividing this income on all household member, this does not automatically mean being wealthier. Therefore the position of wealth was calculated also by the number of household member per sleeping room calculated from the household size divided by the number of sleeping rooms in the dwelling, as richer households are more likely of having bigger houses with more sleeping rooms for their members, also to avoid overcrowding (Rutstein and Johnson, 2004).

In this study, most of the assets owned are associated with being a wealthier household in urban as well as rural settings, and only a few have slightly negative factor loadings, approximating zero. Having a cabinet/cupboard is – confirming previous literature – the main asset indicating wealth (Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016). Summarizing from this, the most relevant household characteristics for higher wealth (LPG as cooking fuel, electricity, drinking water from sachets, owning a refrigerator, television, computer, watch, bank account, and a cabinet/cupboard) at the household level in Ghana are assets and resources, which are usually associated as industrial products, which might be only available for sale and not of natural origin, or which cannot be produced by oneself and are therefore less common in poorer households, while natural resource assets are more common among poorer households. It can be said, that the more of these assets a household owns, the higher it is ranked on the HWI, which has proven to be an effective composition of the HWI, loosened from income or expenditure, as suggested within the literature, which is stating that access to household infrastructure (water source, electricity, fuels) should still be included within urban and rural population measurements, like it is done in this study (Filmer and Pritchett, 2001).

6.4 Mediation effects

When investigating the total effect and direct effects SEP has on fever incidence within the mediation analyses, no direct association was found. Since this study aims at looking merely at the indirect effects through the mediator and is of explorative nature, this lack of association can be neglected (Agler and Boeck, 2017; MacKinnon, 2008). Since the effect of mediation is described by the indirect effect, for many researcher this is the most important criterion to be able to speak of mediation - regardless of the other conditions (Rucker et al., 2011; Zhao et al., 2010). With effective mediators in the model, the total effect will be lower than the NDE and this explains, that there is partial mediation occurring. When the TE would even sink to zero, a full mediation would occur (Abah et al., 2017; MacKinnon, 2008).

Even though, no indirect association of educational attainment alone could be shown, the data still suggest at least no negative and a possible protective association, as with 13.4 % there is quite a large proportion that is mediated through differences of educational attainment, with the upper 95 % confidence interval limit equalling, but not exceeding one. With caution, this would confirm previous research that having a higher education is related to lower risk of malaria infection measured through fever, human biting rate, parasitaemia or fever (Degarege et al., 2019; Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016). Reason for that could be, that a higher education is linked with higher knowledge, attitudes and practices on protective gear against malaria infection (Hwang et al., 2010; Mbohou Nchetnkou et al., 2020; Njama et al., 2003; Tomass et al., 2016), e.g. as reported by Hwang et al. school attendance is expected to be a protective factor of women’s use of ITNs for their children (aOR = 4.4; 95% CI 1.6-12.1). The implications of education on knowledge, attitudes and perceptions are also justifying, why in this study, they were not evaluated as mediators, because they have already proven to have a positive effect on malaria and knowledge about the contribution to the total effect would not add to the information on structural interventions. The contribution of education on the total effect could further be explained by the fact, that higher educated persons and their children are maybe more likely to live in urban areas, where the risk of infection is less likely and access to health facilities is easier, compared to rural

areas (Beavogui et al., 2020). Further, higher educated people might seek health care for them and their children more frequently and in a more timely manner, where they are more exposed to educational campaigns and information on preventive antimalarial treatment (Beavogui et al., 2020). Additionally, the education reflects also directly on wealth, as it is not linked to occupation and can be applicable to every person irrespective of being employed or not (Krieger et al., 1997). This fact might lead to the conclusion, that the effect was not as high as expected, because the direct effect of SEP on the fever incidence was not showing an association in this study (Anabire et al., 2019; Degarege et al., 2019; Ma et al., 2017).

The strongest findings of this explorative analysis of mediators suggest, that the total effect the SEP has on fever incidence is partly explained by the indirect effect of housing construction, when looking also at the educational attainment as a pre-condition. The effect of education on its own is suggestive to be protective against malaria, when entering housing materials into the model. This result proposes that educational attainment and housing might share common pathways and that combined they are causing a stronger relationship between SEP and fever. And by this suggesting, that successful interventions should not only focus on established measures, such as vector control at the individual level, but also on socio-structural improvements, such as investments in the educational system and housing. The argument here is that higher educational attainment can enable individuals and families to improve their livelihood opportunities and SEP, which in turn increases the likelihood of being able to afford better housing and also equitable chances towards health care access for all population groups (Agler and Boeck, 2017; VanderWeele and Vansteelandt, 2014, p. 10). Indeed, this finding is congruent with findings from Rek et al., 2018; Snyman et al., 2015; Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016; Wanzirah et al., 2015 in Uganda. Also raising awareness and knowledge through community health work could be extended to the setting of schools starting already early in live. Therefore (community or) school health work in moderate and high transmission regions could be considered of being a more crucial part, than it is considered up to now. This study did not take into account the bi-directionality of associations, but good

health in general on the other hand can be considered essential for equitable educational chances, and leading back to lowered risk of malaria.

The main explanation for the importance of higher quality housing is the reduced risk of mosquitos entering the houses, when they are built with improved materials, like closed windows and cement walls, as for example open eaves or stick walls of traditional houses can be gateways for the entrance and resting spots of parasite carrying mosquitos (Dlamini et al., 2017; Tusting, Rek, Arinaitwe, Staedke, Kamya, Cano et al., 2016). Housing improvements with modern materials are therefore an integral part for vector control and should be taken more seriously into account for mitigating the risk of malaria infection. Spatial differences on where these houses stand might be an additional stimulus, with modern houses being more prevalent in urban areas, which again changes the position of wealth and the availability of water sources (Beavogui et al., 2020; Florey and Taylor, 2016). Another focus should be set on the question, whether modern houses are also more likely of having installed pipes for water, that are preventing household member and children from having to access other water sources outside of dwellings, that might be mosquito breeding sites, especially in rural areas. Clean piped water in the houses would not only avoid time spent at mosquito breeding sites, but would also reduce the risk of consuming water contaminated with other pathogens and infection risk during open defecation. Further this could reduce waste from water sachets, which are at the moment providing secure drinking-water, but are an additional environmental problem in Ghana, especially in urban settings (Guzmán and Stoler, 2018; Preko, 2020). Improvements of housing could be considererd not only on the micro-level, but also on the macro level. It can be hypothesised, that modern housing construction materials should be available more easily and prices adapted towards realistic abilities of individuals or households to pay for these. This should be supported by governments, as a reduction in malaria cases is also an incentive to save on higher costs for public health expenditures.

It is widely known, that LLINs are effective measures against malaria infection (WHO, 2020, 2021)). In this study, no association between LLINs usage and fever incidence could be shown in terms of the indirect effect between SEP and fever, suggesting, that LLIN usage alone is not enough to lower the burden of malaria, confirming previous research (Loha et al., 2019; Zgambo et al., 2017). The lacking

association should be looked at with caution, since 50 % of the children's caretaker reported, that all children slept under the bed net, and no association can be drawn on whether the child at question actually slept under an LLIN. This discrepancy of usage report can be due to reporting bias of social desirability, as many people know of the protective effect, but also due to the actual common usage of LLIN's, as this is already proven to be an effective prevention strategy. LLIN's are by nature now treated with insecticides, are often distributed in campaigns, and are easily available for all population groups. Nevertheless, poor households should not be overlooked in distribution campaigns. Further, a higher educational attainment, occupation, knowledge or ideation about malaria are also expected as being predictors of LLIN ownership (Abah et al., 2017; Babalola et al., 2016; Deressa, 2017; Zgambo et al., 2017). The LLIN use in this study is serving as a proxy for behavioural risk factors on malaria infection. Thus, the number of children using the LLIN in a household was considered in the present study, instead of whether a net was owned at all, since ownership itself is not protective against malaria, but using it, is. The awareness about the protective effects of LLINs was not evaluated in this study, because it is suspected, that many people would actually use bed nets, without having knowledge on why or how they are protecting against malaria, and it is of higher relevance, that caretaker use the LLINs for their children, irrespective of their intentions and knowledge. In combination with higher educational attainment, this is suggesting, that the education itself has a higher impact on malaria, as the relative contribution to the total effect was lowered by LLINs in the model. Many other factors predicting malaria fever events, such as the number of persons per sleeping room and per LLIN should therefore be taken into account.

As seen in model four, having made no antenatal care visits are compared to visiting skilled health professionals, like public provider, and to other health care provider, such as traditional practitioner, or birth attendants. This mediator is taken as a proxy for treatment-seeking behaviour, and prenatal care visits seem to better represent routine health care seeking, where malaria diagnostic is integrated in the routine care. It seems, that seeking health care during pregnancy, within the formal sector, when having a low SEP, has a positive effect on later fever risk of the children. Similar to the effect of education on its own, the indirect effect of the

choice of antenatal care provider in combination with the educational attainment from SEP on fever development is suggesting that the choice of prenatal care provider seems to be protective, and at least not a risk factor (Onwujekwe et al., 2011). It causes - though only a small- alteration in the total effect, but is adding to the proportion of the total effect that is mediated to a total of 20 %. Adjusting for further risk factors and confounder, this might affect the effect size to prove stronger associations. It should be highlighted, that in this study, almost all women sought prenatal care at least one time, due to that it is further needed to investigate the availability of care provider, the number of prenatal care visits. The WHO recommends at least four antenatal care visits and intermittent preventive treatment (WHO, 2016). Also, whether the health care seeking was initiated by the women herself and her intentions, which in combination can have another insight on effective ANC/PNC and awareness on prevention of infectious diseases might be adding to the explanation of the magnitude of association (Mbuagbaw et al., 2015). Reasons for more effective malaria prevention by visiting formal health care can be that in these facilities, more awareness and strategies to mitigate the malaria risks are communicated. This is indicative for public health interventions promoting antimalarial treatment and the risk for malaria can be tackled by educating also informal health care provider about the risks and prevention of malaria to educate all patients, irrespective of educational attainment or wealth (Njama et al., 2003). The best option to evaluate the pathway of treatment seeking between SEP and malaria infection would include an analysis of treatment seeking for all sorts of conditions in general, but DHS studies don’t provide longitudinal data, and only data on treatment seeking after fever in children occur (with 69 % of caretaker in the GMIS2019 seeking advice or treatment after a child having fever in the last two weeks (GSS and ICF, 2020). Since this study aimed at looking at behavioural factors that are influencing fever events, this chronological information could not be used, whereas the treatment seeking during pregnancy as a proxy can reflect on the routine care seeking, and projects indirectly on protection of the health of the unborn. Whether, SP/Fansidar as antimalarial treatment was taken and the amount of it, is also reflecting on general health care behaviour of women, but cannot be taken as a proxy for the health care seeking behaviour itself, but rather on adherence to IPT (Njama et al., 2003).

Having all mediator evaluated in a joint mediation analysis, the risk difference between the HWI does not seem to impact the fever of children. Adding up of the proportions mediated from the natural effect models 2-4 (accounting for all 4 mediator) the proportion mediated does not add up to 100 %. This is because the mediators are each contributing to the total effect in either positive or negative directions, which can lead to the total proportion mediated in the joint model of being lower, than in the models before (Vansteelandt and Daniel, 2017). This could indicate that the natural effect models are not accounting for all possible mediators in existence, and there are remaining unmeasured effects, that are influencing the pathways with a stronger association.

The effects of additional protective interventions within the houses and concerning the wealth were not evaluated within this analysis, such as the effect of indoor-residual sprayings and whether wealthier households in modern housings are more likely to have sprayed houses. Whether indoor-residual spraying is more effective in modern houses compared to traditional, how the type of treatment and the timeliness of treatment seeking or the nutritional status causally affect fever events would require further adjustments of the model and the comprehensive addition of confounder and moderating factors.

In summary, it can be said, that all mediators considered in the present study, nevertheless seem to impact the pathway between poverty and the risk of developing fever in the last two weeks in the same protective direction through their indirect effects, as they all contribute to the proportion mediated on the total effect. This indicates, that wealth is associated with fever events by affecting the education, housing condition, treatment-seeking and bed net use.

6.5 Limitations

Although the underlying concept of this study provided an in-depth insight into the relationships and pathways of several contributors towards malaria infections and a new perspective on the causal interpretation of relationships using mediation analysis, this study is not without limitations.

Regarding the literature background search, one should keep in mind, that this was not aimed to provide an exhaustive systematic review of current evidence by extracting data for a meta-analysis of results, but aimed at summarising current

knowledge on malaria risk factors on their own and in combination with education and poverty, that could be analysed from the data provided by the GMIS2019. More studies probably exist, that could not be considered by using the search string within the two databases Web of Science and Pubmed or because of different publication types (conference abstracts, posters, theses or reports) and the sole selection of publications in English. Since the topic of malaria risk factors from a socio-economic perspective is very broad and can be analysed from different angles, disciplines and directions, published literature is quite diverse. This highlights again the complexity of the concept and the difficulty in choosing the most relevant causes for malaria for this mediation analysis.

The data underlying this analysis were provided by the GMIS2019 conducted by the DHS Program, which provides a validated tool for investigating wealth and malaria in various ways, but are collected cross-sectionally. This has the advantage of covering a broad range of data to collect, but are not as informative as a cohort study, where one can see developments within individuals to draw causal inferences. Nevertheless, the surveys are repeated frequently within the same study population and are longitudinal in nature, which can inform on the national development to evaluate and monitor intervention strategies. This study could therefore be repeated within the past or next GMIS to draw conclusions on the development and the effectiveness of possible interventions that are suggested through this and other DHS studies.

The advantages of using DHS surveys are that they provide a wide range of information on a large population and randomized sampling strategies, which means that they are less prone to selection bias of households and individuals, improving the external population validity. But the data are being collected through self-reports of the subjects, causing potential bias of social desirability or recall bias, which can lead to limited generalisability. One example of reporting bias could occur e.g. among individuals of different wealth positions. If persons from wealthier socio-economic starting points were reporting diseases of children more often than persons from poorer SEP, drawing a line between SEP and malaria fever events seems difficult, due to under- and over-reporting (Somi et al., 2007, p. 1025). Nevertheless, concerning social desirability the questions asked were phrased in a way to be the least directive as possible. The DHS is aiming for

constant improvements for high quality and best comparability of data within and between countries, ensuring high validity.

The measurement of malaria prevalence (particularly by parasitaemia) is not a standard part of the MIS and malaria confirmation is done only in a sub-group of children. Therefore, this study drew on reported fever events as a proxy for malaria prevalence to remain a larger sample size, which is favourable for the robustness of mediation analysis. The interpretation of results can therefore only draw on conclusions for fever suggestively caused by malaria, and is limited in predicting more precise pathways of health inequities.

PCA is nowadays quite common in social and epidemiological sciences. But it is still widely discussed and there is no consensus, whether it should be used to measure SEP in epidemiological studies in LMIC, as it is not a holistic approach of depicting wealth and there is still room of discussion on which indicator variables should be included in a HWI in general. In this study, the choice for assets included needs to be looked at critically, as one needs to assess all factors representing wealth, but a trade-off between health risk factors and SEP can still be present (McKenzie DJ, 2003; Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016; Vyas and Kumaranayake, 2006) Yet, up to now, it is considered to be a pragmatic way to construct a HWI representing SEP based on assets owned, as the data collection is easy, has little measurement errors and is comparable across regions or countries. The assets chosen in this study represent long-term SEP similar to consumption expenditure, as ownership is resilient to short-term economic changes (Filmer and Pritchett, 2001; Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016). It has proven to be an effective tool to measure wealth without data on expenditure and income in many studies, by the DHS Program but also by Anabire et al., 2019; Ayalneh et al., 2017; Homenauth et al., 2017; Ricotta et al., 2019 to name a few.

In the HWI produced in this study, some indicator variables showed no variation in the answers, and therefore were left out of the PCA. But there are still indicator variables included, that were only used by a minority of respondents, and therefore were assigned factor loadings around zero. This could explain the low percentage of overall variability, but should not be left out of the calculation (Vyas and Kumaranayake, 2006, p. 463). Further, using binary variables in PCA, like Filmer

and Pritchett (2001) did, should be used with caution and accounted for accordingly, because PCA is originally developed for multivariate data (Kolenikov and Angeles, 2009). By using instructions from DHS for constructing a new HWI, this study is accounting for this through adaptive calculations and usage of correlation matrices for standardization of binary variables (Rutstein, 2020). Other weighting strategies to break down variations of indicator variables, such as factor analysis or multiple correspondence analyses could be considered as well. Nevertheless, weighting is said to be of less importance, in contrast to the correct variable coding for measurements of wealth in agreement with consumption (Tusting, Rek, Arinaitwe, Staedke, Kamya, Bottomley et al., 2016).

Concerning the interpretation and quality of the HWI, the differentiation into quintiles was chosen to ensure higher robustness of the model through lower loss of information through the data. The utilisation of a dichotomized variable, as seen in Tusting et. al. (2016) would have resulted in clearer differences or larger effect sizes.

A limiting feature of this mediation analysis was the decision on variables to choose as mediators. As mentioned earlier, the conceptual framework provides an overview of the most striking factors that are expected to form a great part of the total association between socio-economic factors and malaria infection. But due to the data provided, there are multiple factors that could not be considered within this study and accounted for only by proxies, leaving a non-exhaustive representation of mediation pathways and determinants of wealth. Similar to the limited options for choosing the mediator, it is by nature not possible to account for all confounder and other interacting factors within the model. The complexity of the conceptual framework is stressing the need to adjust for different confounder (i.e. exposure-mediator; mediator-outcome; and mediator-mediator) to minimize the bias of the estimation of association (Agler and Boeck, 2017; Castro and Fisher, 2012). The sequential imputation for analysing multiple mediators was conducted with two mediators in a model, with a final mediation model including all four mediators, to account for assumptions of mediator-mediator confounding. Using a counterfactual framework by imputation of an outcome dataset is therefore better suitable for sequential and multiple mediation approaches than single mediation analysis (Loeys et al., 2013; Steen et al., 2017). Even though the multiple

mediation model accounts for M-M-confounding by an empirical approach, a successive sensitivity analysis could shed more light on unmeasured confounding and interaction between exposure and mediator variables to combat this bias (Liu et al., 2016; Vanderweele, 2010). Additionally the mediator of interest could be investigated as a moderating factor or within hierarchical effects (Agler and Boeck, 2017).

6.6 Future research

The relative contribution of each investigated mediator differs in this study, which indicates, that there are still remaining unmeasured factors that should be researched in the future. In this thesis, the question remains, why informal health care providers seem to pose a risk for malaria infection. Besides trying to change the behaviour and beliefs of informal health care patients towards seeking formal health care, it could be a viable way to improve the informal health care provision by educating these providers on recommendations for a higher quality of care, because people might not change their scepticism towards formal health care.

Further research could additionally look at the conceptual framework from interdisciplinary perspectives, bearing the bi-directionality of factors in mind and explore also the potential relationship between education as the exposure and SEP as one mediator towards malaria, measured through proxies, but even so by confirmed diagnosis.

This study was conducted on behalf of the Bernhard-Nocht-Institute for Tropical Medicine (BNITM) in Hamburg, Germany and the results of this explorative thesis shall inform on further mediation analyses to come within the Malaria-Birth-Cohort-Study (MBC) of the BNITM concerning the elaboration of mediation shown in this thesis and additional mediators, such as household food security and composition, child (mal-)nutrition and malaria. This DHS based HWI is representative for Ghana and can be used to compare the data collected by the BNITM within study populations in the Ashanti region of Ghana, to evaluate the relevance and validity of the MBC-Study.

7 Conclusion

This thesis initially introduced malaria and its burden among vulnerable populations in Ghana, followed by an overview over the country's socio-economic situation at the national, household and individual levels, and a review of possible factors and mechanisms influencing the linkage between poverty and malaria. On the basis of a comprehensive (albeit non-exhaustive) literature review, a conceptual framework was developed, which informed the subsequent mediation analysis of behavioural and socio-economic risk factors and pathways associated with malaria in children in Ghana using household and individual level data from the Ghana Malaria Indicator Survey from 2019.

Key findings include that the type of housing material and the level of education of mothers explain the relationship between SEP and malaria infection risk, approximated by fever events, to a large amount (13.4 %) and show that they are indirect pathways and potential causal factors. The respective partial contributions of education, housing types and choice of prenatal care provider indicate that there are still unmeasured factors that are contributing to the remaining proportion of the association. When the children are living in modern houses, having higher educated mothers who are seeking treatment within the formal health care sector, they seem to be better protected against malaria, also when having a poor socio-economic position. The behavioural preventive factor LLIN use, does not seem to be a strongly connected pathway between wealth or poverty and risk of malaria, at least in this study, but has proven to be effective previously.

The findings suggest that current biomedical and behavioural malaria control efforts could be strengthened by investments at the structural levels. Alongside efforts of increased (female) education, targeted improvements in housing and integration of informal health care could be needed. Future research should focus on further examining the complex pathways between poverty and malaria, which can inform more holistic, multisectoral strategies for sustainable malaria control.

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Annex

Table of Annex - Content

Index of Annex Tables

A Household-level: ‘Household Questionnaire’ GMIS 2019

FORMATTING DATE: 16 Sep 2019
ENGLISH LANGUAGE: 29 Sep. 2016

2019 GHANA MALARIA INDICATOR SURVEY
HOUSEHOLD QUESTIONNAIRE

MINISTRY OF HEALTH — GHANA STATISTICAL SERVICE

IDENTIFICATION

LOCALITY NAME _____

NAME OF HOUSEHOLD HEAD _____

REGION ..... | | |

DISTRICT ..... | | |

CLUSTER NUMBER ..... | | | | |

HOUSEHOLD NUMBER ..... | | | | |

INTERVIEWER VISITS

	1	2	3	FINAL VISIT
DATE				DAY / MONTH / YEAR (2019)
INTERVIEWER'S NAME				INT. NO.
RESULT*				RESULT*
NEXT VISIT: DATE				TOTAL NUMBER OF VISITS
TIME				

*RESULT CODES:

1 COMPLETED
2 NO HOUSEHOLD MEMBER AT HOME OR NO COMPETENT RESPONDENT AT HOME AT TIME OF VISIT
3 ENTIRE HOUSEHOLD ABSENT FOR EXTENDED PERIOD OF TIME
4 POSTPONED
5 REFUSED
6 DWELLING VACANT OR ADDRESS NOT A DWELLING
7 DWELLING DESTROYED
8 DWELLING NOT FOUND
9 OTHER _____ (SPECIFY)

TOTAL PERSONS IN HOUSEHOLD

TOTAL ELIGIBLE WOMEN

LINE NO. OF RESPONDENT TO HOUSEHOLD QUESTIONNAIRE

LANGUAGE OF QUESTIONNAIRE** 01 | LANGUAGE OF INTERVIEW** | NATIVE LANGUAGE OF RESPONDENT** | TRANSLATOR USED (YES = 1, NO = 2)

LANGUAGE OF QUESTIONNAIRE** ENGLISH

**LANGUAGE CODES:
01 ENGLISH 03 GA 05 DAGBANI
02 AKAN 04 EWE 06 OTHER _____ (SPECIFY)

SUPERVISOR

_____ NAME | | | | | NUMBER

INTRODUCTION AND CONSENT

Hello. My name is _____. I am working with Ghana Statistical Service and the Ministry of Health. We are conducting a survey about malaria all over Ghana. The information we collect will help the government to plan health services. Your household was selected for the survey. I would like to ask you some questions about your household. The questions usually take about 15 to 20 minutes. All of the answers you give will be confidential and will not be shared with anyone other than members of our survey team. You don't have to be in the survey, but we hope you will agree to answer the questions since your views are important. If I ask you any question you don't want to answer, just let me know and I will go on to the next question or you can stop the interview at any time. In case you need more information about the survey, you may contact the person listed on this card.

GIVE CARD WITH CONTACT INFORMATION

Do you have any questions?
May I begin the interview now?

SIGNATURE OF INTERVIEWER _____ DATE _____

RESPONDENT AGREES TO BE INTERVIEWED . . 1 ↓

RESPONDENT DOES NOT AGREE TO BE INTERVIEWED . . 2 → END

100	RECORD THE TIME.	HOURS . . . . . MINUTES . . . . .

HOUSEHOLD SCHEDULE

LINE NO.	USUAL RESIDENTS AND VISITORS	RELATIONSHIP TO HEAD OF HOUSEHOLD	SEX	RESIDENCE		AGE	DATE OF BIRTH	ELIGIBILITY	
1	2	3	4	5	6	7	7A	8	9
	Please give me the names of the persons who usually live in your household and guests of the household who stayed here last night, starting with the head of the household. AFTER LISTING THE NAMES AND RECORDING THE RELATIONSHIP AND SEX FOR EACH PERSON, ASK QUESTIONS 2A-2C TO BE SURE THAT THE LISTING IS COMPLETE. THEN ASK APPROPRIATE QUESTIONS IN COLUMNS 5-9 FOR EACH PERSON.	What is the relationship of (NAME) to the head of the household? SEE CODES BELOW.	Is (NAME) male or female?	Does (NAME) usually live here?	Did (NAME) stay here last night?	How old is (NAME)? IF 95 OR MORE, RECORD '95'.	What is (NAME)'s date of birth? On what day, month, and year was (NAME) born? IF DON'T KNOW DAY, RECORD '98'. IF DON'T KNOW MONTH, RECORD '98'. IF DON'T KNOW YEAR, RECORD '9998.'	CIRCLE LINE NUMBER OF ALL WOMEN AGE 15-49	CIRCLE LINE NUMBER OF ALL CHILDREN AGE 0-5
01			M F 1 2	Y N 1 2	Y N 1 2	IN YEARS	DAY MONTH YEAR	01	01
02			1 2	1 2	1 2			02	02
03			1 2	1 2	1 2			03	03
04			1 2	1 2	1 2			04	04
05			1 2	1 2	1 2			05	05
06			1 2	1 2	1 2			06	06
07			1 2	1 2	1 2			07	07
08			1 2	1 2	1 2			08	08
09			1 2	1 2	1 2			09	09
10			1 2	1 2	1 2			10	10

2A)	Just to make sure that I have a complete listing: are there any other people such as small children or infants that we have not listed?	YES ☐ → ADD TO TABLE	NO ☐
2B)	Are there any other people who may not be members of your family, such as domestic servants, lodgers, or friends who usually live here?	YES ☐ → ADD TO TABLE	NO ☐
2C)	Are there any guests or temporary visitors staying here, or anyone else who stayed here last night, who have not been listed?	YES ☐ → ADD TO TABLE	NO ☐

CODES FOR Q. 3: RELATIONSHIP TO HEAD OF HOUSEHOLD

01 = HEAD
02 = WIFE OR HUSBAND
03 = SON OR DAUGHTER
04 = SON-IN-LAW OR DAUGHTER-IN-LAW
05 = GRANDCHILD
06 = PARENT
07 = PARENT-IN-LAW
08 = BROTHER OR SISTER
09 = OTHER RELATIVE
10 = ADOPTED/FOSTER/ STEPCHILD
11 = NOT RELATED
98 = DON'T KNOW

HOUSEHOLD SCHEDULE

LINE NO.	USUAL RESIDENTS AND VISITORS	RELATIONSHIP TO HEAD OF HOUSEHOLD	SEX	RESIDENCE		AGE	DATE OF BIRTH	ELIGIBILITY	
1	2	3	4	5	6	7	7A	8	9
	Please give me the names of the persons who usually live in your household and guests of the household who stayed here last night, starting with the head of the household. AFTER LISTING THE NAMES AND RECORDING THE RELATIONSHIP AND SEX FOR EACH PERSON, ASK QUESTIONS 2A-2C TO BE SURE THAT THE LISTING IS COMPLETE. THEN ASK APPROPRIATE QUESTIONS IN COLUMNS 5-9 FOR EACH PERSON.	What is the relationship of (NAME) to the head of the household? SEE CODES BELOW.	Is (NAME) male or female?	Does (NAME) usually live here?	Did (NAME) stay here last night?	How old is (NAME)? IF 95 OR MORE, RECORD '95'.	What is (NAME)'s date of birth? On what day, month, and year was (NAME) born? IF DON'T KNOW DAY, RECORD '98'. IF DON'T KNOW MONTH, RECORD '98'. IF DON'T KNOW YEAR, RECORD '9998.'	CIRCLE LINE NUMBER OF ALL WOMEN AGE 15-49	CIRCLE LINE NUMBER OF ALL CHILDREN AGE 0-5
11			M F 1 2	Y N 1 2	Y N 1 2	IN YEARS	DAY MONTH YEAR	11	11
12			1 2	1 2	1 2			12	12
13			1 2	1 2	1 2			13	13
14			1 2	1 2	1 2			14	14
15			1 2	1 2	1 2			15	15
16			1 2	1 2	1 2			16	16
17			1 2	1 2	1 2			17	17
18			1 2	1 2	1 2			18	18
19			1 2	1 2	1 2			19	19
20			1 2	1 2	1 2			20	20

TICK HERE IF CONTINUATION SHEET USED ☐

CODES FOR Q. 3: RELATIONSHIP TO HEAD OF HOUSEHOLD

01 = HEAD
02 = WIFE OR HUSBAND
03 = SON OR DAUGHTER
04 = SON-IN-LAW OR DAUGHTER-IN-LAW
05 = GRANDCHILD
06 = PARENT
07 = PARENT-IN-LAW
08 = BROTHER OR SISTER
09 = OTHER RELATIVE
10 = ADOPTED/FOSTER/STEPCHILD
11 = NOT RELATED
98 = DON'T KNOW

HOUSEHOLD CHARACTERISTICS

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
101	What is the main source of drinking water for members of your household?	**PIPED WATER** PIPED INTO DWELLING ..... 11 PIPED TO YARD/PLOT ..... 12 PIPED TO NEIGHBOR ..... 13 PUBLIC TAP/STANDPIPE ..... 14 TUBE WELL OR BOREHOLE ..... 21 **DUG WELL** PROTECTED WELL ..... 31 UNPROTECTED WELL ..... 32 **WATER FROM SPRING** PROTECTED SPRING ..... 41 UNPROTECTED SPRING ..... 42 RAINWATER ..... 51 TANKER TRUCK ..... 61 CART WITH SMALL TANK ..... 71 SURFACE WATER (RIVER/DAM/ LAKE/POND/STREAM/CANAL/ IRRIGATION CHANNEL) ..... 81 BOTTLED WATER ..... 91 SACHET WATER ..... 92 OTHER _____ 96 (SPECIFY)	→ 105 → 103 → 103
102	What is the main source of water used by your household for other purposes such as cooking and handwashing?	**PIPED WATER** PIPED INTO DWELLING ..... 11 PIPED TO YARD/PLOT ..... 12 PIPED TO NEIGHBOR ..... 13 PUBLIC TAP/STANDPIPE ..... 14 TUBE WELL OR BOREHOLE ..... 21 **DUG WELL** PROTECTED WELL ..... 31 UNPROTECTED WELL ..... 32 **WATER FROM SPRING** PROTECTED SPRING ..... 41 UNPROTECTED SPRING ..... 42 RAINWATER ..... 51 TANKER TRUCK ..... 61 CART WITH SMALL TANK ..... 71 SURFACE WATER (RIVER/DAM/ LAKE/POND/STREAM/CANAL/ IRRIGATION CHANNEL) ..... 81 OTHER _____ 96 (SPECIFY)	→ 105
103	Where is that water source located?	IN OWN DWELLING ..... 1 IN OWN YARD/PLOT ..... 2 ELSEWHERE 3	→ 105
104	How long does it take to go there, get water, and come back?	MINUTES ..... ☐☐☐ DON'T KNOW 998	
105	What kind of toilet facility do members of your household usually use? IF NOT POSSIBLE TO DETERMINE, ASK PERMISSION TO OBSERVE THE FACILITY.	**FLUSH OR POUR FLUSH TOILET** FLUSH TO PIPED SEWER SYSTEM ..... 11 FLUSH TO SEPTIC TANK ..... 12 FLUSH TO PIT LATRINE ..... 13 FLUSH TO SOMEWHERE ELSE ..... 14 FLUSH, DON'T KNOW WHERE ..... 15 FLUSH, BIO-DIGESTER (BIOFIL) ..... 16 **PIT LATRINE** VENTILATED IMPROVED PIT LATRINE ..... 21 PIT LATRINE WITH SLAB ..... 22 PIT LATRINE WITHOUT SLAB/OPEN PIT .. 23 COMPOSTING TOILET ..... 31 BUCKET TOILET ..... 41 HANGING TOILET/HANGING LATRINE ..... 51 NO FACILITY/BUSH/FIELD ..... 61 OTHER _____ 96 (SPECIFY)	→ 108

HOUSEHOLD CHARACTERISTICS

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
106	Do you share this toilet facility with other households?	YES ..... 1 NO 2	→ 108
107	Including your own household, how many households use this toilet facility?	NO. OF HOUSEHOLDS IF LESS THAN 10 ..... 0 ☐ 10 OR MORE HOUSEHOLDS ..... 95 DON'T KNOW 98	
108	What type of fuel does your household mainly use for cooking?	ELECTRICITY ..... 01 LPG ..... 02 NATURAL GAS ..... 03 BIOGAS ..... 04 KEROSENE ..... 05 COOKING GEL ..... 06 CHARCOAL ..... 07 WOOD ..... 08 STRAW/SHRUBS/GRASS ..... 09 AGRICULTURAL CROP RESIDUE ..... 10 ANIMAL DUNG ..... 11 NO FOOD COOKED IN HOUSEHOLD ..... 95 OTHER _____ 96 (SPECIFY)	
109	How many rooms in this household are used for sleeping?	ROOMS ..... ☐☐	
110	Does this household own any livestock, herds, other farm animals, or poultry?	YES ..... 1 NO 2	→ 112
111	How many of the following animals does this household own? IF NONE, RECORD '00'. IF 95 OR MORE, RECORD '95'. IF UNKNOWN, RECORD '98'. a) Milk cows or bulls? b) Other cattle? c) Horses, donkeys, or mules? d) Goats? e) Sheep? f) Chickens or other poultry? g) Pigs? h) Rabbits? i) Grasscutter?	a) COWS/BULLS ..... ☐☐ b) OTHER CATTLE ..... ☐☐ c) HORSES/DONKEYS/MULES ..... ☐☐ d) GOATS ..... ☐☐ e) SHEEP ..... ☐☐ f) CHICKENS/POULTRY ..... ☐☐ g) PIGS ..... ☐☐ h) RABBITS ..... ☐☐ i) GRASSCUTTER ..... ☐☐	
112	Does any member of your household own any agricultural land?	YES ..... 1 NO 2	→ 114
113	How many hectares or acres or plots of agricultural land do members of this household own? IF 95 OR MORE HECTARES, RECORD '950' IF 95 OR MORE ACRES, RECORD IN HECTARES IF 95 OR MORE PLOTS, RECORD IN ACRES	HECTARES ..... 1 ☐☐.☐ ACRES ..... 2 ☐☐.☐ PLOTS ..... 3 ☐☐.☐ 95 OR MORE HECTARES ..... 950 DON'T KNOW 998	

HOUSEHOLD CHARACTERISTICS

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
114	Does your household have:	YES NO	
	a) Electricity?	a) ELECTRICITY 1 2	
	b) A radio?	b) RADIO 1 2	
	c) A television?	c) TELEVISION 1 2	
	d) A non-mobile telephone?	d) NON-MOBILE TELEPHONE . . 1 2	
	e) A computer/Tablet computer?	e) COMPUTER 1 2	
	f) A refrigerator?	f) REFRIGERATOR 1 2	
	g) A freezer?	g) FREEZER 1 2	
	h) An electric generator/Invertor?	h) GENERATOR 1 2	
	i) A washing machine?	i) WASHING MACHINE 1 2	
	j) A photo camera? (NOT ON PHONE)	j) CAMERA 1 2	
	k) A video deck/DVD/VCD?	k) VIDEO/DVD/VCD 1 2	
	l) A sewing machine?	l) SEWING MACHINE 1 2	
	m) A bed?	m) BED 1 2	
	n) A table?	n) TABLE 1 2	
	o) A chair?	o) CHAIR 1 2	
	p) A cabinet/cupboard?	p) CABINET 1 2	
115	Does any member of this household own:	YES NO	
	a) A wrist watch?	a) WRIST WATCH 1 2	
	b) A mobile phone?	b) MOBILE PHONE 1 2	
	c) A bicycle?	c) BICYCLE 1 2	
	d) A motorcycle or motor scooter?	d) MOTORCYCLE/SCOOTER 1 2	
	e) An animal-drawn cart?	e) ANIMAL-DRAWN CART 1 2	
	f) A car or truck?	f) CAR/TRUCK 1 2	
	g) A boat with a motor?	g) BOAT WITH MOTOR 1 2	
	h) A boat without a motor?	h) BOAT WITHOUT MOTOR 1 2	
116	Does any member of this household have a bank account?	YES . . . . . 1 NO 2	
117	At any time in the past 12 months, has anyone come into your dwelling to spray the interior walls against mosquitoes?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	→ 119
118	Who sprayed the dwelling?	GOVERNMENT WORKER/PROGRAM . . . . . A PRIVATE COMPANY . . . . . B NONGOVERNMENTAL ORGANIZATION (NGO) . . C OTHER _____ (SPECIFY) X DON'T KNOW . . . . . Z	
119	Does your household have any mosquito nets?	YES . . . . . 1 NO 2	→ 131
120	How many mosquito nets does your household have? IF 7 OR MORE NETS, RECORD '7'.	NUMBER OF NETS . . . . . ☐	

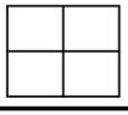
MOSQUITO NETS

		NET #1	NET #2	NET #3
121	ASK THE RESPONDENT TO SHOW YOU ALL THE NETS IN THE HOUSEHOLD. IF MORE THAN 3 NETS, USE ADDITIONAL QUESTIONNAIRE(S).	OBSERVED HANGING . . 1 OBSERVED NOT HANGING/ PACKAGED . . . . . 2 NOT OBSERVED 3	OBSERVED HANGING . . 1 OBSERVED NOT HANGING/ PACKAGED . . . . . 2 NOT OBSERVED 3	OBSERVED HANGING . . 1 OBSERVED NOT HANGING/ PACKAGED . . . . . 2 NOT OBSERVED 3
122	How many months ago did your household get the mosquito net? IF LESS THAN ONE MONTH AGO, RECORD '00'.	MONTHS AGO . . . . . [ ][ ] MORE THAN 36 MONTHS AGO . . . . . 95 NOT SURE 98	MONTHS AGO . . . . . [ ][ ] MORE THAN 36 MONTHS AGO . . . . . 95 NOT SURE 98	MONTHS AGO . . . . . [ ][ ] MORE THAN 36 MONTHS AGO . . . . . 95 NOT SURE 98
123	OBSERVE OR ASK BRAND/TYPE OF MOSQUITO NET. IF BRAND IS UNKNOWN AND YOU CANNOT OBSERVE THE NET, SHOW PICTURES OF TYPICAL NET TYPES/BRANDS TO RESPONDENT.	**LONG-LASTING INSECTICIDE-TREATED NET (LLIN)** OLYSET . . . . 11 PERMANET . . . . 12 INTERCEPTOR . . . . . 13 ROYAL SENTRY . . 14 DURANET . . . . 15 LIFE NET . . . . 16 DAWA PLUS . . . . 17 MAGNET . . . . 18 YORKOOL . . . . 19 OTHER/DON'T KNOW BRAND . . . . 20 OTHER TYPE . . . . 96 DON'T KNOW TYPE . . 98	**LONG-LASTING INSECTICIDE-TREATED NET (LLIN)** OLYSET . . . . 11 PERMANET . . . . 12 INTERCEPTOR . . . . . 13 ROYAL SENTRY . . 14 DURANET . . . . 15 LIFE NET . . . . 16 DAWA PLUS . . . . 17 MAGNET . . . . 18 YORKOOL . . . . 19 OTHER/DON'T KNOW BRAND . . . . 20 OTHER TYPE . . . . 96 DON'T KNOW TYPE . . 98	**LONG-LASTING INSECTICIDE-TREATED NET (LLIN)** OLYSET . . . . 11 PERMANET . . . . 12 INTERCEPTOR . . . . . 13 ROYAL SENTRY . . 14 DURANET . . . . 15 LIFE NET . . . . 16 DAWA PLUS . . . . 17 MAGNET . . . . 18 YORKOOL . . . . 19 OTHER/DON'T KNOW BRAND . . . . 20 OTHER TYPE . . . . 96 DON'T KNOW TYPE . . 98
126	Did you get the net through the 2018 mass distribution campaign, during an antenatal care visit, during an immunization visit, or during a school distribution?	YES, 2018 MASS DIST. CAMPAIGN . . . . 1 YES, ANC . . . . 2 YES, IMMUNIZATION VISIT . . . . 3 YES, SCHOOL DIST. . . 4 (SKIP TO 128) NO 5	YES, 2018 MASS DIST. CAMPAIGN . . . . 1 YES, ANC . . . . 2 YES, IMMUNIZATION VISIT . . . . 3 YES, SCHOOL DIST. . . 4 (SKIP TO 128) NO 5	YES, 2018 MASS DIST. CAMPAIGN . . . . 1 YES, ANC . . . . 2 YES, IMMUNIZATION VISIT . . . . 3 YES, SCHOOL DIST. . . 4 (SKIP TO 128) NO 5
127	Where did you get the net?	PRIVATE HEALTH FACILITY . . . . 01 PHARMACY/ CHEMIST/ DRUG STORE . . . . . 02 SHOP/MARKET . . . . . 03 RELIGIOUS INSTITUTION . . . . . 04 NGO .... 05 COMMUNITY BASED . . AGENTS (CBAs) . . . . . 06 PETROL STATION/ MOBILE MART . . . . . 07 PRIOR MASS DIST. CAMPAIGN 08 OTHER . . . . 96 DON'T KNOW 98	PRIVATE HEALTH FACILITY . . . . 01 PHARMACY/ CHEMIST/ DRUG STORE . . . . . 02 SHOP/MARKET . . . . . 03 RELIGIOUS INSTITUTION . . . . . 04 NGO .... 05 COMMUNITY BASED . . AGENTS (CBAs) . . . . . 06 PETROL STATION/ MOBILE MART . . . . . 07 PRIOR MASS DIST. CAMPAIGN 08 OTHER . . . . 96 DON'T KNOW 98	PRIVATE HEALTH FACILITY . . . . 01 PHARMACY/ CHEMIST/ DRUG STORE . . . . . 02 SHOP/MARKET . . . . . 03 RELIGIOUS INSTITUTION . . . . . 04 NGO .... 05 COMMUNITY BASED . . AGENTS (CBAs) . . . . . 06 PETROL STATION/ MOBILE MART . . . . . 07 PRIOR MASS DIST. CAMPAIGN 08 OTHER . . . . 96 DON'T KNOW 98

MOSQUITO NETS

		NET #1	NET #2	NET #3
128	Did anyone sleep under this mosquito net last night?	YES .... 1 NO .... 2 (SKIP TO 129A) NOT SURE 8	YES .... 1 NO .... 2 (SKIP TO 129A) NOT SURE 8	YES .... 1 NO .... 2 (SKIP TO 129A) NOT SURE 8
129	Who slept under this mosquito net last night? RECORD THE PERSON'S NAME AND LINE NUMBER FROM HOUSEHOLD SCHEDULE.	NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] (SKIP TO 130)	NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] (SKIP TO 130)	NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] NAME ________ LINE NO. ..... [ ][ ] (SKIP TO 130)
129A	Why was this net not used last night? RECORD ALL MENTIONED	TOO HOT .... A NO MOSQUITOES .... B NO MALARIA ...... C PREFER OTHER METHOD (COILS, SPRAY, FANS) .... D NET TOO OLD/TORN .. E CHEMICALS IN NET ARE UNSAFE .... F DON'T LIKE SMELL .... G NET TOO SHORT/ SMALL .... H USUAL USER DID NOT SLEEP HERE .... I EXTRA NET/SAVING FOR LATER ...... J NET WAS BEING WASHED/DRIED/ AIRED .... K SLEPT OUTSIDE .... L NET BROUGHT BUGS .... M DON'T LIKE SHAPE ..... N OTHER X	TOO HOT .... A NO MOSQUITOES .... B NO MALARIA ...... C PREFER OTHER METHOD (COILS, SPRAY, FANS) .... D NET TOO OLD/TORN .. E CHEMICALS IN NET ARE UNSAFE .... F DON'T LIKE SMELL .... G NET TOO SHORT/ SMALL .... H USUAL USER DID NOT SLEEP HERE .... I EXTRA NET/SAVING FOR LATER ...... J NET WAS BEING WASHED/DRIED/ AIRED .... K SLEPT OUTSIDE .... L NET BROUGHT BUGS .... M DON'T LIKE SHAPE ..... N OTHER X	TOO HOT .... A NO MOSQUITOES .... B NO MALARIA ...... C PREFER OTHER METHOD (COILS, SPRAY, FANS) .... D NET TOO OLD/TORN .. E CHEMICALS IN NET ARE UNSAFE .... F DON'T LIKE SMELL .... G NET TOO SHORT/ SMALL .... H USUAL USER DID NOT SLEEP HERE .... I EXTRA NET/SAVING FOR LATER ...... J NET WAS BEING WASHED/DRIED/ AIRED .... K SLEPT OUTSIDE .... L NET BROUGHT BUGS .... M DON'T LIKE SHAPE ..... N OTHER X
130		GO BACK TO 121 FOR NEXT NET; OR, IF NO MORE NETS, GO TO 131.	GO BACK TO 121 FOR NEXT NET; OR, IF NO MORE NETS, GO TO 131.	GO TO 121 IN FIRST COLUMN OF A NEW QUESTIONNAIRE; OR, IF NO MORE NETS, GO TO 131.

ADDITIONAL HOUSEHOLD CHARACTERISTICS

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
131	OBSERVE MAIN MATERIAL OF THE FLOOR OF THE DWELLING. RECORD OBSERVATION.	**NATURAL FLOOR** EARTH/SAND . . . . . 11 DUNG . . . . . 12 **RUDIMENTARY FLOOR** WOOD PLANKS . . . . . 21 PALM/BAMBOO . . . . . 22 **FINISHED FLOOR** PARQUET OR POLISHED WOOD . . . . . 31 VINYL OR ASPHALT STRIPS . . . . . 32 CERAMIC/MARBLE/PORCELAIN TILES/TERRAZO . . . . . 33 CEMENT . . . . . 34 WOOLEN CARPET/SYNTHETIC CARPET . . 35 LINOLEUM/RUBBER CARPET . . . . . 36 OTHER _____ 96 (SPECIFY)	
132	OBSERVE MAIN MATERIAL OF THE ROOF OF THE DWELLING. RECORD OBSERVATION.	**NATURAL ROOFING** NO ROOF . . . . . 11 THATCH/PALM LEAF . . . . . 12 SOD . . . . . 13 **RUDIMENTARY ROOFING** RUSTIC MAT . . . . . 21 PALM/BAMBOO . . . . . 22 WOOD PLANKS . . . . . 23 CARDBOARD . . . . . 24 **FINISHED ROOFING** ZINC/ALUMINIUM . . . . . 31 WOOD . . . . . 32 CERAMIC/BRICK TILES . . . . . 33 CEMENT . . . . . 34 ROOFING SHINGLES . . . . . 35 ASBESTOS/SLATE ROOFING SHEETS . . 36 OTHER _____ 96 (SPECIFY)	
133	OBSERVE MAIN MATERIAL OF THE EXTERIOR WALLS OF THE DWELLING. RECORD OBSERVATION.	**NATURAL WALLS** NO WALLS . . . . . 11 CANE/PALM/TRUNKS . . . . . 12 MUD/LANDCRETE . . . . . 13 **RUDIMENTARY WALLS** BAMBOO WITH MUD . . . . . 21 STONE WITH MUD . . . . . 22 UNCOVERED ADOBE . . . . . 23 PLYWOOD . . . . . 24 CARDBOARD . . . . . 25 REUSED WOOD . . . . . 26 **FINISHED WALLS** CEMENT . . . . . 31 STONE WITH LIME/CEMENT . . . . . 32 BRICKS . . . . . 33 CEMENT BLOCKS . . . . . 34 COVERED ADOBE . . . . . 35 WOOD PLANKS/SHINGLES . . . . . 36 OTHER _____ 96 (SPECIFY)	
134	RECORD THE TIME.	HOURS . . . . .  MINUTES	

INTERVIEWER'S OBSERVATIONS

TO BE FILLED IN AFTER COMPLETING INTERVIEW

COMMENTS ABOUT INTERVIEW:

COMMENTS ON SPECIFIC QUESTIONS:

ANY OTHER COMMENTS:

SUPERVISOR'S OBSERVATIONS

B Individual-level: 'Woman's Questionnaire' GMIS 2019

FORMATTING DATE: 21 Sep 2019
ENGLISH LANGUAGE: Sep 26 2019

2019 GHANA MALARIA INDICATOR SURVEY
WOMAN'S QUESTIONNAIRE

MINISTRY OF HEALTH — GHANA STATISTICAL SERVICE

IDENTIFICATION

LOCALITY NAME _____

NAME OF HOUSEHOLD HEAD _____

REGION .....

DISTRICT .....

CLUSTER NUMBER .....

HOUSEHOLD NUMBER .....

NAME AND LINE NUMBER OF WOMAN _____

INTERVIEWER VISITS

	1	2	3	FINAL VISIT
DATE				DAY / MONTH / YEAR (2019)
INTERVIEWER'S NAME				INT. NO.
RESULT*				RESULT*
NEXT VISIT: DATE				TOTAL NUMBER OF VISITS
TIME				

*RESULT CODES: 1 COMPLETED; 2 NOT AT HOME; 3 POSTPONED; 4 REFUSED; 5 PARTLY COMPLETED; 6 INCAPACITATED; 7 OTHER _____ (SPECIFY)

LANGUAGE OF QUESTIONNAIRE** 01 — LANGUAGE OF INTERVIEW** — NATIVE LANGUAGE OF RESPONDENT** — TRANSLATOR USED (YES = 1, NO = 2)

LANGUAGE OF QUESTIONNAIRE** ENGLISH

**LANGUAGE CODES:
01 ENGLISH; 02 AKAN; 03 GA; 04 EWE; 05 DAGBANI; 06 OTHER _____ (SPECIFY)

SUPERVISOR

NAME _____ NUMBER

INTRODUCTION AND CONSENT

Hello. My name is _____. I am working with Ghana Statistical Service and the Ministry of Health. We are conducting a survey about malaria all over Ghana. The information we collect will help the government to plan health services. Your household was selected for the survey. The questions usually take about 30 to 60 minutes. All of the answers you give will be confidential and will not be shared with anyone other than members of our survey team. You don't have to be in the survey, but we hope you will agree to answer the questions since your views are important. If I ask you any question you don't want to answer, just let me know and I will go on to the next question or you can stop the interview at any time.

In case you need more information about the survey, you may contact the person listed on the card that has already been given to your household.

Do you have any questions?
May I begin the interview now?

SIGNATURE OF INTERVIEWER _____ DATE _____

RESPONDENT AGREES TO BE INTERVIEWED . . 1 ↓

RESPONDENT DOES NOT AGREE TO BE INTERVIEWED . . 2 → END

SECTION 1. RESPONDENT'S BACKGROUND

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
101	RECORD THE TIME.	HOURS . . . . . ☐☐ MINUTES . . . . . ☐☐	
102	In what month and year were you born?	MONTH . . . . . ☐☐ DON'T KNOW MONTH . . . . . 98 YEAR . . . . . ☐☐☐☐ DON'T KNOW YEAR 9998	
103	How old were you at your last birthday? COMPARE AND CORRECT 102 AND/OR 103 IF INCONSISTENT.	AGE IN COMPLETED YEARS . . . . . ☐☐	
104	Have you ever attended school?	YES . . . . . 1 NO 2	→ 108
105	What is the highest level of school you attended: primary, middle, JSS/JHS, SSS/SHS, secondary, or higher?	PRIMARY . . . . . 1 MIDDLE . . . . . 2 JSS/JHS . . . . . 3 SSS/SHS . . . . . 4 SECONDARY . . . . . 5 HIGHER 6	
106	What is the highest grade you completed at that level? IF COMPLETED LESS THAN ONE YEAR AT THAT LEVEL, RECORD '00'.	GRADE . . . . . ☐☐	
107	CHECK 105: PRIMARY, MIDDLE, JSS/JHS SSS/SHS OR SECONDARY ☐ ↓	HIGHER ☐	→ 109

SECTION 1. RESPONDENT'S BACKGROUND

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
108	Now I would like you to read this sentence to me. SHOW CARD TO RESPONDENT. IF RESPONDENT CANNOT READ WHOLE SENTENCE, PROBE: Can you read any part of the sentence to me?	CANNOT READ AT ALL . . . . . 1 ABLE TO READ ONLY PART OF THE SENTENCE . . . . . 2 ABLE TO READ WHOLE SENTENCE . . . . . 3 NO CARD WITH REQUIRED LANGUAGE _____ 4 (SPECIFY LANGUAGE) BLIND/VISUALLY IMPAIRED 5	
109	What is your religion?	CATHOLIC . . . . . 01 ANGLICAN . . . . . 02 METHODIST . . . . . 03 PRESBYTERIAN . . . . . 04 PENTECOSTAL/CHARISMATIC . . . . . 05 OTHER CHRISTIAN . . . . . 06 ISLAM . . . . . 07 TRADITIONAL/SPIRITUALIST . . . . . 08 NO RELIGION . . . . . 95 OTHER _____ 96 (SPECIFY)	
110	To which ethnic group do you belong?	AKAN . . . . . 01 GA/DANGME . . . . . 02 EWE . . . . . 03 GUAN . . . . . 04 MOLE-DAGBANI . . . . . 05 GRUSI . . . . . 06 GURMA . . . . . 07 MANDE . . . . . 08 OTHER _____ 96 (SPECIFY)	
111	I will now ask you a few questions about health insurance. Are you registered by any health insurance?	YES . . . . . 1 NO 2	→ 114
112	Are you currently covered by any health insurance?	YES . . . . . 1 NO 2	→ 114
113	What type of health insurance are you (covered/registered) by? RECORD ALL MENTIONED.	NATIONAL / DISTRICT HEALTH INSURANCE (NHIS) . . . . . A HEALTH INSURANCE THROUGH EMPLOYER . . B MUTUAL HEALTH ORGANIZATION/ COMMUNITY-BASED HEALTH INSURANCE . . C OTHER PRIVATELY PURCHASED COMMERCIAL HEALTH INSURANCE . . . . . D OTHER _____ X (SPECIFY)	
114	Are you aware that malaria care is covered under the NHIS?	YES . . . . . 1 NO 2	

SECTION 2. REPRODUCTION

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
201	Now I would like to ask about all the births you have had during your life. Have you ever given birth?	YES . . . . . 1 NO 2	→ 206
202	Do you have any sons or daughters to whom you have given birth who are now living with you?	YES . . . . . 1 NO 2	→ 204
203	a) How many sons live with you? b) And how many daughters live with you? IF NONE, RECORD '00'.	a) SONS AT HOME . . . . . ☐☐ b) DAUGHTERS AT HOME . . . . . ☐☐	
204	Do you have any sons or daughters to whom you have given birth who are alive but do not live with you?	YES . . . . . 1 NO 2	→ 206
205	a) How many sons are alive but do not live with you? b) And how many daughters are alive but do not live with you? IF NONE, RECORD '00'.	a) SONS ELSEWHERE . . . . . ☐☐ b) DAUGHTERS ELSEWHERE . . . . . ☐☐	
206	Have you ever given birth to a boy or girl who was born alive but later died? IF NO, PROBE: Any baby who cried, who made any movement, sound, or effort to breathe, or who showed any other signs of life even if for a very short time?	YES . . . . . 1 NO 2	→ 208
207	a) How many boys have died? b) And how many girls have died? IF NONE, RECORD '00'.	a) BOYS DEAD . . . . . ☐☐ b) GIRLS DEAD . . . . . ☐☐	
208	SUM ANSWERS TO 203, 205, AND 207, AND ENTER TOTAL. IF NONE, RECORD '00'.	TOTAL BIRTHS . . . . . ☐☐	
209	CHECK 208: Just to make sure that I have this right: you have had in TOTAL _____ births during your life. Is that correct? YES ☐ ↓ NO ☐ → PROBE AND CORRECT 201-208 AS NECESSARY.		
210	CHECK 208: ONE OR MORE BIRTHS ☐ ↓ NO BIRTHS ☐		→ 225
211	Now I would like to ask you about your most recent births. How many births have you had in 2014-2019? RECORD NUMBER OF LIVE BIRTHS IN 2014-2019	TOTAL IN 2014-2019 . . . . . ☐☐ NONE 00	→ 225

SECTION 2. REPRODUCTION

212 Now I would like to record the names of all your births in 2014-2019, whether still alive or not, starting with the most recent one you had.
RECORD IN 213 THE NAMES OF ALL THE BIRTHS BORN IN 2014-2019. RECORD TWINS AND TRIPLETS ON SEPARATE ROWS. IF THERE ARE MORE THAN 5 BIRTHS, USE AN ADDITIONAL QUESTIONNAIRE STARTING WITH THE SECOND ROW.

213 What name was given to your (most recent/ previous) baby? RECORD NAME. BIRTH HISTORY NUMBER.	214 Is (NAME) a boy or a girl?	215 Were any of these births twins?	216 On what day, month, and year was (NAME) born?	217 Is (NAME) still alive?	218 IF ALIVE: How old was (NAME) at (NAME)'s last birthday? RECORD AGE IN COMP-LETED YEARS.	219 IF ALIVE: Is (NAME) living with you?	220 IF ALIVE: RECORD HOUSEHOLD LINE NUMBER OF CHILD. RECORD '00' IF CHILD NOT LISTED IN HOUSEHOLD.	221 Were there any other live births between (NAME) and (NAME OF PREVIOUS BIRTH), including any children who died after birth?
01	BOY 1 GIRL 2	SING 1 MULT 2	DAY ☐☐ MONTH ☐☐ YEAR ☐☐☐☐	YES 1 NO 2 → (NEXT BIRTH)	AGE IN YEARS ☐☐	YES 1 NO 2	HOUSEHOLD LINE NUMBER ☐☐ → (NEXT BIRTH)	
02	BOY 1 GIRL 2	SING 1 MULT 2	DAY ☐☐ MONTH ☐☐ YEAR ☐☐☐☐	YES 1 NO 2 → (SKIP TO 221)	AGE IN YEARS ☐☐	YES 1 NO 2	HOUSEHOLD LINE NUMBER ☐☐	YES 1 (ADD BIRTH) NO 2 (NEXT BIRTH)
03	BOY 1 GIRL 2	SING 1 MULT 2	DAY ☐☐ MONTH ☐☐ YEAR ☐☐☐☐	YES 1 NO 2 → (SKIP TO 221)	AGE IN YEARS ☐☐	YES 1 NO 2	HOUSEHOLD LINE NUMBER ☐☐	YES 1 (ADD BIRTH) NO 2 (NEXT BIRTH)
04	BOY 1 GIRL 2	SING 1 MULT 2	DAY ☐☐ MONTH ☐☐ YEAR ☐☐☐☐	YES 1 NO 2 → (SKIP TO 221)	AGE IN YEARS ☐☐	YES 1 NO 2	HOUSEHOLD LINE NUMBER ☐☐	YES 1 (ADD BIRTH) NO . . . . 2 (NEXT BIRTH)
05	BOY 1 GIRL 2	SING 1 MULT 2	DAY ☐☐ MONTH ☐☐ YEAR ☐☐☐☐	YES 1 NO 2 → (SKIP TO 221)	AGE IN YEARS ☐☐	YES 1 NO 2	HOUSEHOLD LINE NUMBER ☐☐	YES 1 (ADD BIRTH) NO . . . . 2 (NEXT BIRTH)

SECTION 2. REPRODUCTION

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
222	Have you had any live births since the birth of (NAME OF MOST RECENT BIRTH)?"	YES . . . . . 1 (RECORD BIRTH(S) IN TABLE) NO 2	
223	COMPARE 211 WITH NUMBER OF BIRTHS IN BIRTH HISTORY NUMBERS ARE SAME NUMBERS ARE DIFFERENT (PROBE AND RECONCILE)		
224	CHECK 211: ENTER THE NUMBER OF BIRTHS IN 2014-2019	NUMBER OF BIRTHS . . . . . [ ] NONE 0	
225	Are you pregnant now?	YES . . . . . 1 NO . . . . . 2 UNSURE 8	→ 227
226	How many months pregnant are you? RECORD NUMBER OF COMPLETED MONTHS.	MONTHS . . . . . [ ][ ]	
227	CHECK 224: ONE OR MORE BIRTHS IN 2014-2019 (GO TO 301) NO BIRTHS IN 2014-2019 Q. 224 IS BLANK		→ 501 → 501

SECTION 3. PREGNANCY AND INTERMITTENT PREVENTIVE TREATMENT

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
301	RECORD THE NAME AND SURVIVAL STATUS OF THE MOST RECENT BIRTH FROM 213 AND 217,	MOST RECENT BIRTH NAME _____ LIVING ☐ ↓ DEAD ☐ ↓	
302	Now I would like to ask you some questions about your last pregnancy that resulted in a live birth. When you got pregnant with (NAME), did you see anyone for antenatal care for this pregnancy?	YES . . . . . 1 NO 2	→ 304
303	Whom did you see? Anyone else? PROBE TO IDENTIFY EACH TYPE OF PERSON AND RECORD ALL MENTIONED.	**HEALTH PERSONNEL** DOCTOR . . . . . A NURSE/MIDWIFE . . . . . B COM. HEALTH OFFICER/NURSE . . . . . C **OTHER PERSON** TRADITIONAL BIRTH ATTENDANT . . . . . D COMMUNITY/VILLAGE HEALTH WORKER . . E TRADITIONAL HEALTH PRACTITIONER . . F OTHER _____ X (SPECIFY)	
303A	Where did you receive antenatal care for this pregnancy? Anywhere else? PROBE TO IDENTIFY THE TYPE OF SOURCE. IF UNABLE TO DETERMINE IF PUBLIC OR PRIVATE SECTOR, WRITE THE NAME OF THE PLACE. _____ (NAME OF PLACE)	**HOME** HER HOME . . . . . A OTHER HOME . . . . . B **PUBLIC SECTOR** GOVERNMENT HOSPITAL . . . . . C GOVERNMENT HEALTH CENTER . . . . . D GOVERNMENT HEALTH POST . . . . . E OTHER PUBLIC SECTOR _____ F (SPECIFY) **PRIVATE MEDICAL SECTOR** PRIVATE HOSPITAL/ CLINIC . . . . . G OTHER PRIVATE MEDICAL SECTOR _____ H (SPECIFY) OTHER _____ X (SPECIFY)	
303B	How many months pregnant were you when you first received antenatal care for this pregnancy?	MONTHS . . . . . ☐☐ DON'T KNOW 98	
303C	How many times did you receive antenatal care during this pregnancy?	NUMBER OF TIMES . . . . . ☐☐ DON'T KNOW 98	
304	During this pregnancy, did you take SP/Fansidar to keep you from getting malaria?	YES . . . . . 1 NO . . . . . 2 DON'T KNOW 8	→ 307
305	How many times did you take SP/Fansidar during this pregnancy?	TIMES . . . . . ☐☐	

SECTION 3. PREGNANCY AND INTERMITTENT PREVENTIVE TREATMENT

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
305A	CHECK 305: TOOK SP ONLY 1 OR 2 TIMES DURING THIS PREGNANCY	CODE '01' OR '02' TIMES ENTERED ☐ OTHER ☐ → 306	
305B	Why did you take SP/Fansidar only one or two times during this pregnancy? RECORD ALL MENTIONED.	FACILITY TOO FAR . . . . . A HAD NO MONEY . . . . . B SIDE EFFECTS . . . . . C NOT AWARE HAD TO TAKE MORE . . . . . D DID NOT WANT TO TAKE . . . . . E NOT GIVEN . . . . . F NOT AVAILABLE . . . . . G OTHER _____ X (SPECIFY) DON'T KNOW . . . . . Z	
306	Did you get the SP/Fansidar during any antenatal care visit, during another visit to a health facility or from another source? IF MORE THAN ONE SOURCE, RECORD THE HIGHEST SOURCE ON THE LIST.	ANTENATAL VISIT . . . . . 1 ANOTHER FACILITY VISIT . . . . . 2 OTHER SOURCE 6	
307	CHECK 216 AND 217: ONE OR MORE LIVING CHILDREN BORN IN 2014-2019 ☐ → (GO TO 401) NO LIVING CHILDREN BORN IN 2014-2019 ☐		→ 501

SECTION 4. FEVER IN CHILDREN

401	CHECK 213: RECORD THE BIRTH HISTORY NUMBER IN 402 AND THE NAME AND SURVIVAL STATUS IN 403 FOR EACH BIRTH IN 2014-2019. ASK THE QUESTIONS ABOUT ALL OF THESE BIRTHS. BEGIN WITH THE MOST RECENT BIRTH. IF THERE ARE MORE THAN 2 BIRTHS, USE ADDITIONAL QUESTIONNAIRE(S). Now I would like to ask some questions about the health of your children born since January 2014. (We will talk about each separately.)		
402	BIRTH HISTORY NUMBER FROM 213 IN BIRTH HISTORY.	MOST RECENT BIRTH BIRTH HISTORY NUMBER	NEXT MOST RECENT BIRTH BIRTH HISTORY NUMBER . . . . .
403	FROM 213 AND 217:	NAME _____ LIVING / DEAD (SKIP TO 428)	NAME _____ LIVING / DEAD (SKIP TO 428)
403A	Since 2017, was (NAME) enrolled in a program to receive a dose of medicine, every month for four months, to prevent malaria? IF YES: were you enrolled in that program in 2017, 2018 or in 2017 and 2018?	YES, IN 2017 . . . . . 1 YES, IN 2018 . . . . . 2 YES, IN 2017 AND IN 2018 . . 3 NO, NEVER ENROLLED . . . . . 4 (SKIP TO 404)	YES, IN 2017 . . . . . 1 YES, IN 2018 . . . . . 2 YES, IN 2017 AND IN 2018 . . 3 NO, NEVER ENROLLED . . . . . 4 (SKIP TO 404)
403B	How many rounds/months did (NAME) take in 2017 or 2018?	ROUNDS IN 2017 1. ____ ROUNDS IN 2018 2. ____	ROUNDS IN 2017 1. ____ ROUNDS IN 2018 2. ____
404	Has (NAME) been ill with a fever at any time in the last 2 weeks?	YES . . . . . 1 NO . . . . . 2 (SKIP TO 428) DON'T KNOW 8	YES . . . . . 1 NO . . . . . 2 (SKIP TO 428) DON'T KNOW 8
405	At any time during the illness, did (NAME) have blood taken from (NAME)'s finger or heel for testing?	YES . . . . . 1 NO . . . . . 2 (SKIP TO 406) DON'T KNOW 8	YES . . . . . 1 NO . . . . . 2 (SKIP TO 406) DON'T KNOW 8
405A	When (NAME) had blood taken from (NAME)'s finger or heel for testing, were you told that (NAME) had malaria?	POSITIVE MALARIA . . . . . 1 POSITIVE OTHER ILLNESS . . . . . 2 NEGATIVE . . . . . 3 DON'T KNOW/DON'T REMEMBER 8	POSITIVE MALARIA . . . . . 1 POSITIVE OTHER ILLNESS . . . . . 2 NEGATIVE . . . . . 3 DON'T KNOW/DON'T REMEMBER 8
406	Did you seek advice or treatment for the illness from any source?	YES . . . . . 1 NO . . . . . 2 (SKIP TO 411)	YES . . . . . 1 NO . . . . . 2 (SKIP TO 411)

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SECTION 4. FEVER IN CHILDREN

NO.	QUESTIONS AND FILTERS	MOST RECENT BIRTH NAME _____	NEXT MOST RECENT BIRTH NAME _____
407	Where did you seek advice or treatment? Anywhere else? PROBE TO IDENTIFY THE TYPE OF SOURCE. IF UNABLE TO DETERMINE IF PUBLIC OR PRIVATE SECTOR, WRITE THE NAME OF THE PLACE(S). _____ (NAME OF PLACE)	**PUBLIC SECTOR** GOVERNMENT HOSPITAL . . A GOVERNMENT HEALTH CENTER . . . . . B GOVERNMENT HEALTH POST/CHPS . . . . . C MOBILE CLINIC . . . . . D FIELDWORKER/CHW . . . . . E OTHER PUBLIC SECTOR _____ F (SPECIFY) **PRIVATE MEDICAL SECTOR** PRIVATE HOSPITAL/ CLINIC . . . . . G PHARMACY . . . . . H CHEMIST/DRUG STORE . . I FPG/PPAG CLINIC . . . . . J PRIVATE DOCTOR . . . . . K MOBILE CLINIC . . . . . L FIELDWORKER/CHW . . . . . M OTHER PRIVATE MEDICAL SECTOR _____ N (SPECIFY) **OTHER SOURCE** SHOP . . . . . O TRADITIONAL PRACTITIONER . . . . . P MARKET . . . . . Q ITINERANT DRUG SELLER . . . . . R OTHER _____ X (SPECIFY)	**PUBLIC SECTOR** GOVERNMENT HOSPITAL . . A GOVERNMENT HEALTH CENTER . . . . . B GOVERNMENT HEALTH POST/CHPS . . . . . C MOBILE CLINIC . . . . . D FIELDWORKER/CHW . . . . . E OTHER PUBLIC SECTOR _____ F (SPECIFY) **PRIVATE MEDICAL SECTOR** PRIVATE HOSPITAL/ CLINIC . . . . . G PHARMACY . . . . . H CHEMIST/DRUG STORE . . I FPG/PPAG CLINIC . . . . . J PRIVATE DOCTOR . . . . . K MOBILE CLINIC . . . . . L FIELDWORKER/CHW . . . . . M OTHER PRIVATE MEDICAL SECTOR _____ N (SPECIFY) **OTHER SOURCE** SHOP . . . . . O TRADITIONAL PRACTITIONER . . . . . P MARKET . . . . . Q ITINERANT DRUG SELLER . . . . . R OTHER _____ X (SPECIFY)
407A	CHECK 407: ONLY CODE O-R CIRCLED?	YES ↓ / NO → (SKIP TO 408)	YES ↓ / NO → (SKIP TO 408)
407B	Why did you seek advice or treatment from this source?	CHILD JUST FELL ILL . . . . . A CHILD NOT VERY ILL . . . . . B CLINIC TOO FAR . . . . . C HAVE NO MONEY . . . . . D WAITING FOR CHILD'S FATHER . . . . . E DON'T KNOW WHAT TO DO . . . . . F THIS SITE WAS CLOSER . . . . . G TRUST THIS SOURCE . . . . . H INSTRUCTION BY HOUSEHOLD HEAD . . . . . I OTHER _____ X (SPECIFY)	CHILD JUST FELL ILL . . . . . A CHILD NOT VERY ILL . . . . . B CLINIC TOO FAR . . . . . C HAVE NO MONEY . . . . . D WAITING FOR CHILD'S FATHER . . . . . E DON'T KNOW WHAT TO DO . . . . . F THIS SITE WAS CLOSER . . . . . G TRUST THIS SOURCE . . . . . H INSTRUCTION BY HOUSEHOLD HEAD . . . . . I OTHER _____ X (SPECIFY)
408	CHECK 407:	TWO OR MORE CODES CIRCLED ↓ / ONLY ONE CODE CIRCLED → (SKIP TO 410)	TWO OR MORE CODES CIRCLED ↓ / ONLY ONE CODE CIRCLED → (SKIP TO 410)
409	Where did you first seek advice or treatment? USE LETTER CODE FROM 407	FIRST PLACE . . . . . ☐	FIRST PLACE . . . . . ☐
410	How many days after the illness began did you first seek advice or treatment for (NAME)? IF THE SAME DAY RECORD '00'.	DAYS . . . . . ☐☐	DAYS . . . . . ☐☐

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SECTION 4. FEVER IN CHILDREN

NO.	QUESTIONS AND FILTERS	MOST RECENT BIRTH NAME_____	NEXT MOST RECENT BIRTH NAME_____
411	At any time during the illness, did (NAME) take any drugs for the illness?	YES ..... 1 NO ..... 2 → (SKIP TO 428) DON'T KNOW 8	YES ..... 1 NO ..... 2 → (SKIP TO 428) DON'T KNOW 8
412	What drugs did (NAME) take? Any other drugs? RECORD ALL MENTIONED. PLEASE NOTE BRAND NAMES: ARTEMISININ COMBINATION THERAPY (ACT) Coartem Lumarterm Artefan Lonart Gen-m Artemos plus P-alaxin Duo-cotexcin Artesunate amodiaquine wintrhop Arsuamoon Camoquine plus G sunate Co-arsucam	**ANTIMALARIAL DRUGS** ARTEMISININ COMBINATION THERAPY (ACT) ..... A SP/FANSIDAR ..... B CHLOROQUINE ..... C AMODIAQUINE ..... D QUININE PILLS ..... E INJECTION/IV ..... F ARTESUNATE RECTAL ..... G INJECTION/IV ..... H OTHER ANTIMALARIAL _____ (SPECIFY) I **ANTIBIOTIC DRUGS** PILL/SYRUP ..... J INJECTION/IV ..... K **OTHER DRUGS** ASPIRIN ..... L ACETAMINOPHEN ..... M IBUPROFEN ..... N HERBAL MEDICINE ..... O OTHER _____ (SPECIFY) X DON'T KNOW ..... Z	**ANTIMALARIAL DRUGS** ARTEMISININ COMBINATION THERAPY (ACT) ..... A SP/FANSIDAR ..... B CHLOROQUINE ..... C AMODIAQUINE ..... D QUININE PILLS ..... E INJECTION/IV ..... F ARTESUNATE RECTAL ..... G INJECTION/IV ..... H OTHER ANTIMALARIAL _____ (SPECIFY) I **ANTIBIOTIC DRUGS** PILL/SYRUP ..... J INJECTION/IV ..... K **OTHER DRUGS** ASPIRIN ..... L ACETAMINOPHEN ..... M IBUPROFEN ..... N HERBAL MEDICINE ..... O OTHER _____ (SPECIFY) X DON'T KNOW ..... Z
412A	CHECK 412: ONLY CODE J-O CIRCLED?	YES / NO → (SKIP TO 413)	YES / NO → (SKIP TO 413)
412B	Why did you not take an antimalarial drug?	FEVER WAS NOT MALARIA .. A NONE AVAILABLE AT FACILITY ..... B PROVIDER DID NOT OFFER ANTIMALARIAL DRUG .. .. C PROVIDER REFUSED TO GIVE ANTIMALARIAL ..... D AFRAID OF EFFECTS OF DRUGS ON HEALTH ..... E CHILD NOT VERY ILL ..... F CLINIC TOO FAR ..... G HAVE NO MONEY ..... H DO NOT KNOW TO TAKE ANTIMALARIAL .... I MEDICINE AT HOME ..... J DID NOT THINK IT WAS MALARIA .... K OTHER _____ (SPECIFY) X	FEVER WAS NOT MALARIA .. A NONE AVAILABLE AT FACILITY ..... B PROVIDER DID NOT OFFER ANTIMALARIAL DRUG .. .. C PROVIDER REFUSED TO GIVE ANTIMALARIAL ..... D AFRAID OF EFFECTS OF DRUGS ON HEALTH ..... E CHILD NOT VERY ILL ..... F CLINIC TOO FAR ..... G HAVE NO MONEY ..... H DO NOT KNOW TO TAKE ANTIMALARIAL .... I MEDICINE AT HOME ..... J DID NOT THINK IT WAS MALARIA .... K OTHER _____ (SPECIFY) X
413	CHECK 412: ANY CODE A-I CIRCLED?	YES / NO → (SKIP TO 428)	YES / NO → (SKIP TO 428)
414	CHECK 412: ARTEMISININ COMBINATION THERAPY ('A') GIVEN	CODE 'A' CIRCLED / CODE 'A' NOT CIRCLED → (SKIP TO 416)	CODE 'A' CIRCLED / CODE 'A' NOT CIRCLED → (SKIP TO 416)
415	How long after the fever started did (NAME) first take an artemisinin combination therapy?	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8

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SECTION 4. FEVER IN CHILDREN

NO.	QUESTIONS AND FILTERS	MOST RECENT BIRTH NAME_____	NEXT MOST RECENT BIRTH NAME_____
416	CHECK 412: SP/FANSIDAR ('B') GIVEN	CODE 'B' CIRCLED ☐ → CODE 'B' NOT CIRCLED ☐ (SKIP TO 418)	CODE 'B' CIRCLED ☐ → CODE 'B' NOT CIRCLED ☐ (SKIP TO 418)
417	How long after the fever started did (NAME) first take SP/Fansidar?	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8
418	CHECK 412: CHLOROQUINE ('C') GIVEN	CODE 'C' CIRCLED ☐ → CODE 'C' NOT CIRCLED ☐ (SKIP TO 420)	CODE 'C' CIRCLED ☐ → CODE 'C' NOT CIRCLED ☐ (SKIP TO 420)
419	How long after the fever started did (NAME) first take chloroquine?	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8
420	CHECK 412: AMODIAQUINE ('D') GIVEN	CODE 'D' CIRCLED ☐ → CODE 'D' NOT CIRCLED ☐ (SKIP TO 422)	CODE 'D' CIRCLED ☐ → CODE 'D' NOT CIRCLED ☐ (SKIP TO 422)
421	How long after the fever started did (NAME) first take amodiaquine?	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8
422	CHECK 412: QUININE ('E' OR 'F') GIVEN	CODE 'E' OR 'F' CIRCLED ☐ → CODE 'E' OR 'F' NOT CIRCLED ☐ (SKIP TO 424)	CODE 'E' OR 'F' CIRCLED ☐ → CODE 'E' OR 'F' NOT CIRCLED ☐ (SKIP TO 424)
423	How long after the fever started did (NAME) first take quinine?	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8	SAME DAY ..... 0 NEXT DAY ..... 1 TWO DAYS AFTER FEVER ..... 2 THREE OR MORE DAYS AFTER FEVER ..... 3 DON'T KNOW 8

SECTION 4. FEVER IN CHILDREN

NO.	QUESTIONS AND FILTERS	MOST RECENT BIRTH NAME_____	NEXT MOST RECENT BIRTH NAME_____
424	CHECK 412: ARTESUNATE ('G' OR 'H') GIVEN	CODE 'G' OR 'H' CIRCLED CODE 'G' OR 'H' NOT CIRCLED (SKIP TO 426)	CODE 'G' OR 'H' CIRCLED CODE 'G' OR 'H' NOT CIRCLED (SKIP TO 426)
425	How long after the fever started did (NAME) first take artesunate?	SAME DAY . . . . . 0 NEXT DAY . . . . . 1 TWO DAYS AFTER FEVER . . . . . 2 THREE OR MORE DAYS AFTER FEVER . . . . . 3 DON'T KNOW 8	SAME DAY . . . . . 0 NEXT DAY . . . . . 1 TWO DAYS AFTER FEVER . . . . . 2 THREE OR MORE DAYS AFTER FEVER . . . . . 3 DON'T KNOW 8
426	CHECK 412: OTHER ANTIMALARIAL ('I') GIVEN	CODE 'I' CIRCLED CODE 'I' NOT CIRCLED (SKIP TO 428)	CODE 'I' CIRCLED CODE 'I' NOT CIRCLED (SKIP TO 428)
427	How long after the fever started did (NAME) first take (OTHER ANTIMALARIAL)?	SAME DAY . . . . . 0 NEXT DAY . . . . . 1 TWO DAYS AFTER FEVER . . . . . 2 THREE OR MORE DAYS AFTER FEVER . . . . . 3 DON'T KNOW 8	SAME DAY . . . . . 0 NEXT DAY . . . . . 1 TWO DAYS AFTER FEVER . . . . . 2 THREE OR MORE DAYS AFTER FEVER . . . . . 3 DON'T KNOW 8
428		GO BACK TO 403 IN NEXT COLUMN; OR, IF NO MORE BIRTHS, GO TO 501.	GO TO 403 IN FIRST COLUMN OF NEW QUESTIONNAIRE; OR, IF NO MORE BIRTHS, GO TO 501.

SECTION 5. SOCIAL BEHAVIOR CHANGE AND COMMUNICATION

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
501	In the past six months, have you seen or heard any messages about malaria?	YES . . . . . 1 NO 2	→ 508
502	Where did you see or hear these messages? Where else? RECORD ALL MENTIONED.	RADIO . . . . . A TELEVISION . . . . . B POSTER/BILLBOARD . . . . . C NEWSPAPER/MAGAZINE . . . . . D LEAFLET/BROCHURE . . . . . E HEALTH WORKER . . . . . F COMMUNITY HEALTH WORKER . . . . . G COMMUNITY VOLUNTEER/CBA . . . . . H WORD OF MOUTH . . . . . I COMMUNITY EVENT/DURBAR MEETING . . . . J ANYWHERE ELSE _____ X (SPECIFY) DON'T REMEMBER . . . . . Z	
503	CHECK 502: IF A COMMUNICATION CHANNEL WAS MENTIONED IN 502, CIRCLE 0; IF NOT ASK:		
	Have you seen or heard these messages: a) On the radio? b) On the television? c) On a poster or a billboard? d) In a newspaper or a magazine? e) On a leaflet or a brochure? f) From a health worker? g) From a community health worker (CHW)? h) A community volunteer or a community based agent i) Word of mouth? j) At a community event/durbar meeting?	MENT. YES NO a) RADIO . . . . . O 1 2 b) TELEVISION . . . . . O 1 2 c) POSTER/BILLBOARD . . . . . O 1 2 d) NEWSPAPER/MAGAZINE . . O 1 2 e) LEAFLET/BROCHURE . . . . . O 1 2 f) HEALTH WORKER . . . . . O 1 2 g) CHW . . . . . O 1 2 h) VOLUNTEER/CBA . . . . . O 1 2 i) WORD OF MOUTH . . . . . O 1 2 j) COMMUNITY EVENT/ DURBAR MEETING . . . . . O 1 2	
504	What messages about malaria have you seen or heard in the past 6 months? What else? RECORD ALL MENTIONED.	IF HAVE FEVER GO TO HEALTH FACILITY . . . . . A SLEEP UNDER AN INSECTICIDE-TREATED MOSQUITO NET . . . . . B PREGNANT WOMEN SHOULD TAKE DRUGS TO PREVENT MALARIA . . . . . C SP PROTECTS PREGNANT WOMEN AND UNBORN BABY FROM GETTING MALARIA D ALWAYS TEST BEFORE TREATING MALARIA . . E TREAT MALARIA WITH ACTs . . . . . F MALARIA KILLS . . . . . G OTHER _____ X (SPECIFY) DON'T KNOW/DON'T REMEMBER . . . . . Z	
505	In the past six months, have you seen/heard any of the following malaria messages on television or radio:	YES,TV / YES, RADIO / YES, TV AND RADIO / NO	
	a) Goodlife campaign recommending pregnant women to sleep under treated bed nets	a) 1 2 3 4	
	b) Goodlife campaign recommending sleeping under treated bed nets every night all through the night	b) 1 2 3 4	
	c) Advert about "My net my life" addressing availability of different types (shapes, sizes and colour) of treated bednet on sale at designated points	c) 1 2 3 4	
	d) Advert where people were asked to test first before treated	d) 1 2 3 4	

SECTION 5. SOCIAL BEHAVIOR CHANGE AND COMMUNICATION

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
506	During the past six months, have you seen/heard any advert on the use of ACTs/ malaria medicines?	YES ..... 1 NO 2	→ 508
507	Where did you see/hear the advert on the use of ACTs/ malaria medicines? Any other media? RECORD ALL MENTIONED.	TELEVISION ..... A RADIO ..... B NEWSPAPER/MAGAZINE ..... C POSTER /LEAFLETS ..... D BILLBOARD ..... E OTHER _____ X (SPECIFY) DON'T KNOW/DON'T REMEMBEF ..... Z	
508	What are the things that people can do to prevent themselves from getting malaria? RECORD ALL MENTIONED.	SLEEP UNDER A MOSQUITO NET ..... A SLEEP UNDER AN INSECTICIDE-TREATED MOSQUITO NET ..... B USE MOSQUITO REPELLENT ..... C TAKE PREVENTATIVE MEDICATIONS ..... D SPRAY HOUSE WITH INSECTICIDE ..... E FILL IN STAGNANT WATERS (PUDDLES) ..... F KEEP SURROUNDING CLEAN ..... G PUT MOSQUITO SCREEN ON WINDOWS ..... H OTHER _____ X (SPECIFY) DON'T KNOW ..... Z	
509	When a child has a fever, you almost always worry it might be malaria.	AGREE ..... 1 DISAGREE ..... 2 DON'T KNOW 8	
510	You don't worry about malaria because it can be easily treated.	AGREE ..... 1 DISAGREE ..... 2 DON'T KNOW 8	
511	Have you heard about the malaria vaccine?	YES ..... 1 NO ..... 2 DON'T KNOW 8	
512	Would you allow your child to be vaccinated against malaria?	YES ..... 1 NO ..... 2 DON'T KNOW 8	
513	RECORD THE TIME.	HOURS ..... [ ][ ] MINUTES ..... [ ][ ]	

CVI

INTERVIEWER'S OBSERVATIONS

TO BE FILLED IN AFTER COMPLETING INTERVIEW

COMMENTS ABOUT INTERVIEW:

COMMENTS ON SPECIFIC QUESTIONS:

ANY OTHER COMMENTS:

SUPERVISOR'S OBSERVATIONS

C Supplement: data preparation

i. PCA – Wealth Index variables

The variables of question for the construction of the HWI are identified within the the ‘household recode file’ provided by the GMIS2019. All variables are used, when they are answered by the majority of households and if applicable needed recoding into binary variables. A list of all given and computed variables is contained within the syntax (Annex D)

A household is defined as one or more persons, that live together in the same dwelling unit(s), have one adult female or male defined as the head of the household, share the same housekeeping arrangements and are considered a single unit. All persons who stayed in the household the night before the interview are counted within the ‘de facto member’ of the household, irrespective of residential or visiting status, while ‘de jure member’ are all persons, that are usually residents of the household, irrespective of whether they stayed at the residency the night before or not (GSS and ICF, 2020).

A descriptive analysis of frequencies of the variables serves to identify empty cells, and all indicators with no variation are to be excluded from the PCA, when not reaching the threshold of a standard deviation above 0.5. This is usually happening, if no or only few cases are present (Rutstein, 2020).

The *source of non-drinking-water* was not used, as the majority of households did not answer this question (4,023 households: ‘NA’). The level of education, the occupation and the housing material are not included into the calculation of the HWI, because they are determinants of health status in their own way and were looked at within the mediation analysis.

The ‘*type of toilet facility’* and whether it is shared with other households are treated as separate indicators and are both included in the PCA, since a combined variable for toilet type and sharing provides only little additional information with a small effect. If no toilet is available in the dwelling, the sharing-variable is set from missing to 0.

The continuous variable ‘*number of household member per sleeping room’* is calculated by the number of de jure household (and if no de jure data is available, by the number of de facto persons) listed in the household schedule, divided by

the number of rooms used for sleeping in the household. The minimum number of rooms used for sleeping is set from 0 to 1, since the household must have one room for sleeping at least. Missing values and ‘don’t know’ are imputed by the mean number of sleeping rooms to avoid loss of information from exclusion of subjects, if there are only few missings and are omitted, if there are many missing values. Whether the household owns agricultural land and the number of hectares owned is used as a continuous indicator variable. If no land is owned, 0 indicates this, 95 is indicating having 95 or more hectares of land, while missing values of the amount owned and ‘don’t know’ are replaced by the mean. For each amount of livestock type owned, a continuous variable is created, 95 equals 95 or more animals, and the mean is being imputed for missing values and ‘don’t know’. (Rutstein, 2020, pp. 3–4).

The indicating variables are merged into a new dataset and by using ‘princomp()’ the PCA is conducted for the national index containing all variables, the urban index and the rural index containing region specific variables. For each index, the first principle component is extracted, as a continuous scaled variable, and merged into one composite score using linear regression. From the continous scale of the composite HWI, a categorical variable is created by dividing the unweighted values into quintiles, with assigned categories from 1 (‘lowest’ or ‘poorest’) to 5 (‘highest’ or ‘least poor’) to create equally sized groups of households within each HWI category. Since the number of people per sleeping room is included in the HWI, it is not used to weight the individuals within the quintilisation by it.

The created categorical variable is extracted and merged by household ID with the individuals dataset used for the mediation analysis. Through merging, the HWI is assigned to all children living in these households and therefore one HWI-score can be found in several children (e.g. siblings will have the same HWI-score).

ii. Mediation variables

All needed variables were introduced into a new dataset by merging the household HWI-variable dataset and the childrens' dataset holding the outcome variable and the mediating variables by the household ID (HHID) and the case ID. The case ID consists of the HHID with two additional digits for each child of the household and can be set identical to the HHID by cutting the last two digits off the case ID.

The mediators are prepared to fit into the MA as follows:

The level of educational attainment of mothers (EA) provided in the dataset as an ordinal variable 'educational attainment [V149]' coding from 'no education [=0]', 'incomplete primary [=1]', 'complete primary [=2]', 'incomplete secondary [=3]', 'complete secondary [=4]' and 'higher [=5]' and used like this for the MA.

The childrens' dataset is providing the variable 'Children under 5 slept under mosquito bed net last night (household questionnaire)' [V460] and the expressions are then recoded in a hierarchical order from 'no net in household [=0]', 'no [=1]', 'some children [=2]' to 'all children [=3]', since having no net at all is expected to be worse than owning, but not using a LLIN and having all children sleep under an LLIN is expected as the best outcome of LLIN use.

The treatment seeking behaviour is approximated by the type of health care provider that was visited during pregnancy (prenatal care).. If no care was sought, then 'none' is stated. The variable is coded hierarchically from 'none [=0]', 'other personell [=1]': 'traditional birth attendant', 'community/village health worker' and 'traditional health practitioner' and 'other:_', considered as informal HC provider and 'Health personnel [=2]: 'doctor'; 'nurse/midwife', or 'community health officer/nurse' considered as formal HC provider.

The mediator housing type is coded as a dichotomous variable for 'modern houses' [=1] vs. 'traditional houses'[=0] and calculated from the observations of improved or unimproved main materials of the floor, roof and walls. The quality of the housing condition the individuals live in is evaluated as modern if the floor, roof and walls are improved, and counted as traditional, when at least one material is unimproved (**Annex Table 1**) (Florey and Taylor, 2016).

Annex Table 1: Unimproved and improved housing characteristics define for modern and traditional houses (adapted from Florey and Taylor, 2016)

Characteristic		Floor	Wall	Roof
Unimproved	Natural	earth, sand, clay, mud, dung	no wall, cane/palm/trunks, dirt, mud and sticks, tin/cardboard/paper/bags, thatched/straw	no roof, grass/thatch/palm leaf/ sod, straw
Improved	Rudimentary	tablets/wood planks palm, bamboo mat, adobe	bamboo with mud stone with mud, uncovered adobe, plywood, cardboard, reused wood, trunks with mud, unburnt bricks, unburnt bricks with plaster, unburnt bricks with mud	rustic mat, palm/bamboo wood planks cardboard, tarpaulin, plastic
	Finished	parquet, polished wood vinyl, asphalt strips, floor mat, linoleum, ceramic tiles, mosaic cement, carpet, stone, bricks	cement, stone with lime/cement bricks, cement blocks, covered adobe, wood planks/shingles burnt bricks with cement	metal, wood, calamine/cement fiber ceramic tiles, cement, roofing shingles, asbestos/slate roofing sheets

D Syntax

i. Dataset-preparation for PCA

```
### Theresa Habermann - 15.12.2020 – Dataset preparation for PCA and
further analyses ###
###next steps with syntax file "PCA_all_urban_rural_" ###

library(dbplyr)
library(haven)
library(base)
library(sjlabelled)
library(expss)
library(tidyverse)

##Installing R-Tools:
writeLines('PATH="${RTOOLS40_HOME}\\usr\\bin;${PATH}"', con =
"~/.Renviron")
Sys.which("make")

## "C:\\rtools40\\usr\\bin\\make.exe"
install.packages("jsonlite", type = "source")

### Getting started ###
#Package to  use to convert SPSS-file in R:
library(haven)
#########################################################################
# GETTING Datasets from SPSS-Files:
#1. Household recode
path1
=file.path('C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesis/DHS_Da
ta_Ghana/GH2019MIS/GHHR82SV/GHHR82FL.sav')
household = read_sav(path1)
names(household)

#2. Individual recode
path2 =
file.path('C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesis/DHS_Dat
a_Ghana/GH2019MIS/GHIR82SV/GHIR82FL.sav')
individual = read_sav(path2)

#3. Childrens recode
path3 =
file.path('C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesis/DHS_Dat
a_Ghana/GH2019MIS/GHKR82SV/GHKR82FL.sav')
children = read_sav(path3)

#4. Household member recode
path4 =
file.path('C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesis/DHS_Dat
a_Ghana/GH2019MIS/GHPR82SV/GHPR82FL.sav')
member = read_sav(path4)

#################################################
### Where to find WI - variables:
# Wealth INDEX combined: HV270
# WI urban/ rural: HV270a
# WI (both each) in decimals: HV271 & HV271a
#with given Wealth Indices:
HH_WIgiven <- household[,111:114]
#########################################################################
```

```
######## Creating WI (List of needed variables) ###########
####  Dichotomous variables:
# access to electricity [HV206]
# ownership of radio [HV207]
# ownership of TV [HV208]
# ownership of refrigerator [HV209]
# ownership of bicycle [HV210]
# ownership of motorcycle/scooter [HV211]
# ownership of car/ truck [HV212]
# ownership of telephone (landline) [HV221]
# ownership of mobile phone [HV243A]
# ownership of clocks/ watches [HV243B]
# ownership of bank account [HV247]
# ownership of animal drawn cart [HV243C]
# ownership of boat with motor [HV243D]
# ownership of computer [HV243E]
# ownership of Freezer [SH114G]
# ownership of Electric Generator/ [SH114H]
# ownership of Washing machine [SH114I]
# ownership of Camera [SH114J]
# ownership of Video/DVD/VCD [SH114K]
# ownership of Sewing machine [SH114L]
# ownership of Bed [SH114M]
# ownership of Table [SH114N]
# ownership of Chair [SH114O]
# ownership of Cabinet/ Cupboard [SH114P]
# ownership of Boat without motor [SH115H]
# ownership of agricultural land [HV244]
# toilet shared with other household (yes/ no) [HV225]

#### to be calculated:
# number of people/ sleeping room [from HV216 and HV012]
#      if hhusual = 0 dann hhusual=hhslept
#      number of de jure household member [HV012]
#      number of rooms used for sleeping [HV216] column 68

#### to be dichotomized:
# source of drinking water [HV201]
# source of non-drinking water [HV202] - not many cases, not in PCA
# type of toilet facility [HV204]
# type of cooking fuel [HV226]

# Housing: not in PCA, but are Mediator
# -Type of floor material [HV213]
# -Type of wall material [HV214]
# -Type of roof material [HV215]
# house type: modern (wood, cement or brick walls; metal or tiled roof;
# closed eaves)
# house type: traditional (all other homes)

# ownership of livestock [HV246] yes/no,
#  (cattle, cows, horses, goats,sheep, chicken,
#  pigs, rabbits, grasscutter: HV246A-I)
# number of livestock owned, by animal type

# hectares agricultural land (1 decimal) [HV245]
#### makes Variables for common score + 9 for animals (for urban/rural
score) and HHID, HHNumber and Number of de jure members

# - rank by score and group into quintiles to give categorical measures
of SEP
```

```
#Column 28: type of place of residence (HV025) 1=Urban, 2= rural

#finding out how to see value labels
install.packages("sjlabelled")
library(sjlabelled)
get_labels(HH_need)
get_label(HH_need)
val_lab(household$HV024)
val_lab(household$HV025)

# creation of dataset with needed variables for PCA [Command: x[,c(1,3)]
columns 1 and 3 ]
HH_need <- household[,c(1,4, 15, 28, 53, 55, 57:68, 73, 74, 75, 80:85,
86:96, 99, 119:129)]
head(HH_need)
summary(HH_need)
table(HH_need)

# calculate  "HH_need$hhslept"= "Member per sleeping room" continous
# scale
library(expss) # for val_lab function
HH_need$HV216 <- ifelse(household$HV216>0, household$HV216, 1) #because 0
#can't be right, person must sleep somewhere
var_lab(HH_need$HV216) = "Number of rooms used for sleeping"
summary(HH_need$HV216)
HH_need$hhslept<- ifelse (WI$HV012!=0,(HH_need$HV012/HH_need$HV216),
(household$HV013/HH_need$HV216))
var_lab(HH_need$hhslept) = "Members per sleeping room"
var_lab(HH_need$hhslept)
summary(HH_need$hhslept)
head(HH_need$hhslept)

install.packages("expss")
library(expss)
HH_need2 <- HH_need # to have as a backup
# HH_need <- HH_need2 #to get backup /reset df

## Ownership of hectares of agricultural land , 950= "95 or more", 998 =
"Unknown"
val_lab(HH_need$HV245)
#if HH_need$HV244 = 0 (no land owned), then HH_need$HV245 = 0, sonst
="HH_need$HV245"
xtabs(household$HV244 ~ household$HV245)

HH_need$HV245_new <- ifelse(is.na(HH_need$HV245),0,HH_need$HV245)   #to
have answer 0 from HV244 too, no NAs if HV244=1 were there!
HH_need$HV245_new <- ifelse(HH_need$HV245_new==998, NA,
HH_need$HV245_new) #if DK, then set at NA
val_lab(HH_need$HV245_new) <- c("95 or more" = 95)
var_lab(HH_need$HV245_new)= "Hectares of agricultural land - new"
head(HH_need$HV245_new)
summary(HH_need$HV245_new)
summary(HH_need$HV245[HH_need$HV245!=998]) # without 998="Unknown"
# fill NA with mean values
mean(HH_need$HV245_new, na.rm= TRUE)
HH_need$HV245_new <- ifelse(is.na(HH_need$HV245_new), 11.89702,
HH_need$HV245_new) #11.9= mean
summary(HH_need$HV245_new)
describe(HH_need$HV245_new)
```

```
#Livestock: if 98=Dont know, then set to NA, no other NA's were there
before - code continuous indicator variable!
val_lab(HH_need$HV246A)

HH_need$HV246A<- ifelse(HH_need$HV246A == 98, NA, HH_need$HV246A)
var_lab(HH_need$HV246A)= "Owns cattle"
val_lab(HH_need$HV246A) <- c("95 or more" = 95)
mean(HH_need$HV246A, na.rm=TRUE) # 0.2402071
HH_need$HV246A <- ifelse(is.na(HH_need$HV246A), 0.2402071,
HH_need$HV246A)
summary(HH_need$HV246A) #no NAs anymore, substituted with mean

HH_need$HV246B <- ifelse(HH_need$HV246B == 98, NA, HH_need$HV246B)
var_lab(HH_need$HV246B)= "Owns cows/bulls"
val_lab(HH_need$HV246B) <- c("95 or more" = 95)
mean(HH_need$HV246B, na.rm=TRUE)
#mean= 0.270783
HH_need$HV246B <- ifelse(is.na(HH_need$HV246B), 0.270783, HH_need$HV246B)
summary(HH_need$HV246B) #no NAs anymore

HH_need$HV246C <- ifelse(HH_need$HV246C == 98, NA, HH_need$HV246C)
var_lab(HH_need$HV246C)= "Owns horses/donkeys/mules"
val_lab(HH_need$HV246C) <- c("95 or more" = 95)
mean(HH_need$HV246C, na.rm=TRUE)
#mean= 0.04655975
HH_need$HV246C <- ifelse(is.na(HH_need$HV246C), 0.04655975,
HH_need$HV246C)
summary(HH_need$HV246C) #no NAs anymore

HH_need$HV246D <- ifelse(HH_need$HV246D == 98, NA, HH_need$HV246D)
var_lab(HH_need$HV246D)= "Owns goats"
val_lab(HH_need$HV246D) <- c("95 or more" = 95)
summary(HH_need$HV246D)
mean(HH_need$HV246D, na.rm=TRUE)
#mean= 1.319765
HH_need$HV246D <- ifelse(is.na(HH_need$HV246D), 1.319765, HH_need$HV246D)
summary(HH_need$HV246D) #no NAs anymore

HH_need$HV246E <- ifelse(HH_need$HV246E == 98, NA, HH_need$HV246E)
var_lab(HH_need$HV246E)= "Owns sheep"
val_lab(HH_need$HV246E) <- c("95 or more" = 95)
summary(HH_need$HV246E) #no NAs


HH_need$HV246F <- ifelse(HH_need$HV246F == 98, NA, HH_need$HV246F)
var_lab(HH_need$HV246F)= "Owns chickens/poultry"
val_lab(HH_need$HV246F) <- c("95 or more" = 95)
summary(HH_need$HV246F)
mean(HH_need$HV246F, na.rm=TRUE)
#mean= 5.259751
HH_need$HV246F <- ifelse(is.na(HH_need$HV246F), 5.259751, HH_need$HV246F)
summary(HH_need$HV246F) #no NAs anymore

HH_need$HV246G <- ifelse(HH_need$HV246G == 98, NA, HH_need$HV246G)
var_lab(HH_need$HV246G)= "Owns pigs"
val_lab(HH_need$HV246G) <- c("95 or more" = 95)
summary(HH_need$HV246G) #no NAs

HH_need$HV246H <- ifelse(HH_need$HV246H == 98, NA, HH_need$HV246H)
var_lab(HH_need$HV246H)= "Owns rabbits"
val_lab(HH_need$HV246H) <- c("95 or more" = 95)
```

```
summary(HH_need$HV246H) #no NAs

HH_need$HV246I <- ifelse(HH_need$HV246I == 98, NA, HH_need$HV246I)
var_lab(HH_need$HV246I)= "Owns grasscutter"
val_lab(HH_need$HV246I) <- c("95 or more" = 95)
summary(HH_need$HV246I) #no NAs

### dichotomize: calculate categorical variables into own each with 0/1
## (n/y)
## as.dichotomy returns dataframe:

#drinkingwatersource
drinkingwater <-  as.dichotomy(HH_need$HV201, prefix = "drinkingwater",)
val_lab(drinkingwater) <- c("yes" =1, "no" = 0)
val_lab(drinkingwater)
head(drinkingwater)
summary(drinkingwater)
table(drinkingwater$drinkingwater11)

#non_drinkingwatersource
nodrinkingwater <-  as.dichotomy(HH_need$HV202, prefix =
"nodrinkingwater",) #inlcude in PCA?
val_lab(nodrinkingwater) <- c("yes" =1, "no" = 0)
val_lab(nodrinkingwater)
head(nodrinkingwater)
summary(nodrinkingwater)

#toiletfacilitytype
toilettype <-  as.dichotomy(HH_need$HV205, prefix = "toilettype")
val_lab(toilettype) <- c("yes" =1, "no" = 0)
val_lab(toilettype)
head(toilettype)

# shared toilet - if no toilet, then set NA to 0!
HH_need$toiletshared <- household$HV225
summary(HH_need$toiletshared)
HH_need$toiletshared <- ifelse(is.na(HH_need$toiletshared), 0,
HH_need$toiletshared)
summary(HH_need$toiletshared)

#cookingfueltype
cookingfuel <-  as.dichotomy(HH_need$HV226, prefix = "cookingfuel")
val_lab(cookingfuel) <- c("yes" =1, "no" = 0)
val_lab(cookingfuel)
head(cookingfuel)

#mainfloormaterial
floor <-  as.dichotomy(HH_need$HV213, prefix = "floor")
val_lab(floor) <- c("yes" =1, "no" = 0)
val_lab(floor)
head(floor)

#mainwallmaterial
wall <-  as.dichotomy(HH_need$HV214, prefix = "wall")
val_lab(wall) <- c("yes" =1, "no" = 0)
val_lab(wall)
head(wall)

#mainroofmaterial
roof <-  as.dichotomy(HH_need$HV215, prefix = "roof")
val_lab(roof) <- c("yes" =1, "no" = 0)
```

```
val_lab(roof)
head(roof)

##### descriptives
summary(HH_need)
table(HH_need$HV025)
val_lab(HH_need$HV025)

summary(drinkingwater)
summary(toilettype)
summary(cookingfuel)
summary(wall)
summary(roof)
summary(floor)

summary(HH_WIgiven)

install.packages("stats")
library(stats)

library(help = "stats")
sd(hh_all$HV206)
```

ii. Calculation PCA

```
## Principle Component Analysis - Thesis ##
## Theresa Habermann - 08.04.2021        ##

library(psych)
library(sjlabelled)
library(stats)

#HWI - all observations
#create dataset with assets (hh1) and housing (hh_all):
# - source of non-drinking water to includ? column 6 no, due to 4023 NAs!
hh1 <- data.frame(HH_need[c(1, 4, 8:14, 19, 22:27, 30:53)]) #select only
# needed variables for PCA from HH_needed, urban/rural variable and HHID,
# and toiletshared
hh_all <- data.frame(hh1, cookingfuel, drinkingwater, toilettype, roof,
wall, floor) #hh1 plus cookingfuel, drinkingwater, toilettype plus
housing
colnames(hh_all)

# run descriptives to find all variables with Stdev=0 (rounded from 0.05)
summary(hh_all)
describe(hh_all)
describe(hh_all[c(77:121)])
summary(HH_WIgiven)
summary(is.na(hh_all))
# remove those with stdev=0 from PCA:
# cookingfuel3 (0,02), cookingfuel4 (0,02),  cookingfuel5 (0,02),
# cookingfuel6  (0,03),  cookingfuel10 (0,02), cookingfuel96 (0,01)
# drinkingwater41 (0,03), drinkingwater62 (0,02), toilettype96 (0.01)
hh_common <- hh_all[c(1:42, 47:49, 51, 53:59, 61:64, 66:80, 82:121)]
colnames(hh_common)

## hh1$HV025 (column 1) = type of place of residence (urban/rural)
##create subset for urban / rural separate WI-Calculation
hh_urban <- subset(hh_common, HV025 ==1) #urban =1
hh_rural <- subset(hh_common, HV025 ==2) #rural =2
```

```
summary(hh_urban)
describe(hh_urban)
summary(hh_rural)
describe(hh_rural)
table(hh_all$HV025)
colnames(hh_rural)
colnames(hh_urban)
library(expss)
var_lab(hh_urban$HV246D)
var_lab(hh_all$HV025)

head(hh_urban)
head(hh_rural)
table(hh_urban$HV225)
str(hh_all)

# now all WI calculated are derived from hh_urban and hh_rural /
# hh_common for national WI! without housing (select until column 72)!!

# using correlation matrix in pca - as variables were not standardized
# beforehand
#WI-Score for Urban area, using only specific variables for rural area
pca_urb2 <- princomp((hh_urban[c(3:72)]), cor = TRUE, scores = TRUE,
fix_sign = TRUE) #Correlation=True, because no standardized variables,
# create score through: Scores=TRUE
summary(pca_urb2)
pca_urb2$scores
summary(pca_urb2$scores)
table_loadingsurban <- loadings(pca_urb2)
write.csv(table_loadingsurban,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/
Masterthesis/Analysis/Results/table_loadingsurban.csv", row.names = TRUE)

head(round(pca_urb2$scores, 1))
(pca_urb2$scores)
pca_urb2

#WI-Score for Rural area, using only specific variables for rural area
pca_rur2 <- princomp((hh_rural[c(3:72)]),  cor = TRUE , scores = TRUE,
fix_sign = TRUE)
summary(pca_rur2)
pca_rur2$scores
summary(pca_rur2$scores)
loadings(pca_rur2)

table_loadingsrural <- loadings(pca_rur2)
write.csv(table_loadingsrural,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/
Masterthesis/Analysis/Results/table_loadingsrural.csv", row.names = TRUE)

# WI-score for national (=common) (all assets) - no adjustment for place
# of residence
pca_nat2 <- princomp((hh_common[c(3:72)]), cor = TRUE, scores = TRUE,
fix_sign = TRUE)
summary(pca_nat2)
pca_nat2$scores
summary(pca_nat2$scores)
pca_nat2$loadings
pca_nat2$center

#WI-score for national_specifics (all but without nb. of livestock and
# amount of landarea)
```

```
pca_nat_spec2 <- princomp((hh_common[c(3:16, 26:38, 40:72)]), cor = TRUE,
scores = TRUE, fix_sign = TRUE)
summary(pca_nat_spec2)
pca_nat_spec2$scores
pca_nat_spec2$loadings
summary(pca_nat_spec2$scores)

### saving Score into variable --> when using PC1 as Index:  #######
index_urb2=pca_urb2$scores[,1]
summary(index_urb2)
barplot(index_urb2)
hh_urban$index_urb2 <- index_urb2

index_rur2=pca_rur2$scores[,1]
summary(index_rur2)
barplot(index_rur2)
hh_rural$index_rur2 <- index_rur2

index_nat2=pca_nat2$scores[,1]
summary(index_nat2)
barplot(index_nat2)
hh_common$index_nat2 <- index_nat2
describe(index_nat2)

index_nat_spec2=pca_nat_spec2$scores[,1]
summary(index_nat_spec2)
barplot(index_nat_spec2)
hh_common$index_nat_spec2 <- index_nat_spec2
describe(index_nat_spec2)

### 1. Combine rural/urban into one index!
# output file - bind all indices in one dataframe
WI <- data.frame(HH_need[c(1:4)]) # column 1-4: HHID, HH-number, nb. of
de jure member, type of place of residence
WI$index_urb2 <- ifelse(WI$HV025 == 1, 0, NA) #creating variable for
urban WI
WI$index_rur2 <- ifelse(WI$HV025 == 2, 0, NA) #creating variable for
rural WI
WI$index_urb2 <- ifelse(WI$index_urb2==0, index_urb2, NA)
WI$index_rur2 <- ifelse(WI$index_rur2==0, index_rur2, NA)
WI$index_nat2 <- index_nat2
WI$index_nat_spec2 <- index_nat_spec2

#combine rural/urban into one variable - by regression of index_urb and
# index_nat_spec / index_rur and index_nat_spec:
#"Select urban area cases. Run a regression with the common factor score
#(index_nat_spec) as the dependent variable and the urban area factor
# score (index_urb) as the independent variable. The data should be
# unweighted. Note the constant term and the coefficient. Also check the
# significance of the regression and terms. They should be highly
# significant. Repeat for rural areas selecting rural cases using the
# rural area factor score (index_rur) as the independent variable."

# DV: WI$index_nat_spec
# IV: WI$index_urb / WI$index_rur
# lm(DV ~ IV)
summary(lm(WI$index_nat_spec2~ WI$index_urb2))
summary(lm(WI$index_nat_spec2~ WI$index_rur2))

##Calculate combined score:
#Using all cases, first make a new variable for the combined score,
```

```
#index_com, with five decimal places and set it equal to 0. Then for each
# area calculate the combined score using the appropriate urban or rural
# factor scores, constants and coefficients obtained in substep 5a.

## constant_Urban: 1.50947 coefficient WI$index_urb2: 0.05528
## constant_rural:-1.40024 coefficient WI$index_rur3: 0.07775
WI$index_com2 <- 0 #WI combined
WI$index_com2 <- ifelse(WI$HV025 == 1, ( 1.50946*0.05528 +
WI$index_urb2), NA) #WI$index_com <- urban constant + urban coefficient
*WI$index_urb2
WI$index_com2 <- ifelse(WI$HV025 == 2, (-1.40023*0.07775 +
WI$index_rur2), WI$index_com) #WI$index_com <- rural constant + rural
# coefficient *WI$index_rur2
summary(WI$index_com2)
describe(WI$index_com2)
hist(WI$index_com2)

###3. creating Quintiles of combined index_com2, and urban and rural
#combined into WI$quint_com2
quantile(WI$index_com2 , c(0.20, 0.40, 0.60, 0.80, 1.0)) # Cut-off-Values
# to get upper threshold for Quintiles
WI$quint_com2 <- NA
quint_com2 <- c(1,2,3,4,5) # variable for quintile categorization - if
# value xy put in 1lowest, 2second, 3middle, 4fourth 5highest)
WI$quint_com2 <- set_labels(quint_com2, labels = c("lowest", "second",
"middle", "fourth", "highest"))
val_labels(quint_com2)
#   20%        40%        60%        80%       100%
#-2.1688833 -0.9982031  0.2905724  1.9023159 10.3721552
# set up cut-off values for combined Wealth index (quintiles)
quint_com2 <- c(-Inf, -2.1688833, -0.9982031 , 0.2905724, 1.9023159, Inf)
# specify interval/bin labels
#(-6.84130)-(-2.1689462))","[(-2.1689461)-(-0.9982038))", "[(-0.9982037)-
# 0.2905642)
names <- c("1","2", "3", "4" ,"5")
# bucketing values into bins
WI$quint_com2 <- as.numeric(cut(WI$index_com2, breaks = quint_com2,
                  include.lowest=TRUE,
                  right=FALSE,
                  labels= names,
                  ordererd_result=TRUE))

describe(WI2$index_com2)
hist(WI$index_com2)

### Quintiles for Urban/Rural index
quantile(WI$index_urb2, c(0.20, 0.40, 0.60, 0.80, 1.0), na.rm=TRUE) # to
get upper threshold for Quintiles
#  20%        40%        60%        80%       100%
# -1.9185851 -0.5637452  0.5550822  1.9227084  7.3755186
quint_urb2 <- c(-Inf, -1.9185851, -0.5637452 , 0.5550822 , 1.9227084,
Inf) #variable for quintile categorization - if value xy put in
# Q1 (poorest), Q5 (richest)
names <- c("1","2", "3", "4" ,"5")
# bucketing values into bins
WI$quint_urb2 <- as.numeric(cut(WI$index_urb2,
                                  breaks= quint_urb2,
                                  include.lowest=TRUE,
                                  right=FALSE,
                                  labels= names,
                                  ordererd_result=TRUE))
```

```
quantile(WI$index_rur2, c(0.20, 0.40, 0.60, 0.80, 1.0), na.rm=TRUE) # to
get upper threshold for Quintiles
#  20%        40%        60%        80%       100%
# -2.26635176 -1.26598097 -0.05812005  1.80744013 10.48102305
quint_rur2 <- c(-Inf, -2.26635176, -1.26598097 ,-0.05812005 , 1.80744013,
Inf) #variable for quintile categorization - if value xy put in Q1
# (poorest), Q5 (richest)
names <- c("1","2", "3", "4" ,"5")
# bucketing values into bins
WI$quint_rur2 <- as.numeric(cut(WI$index_rur2,
                                breaks= quint_rur2,
                                include.lowest=TRUE,
                                right=FALSE,
                                labels= names,
                                ordererd_result=TRUE))

# merging rural /urban into one variable (not mapped by national
(nat_spec2)!!)
WI$index_urb_rur <- ifelse(WI$index_urb2, WI$index_urb2, WI$index_rur2)
WI$index_urb_rur <- ifelse((is.na(WI$index_urb_rur)), WI$index_rur2,
WI$index_urb2)
describe(WI2$index_urb_rur)
hist(WI$index_urb_rur)

WI$quint_urb_rur <- ifelse(WI$quint_urb2, WI$quint_urb2, WI$quint_rur2)
WI$quint_urb_rur <- ifelse((is.na(WI$quint_urb_rur)), WI$quint_rur2,
WI$quint_urb2)
describe(WI$quint_urb_rur)
describe(WI$quint_com2)

#further:
hist(WI2$index_com2)
describe(WI2$index_com2)
hist(WI$index_urb2)
hist(WI$index_rur2)
hist(WI$index_urb_rur)
cro(WI2$quint_com2)

summary(HH_WIgiven$HV270)
hist(HH_WIgiven$HV271)

plot(table(WI$HV025, WI$quint_com2))
prop.table(table(WI$HV025, WI$quint_com2))
plot(prop.table(table(WI$HV025, WI$quint_com2)))

#safe dataframe in excel
write.csv(WI,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesis/Anal
ysis/Results/assets_WI.csv", row.names = FALSE)
write.csv(WI2,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesis/Ana
lysis/Results/assets_WI_weights.csv", row.names = FALSE)
```

iii. Dataset preparation and calculation MA

```
### Theresa Habermann - 19.01.2020 - Preparation for mediation
### Childrens recode:
#path3 =
file.path('C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesis/DHS_Dat
a_Ghana/GH2019MIS/GHKR82SV/GHKR82FL.sav')
#children = read_sav(path3)
```

```
################################
# Install mediation package etc.
install.packages("mediation")
library(mediation) # not used
# not used: install.packages("mice")
# not used: library(mice)

install.packages("epiDisplay")
install.packages("medflex")
library(medflex)
library(sjlabelled)
library(expss)
library(psych)
library(epiDisplay)
library(stats)
library(haven)

### 1.) creation of dataset with relevant variables for mediation/
Pathway analysis
## needed variables from 'children' dataset and "WI2" dataset:
##with 4 different Wealth Indice
# DHS WI assets and housing based//rural/ urban[V190A] and common [V190]
# urban/ rural - assets based [WI$quint_urb_rur]
# combined - assets based [WI$quint_com2]

#all possible variables: ID, demographics, mediator, confounder, outcome
medchild <- data.frame(children[c(1:2, 16, 30, 48, 60:62, 72, 85:88, 89,
113, 114, 115, 117:121, 133, 135, 136, 144, 146:148, 152:154, 156, 159,
160:162, 172, 173, 176:179, 184:185, 194, 195, 196:201, 205:212, 214:217,
219:223, 226, 236, 238, 239:240, 243:250, 253:259, 262:264, 269, 272,
275, 278, 290, 299, 303, 305:307, 383)])

get_labels(children$V025)
val_lab(children$ML101)
var_lab(children$ML101)

library(sjlabelled)
get_labels(medchild)
get_label(medchild)

## 2. Identification
# household ID [CASEID]
medchild$CASEID

# Creation of HHID from CASEID - to have matching variable
medchild$HHID <- medchild$CASEID
medchild$HHID <- substr(medchild$HHID,1,nchar(medchild$HHID)-3)

# matching WI with household ID
library(tidyverse)
medchild <- left_join(x = medchild, y = WI2, by = "HHID")

## 3. Mediators (in 'children')
# - Individuals Education (mother) [V106 highest educational level "No
education" "Primary"      "Secondary"    "Higher" , V107 highest year of
education, V133 education in single years, V194 Educational attainment 1-
5, V155 Literacy, children$S105 $105A]
cro(medchild$V106) #Highest level of Education
val_lab(medchild$V106)
# 0 No education |    826 |
# 1 Primary      |    646 |
```

```
# 2 Secondary    |   1386 |
# 3 Higher       |    146 |

cro(medchild$V149) #educational attainment # For MA!
val_lab(medchild$V149)
#0| Educational attainment   |         No education |    826 |
#|1                          |   Incomplete primary |    493 |
#  2|                        |     Complete primary |    153 |
#  |3                        | Incomplete secondary |   1109 |
#  | 4                       |   Complete secondary |    277 |
#  |  5                      |               Higher |    146 |

# - LLIN use [ML101/ ML0 - type of bednet used last night 1-3]
cro(medchild$ML101)
#Type of mosquito bed net(s) slept under last night
#                  0 | No net                            | 1161 |
#                  1 | Only treated nets                 | 1840 |
#                  2 | Both treated and untreated nets |    0 |
#                  3 | Only untreated nets               |    3 |
#                                        #Total cases | 3004 |

# re-coding in right hierarchical order: 0= no net; 1= only untreated, 2=
Both, 3= only treated (from worst to best)
medchild$bednettype <- medchild$ML101
medchild$bednettype <-  ifelse(medchild$ML101==1, 3, medchild$ML101)
medchild$bednettype <-  ifelse(medchild$ML101==3, 1, medchild$bednettype)
val_lab(medchild$bednettype) <- c("No net"=0, "only untreated" = 1, "Both
treated and untreated nets"=2, "only treated" = 3)
var_lab(medchild$bednettype)= "Type of mosquito bed net(s) slept under
last night - ordered"
cro(medchild$bednettype)

##-->V460 Children u5 slept under bed net
##   more informative then treated/no net = yes or not owning!
cro(medchild$V460)
# 0    No                  |    617 |
# 1  All children          |   1555 |
# 2 Some children          |    348 |
# 3 No net in household    |    396 |
#  Total cases             |   2916 |

#Compute dichotomous variable 1 and 2 = "slept under at least some
# children"=1; "no and not net" = 0
medchild$sleptbednet <- medchild$V460
medchild$sleptbednet <-  ifelse(medchild$V460==2, 1, medchild$V460)
medchild$sleptbednet <-  ifelse(medchild$V460==3, 0,
medchild$sleptbednet)
val_lab(medchild$sleptbednet) <- c("at least some children" = 1, "no
child or no net in household" = 0)
var_lab(medchild$sleptbednet)= "Children under 5 slept under mosquito bed
net last night (household questionnaire) binary"
cro(medchild$sleptbednet)

#recode V460 in hierarchical order:  no net=0, no=1, some=2, all=3
medchild$sleptbednet2 <- medchild$V460
medchild$sleptbednet2 <-  ifelse(medchild$V460==0, 1, medchild$V460)
medchild$sleptbednet2 <-  ifelse(medchild$V460==3, 0,
medchild$sleptbednet2)
medchild$sleptbednet2 <-  ifelse(medchild$V460==1, 3,
medchild$sleptbednet2) #2 stays 2
```

```
val_lab(medchild$sleptbednet2) <- c("No net in household" = 0, "no" = 1,
"Some children"=2, "All children"=3)
var_lab(medchild$sleptbednet2)= "Children under 5 slept under mosquito
bed net last night (household questionnaire) - ordered"
cro(medchild$sleptbednet2) #For MA

#### as HC seeking behaviour alternative:
#- Treatment seeking for pregnancy: Prenatal visits
cro(medchild$M2A)
medchild$prenatal <- NA
medchild$prenatal <- ifelse((medchild$M2A==1 | medchild$M2B==1 |
medchild$M2C==1), 2,
                            ifelse(medchild$M2G==1 | medchild$M2H==1 |
medchild$M2I==1 | medchild$M2K==1, 1,
                                   ifelse(medchild$M2N==1, 0 , NA)))
val_lab(medchild$prenatal) <- c("Health personnel"=2, "Other person"=1,
"none" =0)
var_lab(medchild$prenatal)= "Place for prenatal care"
cro(medchild$prenatal)
cro_cpct(medchild$H22bin, medchild$prenatal)
cro_cpct(medchild$H22, medchild$prenatal)

#
# children(c(4,5,6,7,8,9,14,15,16,17,
23,24,26,34,35,57,58,59,61,62,63,64,82, 83,84, 85, 86,87, 88,96,103,112,
113,114,115,116,117)]))
cro(children$H22, children[c(146:148, 152:154 , 156, 159)])

# - housing construction (Modern vs. traditional) - to be computed from
V127-V129
## calculate type of housing into modern/ traditional housing-dichotomy
#modern house = IMPROVED (non-earth floors, non-thatched roofs and non-
mud walls)
#$V127 FLOOR
#[1] "NATURAL"
#--> [2] "Earth/sand"   Unimproved
#--> [3] "Dung"         Unimproved
#[4] "RUDIMENTARY"
#[5] "Wood planks"      Improved
#[6] "Palm/bamboo"         Improved
#[7] "FINISHED"
#[8] "Parquet or polished wood"      Improved
#[9] "Vinyl or asphalt strips"      Improved
#[10] "Ceramic/marble/porcelain tiles/terrazo" Improved
#[11] "Cement"                                  Improved
#[12] "Woolen carpet/synthetic carpet"        Improved
#[13] "Linoleum/rubber carpet"                Improved
#[14] "Other"
#[15] "Not a dejure resident"
#Improved floor = Rudimentary and Finished materials, (everything except
for earth, sand, clay, mud and dung)
library(expss)
cro(medchild$V127)
medchild$floor_improved <- 0
medchild$floor_improved <- ifelse(medchild$V127==97, NA, 1)
medchild$floor_improved <- ifelse((medchild$V127==11 |medchild$V127==12),
0, 1)
val_lab(medchild$floor_improved) <- c("yes" = 1, "no" = 0)
var_lab(medchild$floor_improved)= "Floor improved y/n (1/0)"
cro(medchild$floor_improved)
```

```
#$V128 WALL
# Improved wall = finished wall
# finished =covered adobe, bricks, cement blocks, wood planks)
#[1] "NATURAL"          11 "No walls"              12 "Cane/palm/trunks"
#[4]13 "Mud/landcrete"       "RUDIMENTARY"          21  "Bamboo with mud"
#[7] 22 "Stone with mud"        23 "Uncovered adobe"     24   "Plywood"
#[10] 25 "Cardboard"           26   "Reused wood"            "FINISHED"
#[13] 31 "Cement"               32  "Stone with lime/cement" 33 "Bricks"
#[16] 34 "Cement blocks"         35 "Covered adobe"        36  "Wood
# planks/shingles"  [19] 96 "Other"        97 "Not a dejure resident"
cro(medchild$V128)
table(medchild$V128)
medchild$wall_improved <- 0
medchild$wall_improved <- ifelse(medchild$V128==97, NA, 1)
medchild$wall_improved <-
ifelse((medchild$V128==11|medchild$V128==12|medchild$V128==13|medchild$V1
28==21|medchild$V128==22|medchild$V128==24|medchild$V128==25|medchild$V12
8==26),
                                0,1)
val_lab(medchild$wall_improved) <- c("yes" = 1, "no" = 0)
var_lab(medchild$wall_improved)= "Wall improved y/n (1/0)"
cro(medchild$wall_improved)

#$V129 ROOF
#Improved roof categorized as having a finished roof
#(i.e., metal, wood, ceramic tiles, cement, roofing shingles)
#[1] "NATURAL"                       "No roof"
#[3] "Thatch/palm leaf"              "Sod"
#[5] "RUDIMENTARY"                   "Rustic mat"
#[7] "Palm/bamboo"                   "Wood planks"
#[9] "Cardboard"                     "FINISHED"
#[11] "Zinc/aluminum"                 "Wood"
#[13] "Ceramic/brick tiles"           "Cement"
#[15] "Roofing shingles"              "Asbestos/slate roofing sheets"
#[17] "Other"                         "Not a dejure resident"

cro(medchild$V129)
table(medchild$V129)
medchild$roof_improved <- 0
medchild$roof_improved <- ifelse(medchild$V129==97, NA, 1)
medchild$roof_improved <-
ifelse((medchild$V129==11|medchild$V129==12|medchild$V129==13|medchild$V1
29==21|medchild$V129==22|medchild$V129==23),
                                 0,1)
val_lab(medchild$roof_improved) <- c("yes" =1 , "no" =0)
var_lab(medchild$roof_improved)= "Roof improved y/n (1/0)"
cro(medchild$roof_improved)

#Composite variable "modernhousing" from improved floor, improved
wall,improved roof (yes in all 3 = modern)
medchild$modernhousing <- 0 # 0= traditional, 1= modern
medchild$modernhousing <- ifelse((medchild$floor_improved==1 &
medchild$wall_improved==1 &medchild$roof_improved==1), 1, 0)
val_lab(medchild$modernhousing) <- c("traditional" =0 , "modern" =1)
var_lab(medchild$modernhousing)= "housing type [modern vs. traditional
(1/0)]"
cro(medchild$modernhousing)
cro(medchild$V025, medchild$modernhousing)
cro(medchild$H22, medchild$modernhousing)
cro(medchild$S405A, medchild$modernhousing)
cro(medchild$quint_com2, medchild$modernhousing)
```

```
## 4. Confounder of SEP (in 'children')
# -Age [-->V012 current age mother!, V013 in 5y group mother; B8 current
age of child in years, B19/ HW1 in months ]
summary(medchild$V012)
# (-Sex) all female / Child: [B4] not necessary
cro(medchild$B4)
# - Area of residence (if not in WI) [children$V025]
# (-seasonality [children$V006 (month), V007 (year), V016 (day)] of
interview] - no: all in Oct,Nov,Dec 2019])

## 5. Outcome (in 'children')
# -> reported fever incidence (proxy) [children$H22]
cro(medchild$H22)
# | Had fever in last two weeks |           No |   1980 |
#|                              |          Yes |    929 |
 # |                             |   Don't know |     19
# |                              | #Total cases |   2928 |

#For mediation: needed binary outcome variable:
medchild$H22bin <- medchild$H22 # Set 19 "Don't know" as NA, to get
binary variable
medchild$H22bin<- ifelse(medchild$H22==8, NA, medchild$H22bin)
val_lab(medchild$H22bin) <- c("yes" =1 , "no" =0)
var_lab(medchild$H22bin)= "Had fever in last two weeks [y/n (1/0)]"
summary(medchild$H22bin)
cro(medchild$H22bin) #95 NA's, N=2928!!

# - RDT result
# - Result of malaria blood test [children$S405A]
cro(medchild$S405A)
#| Result of malaria blood test |                  Negative |     56 |
 # |                              |          Positive malaria |    232 |
  #|                              |    Positive other illness |     20 |
#  |                              | Don't know/don't remember |     46 |
#  |                              |              #Total cases |    354 |

#Descriptives Table:
# number of children aged under 5 and fever:
cro(medchild$B8, medchild$H22)
prop(table(medchild$B8, medchild$H22))
plot(table(medchild$B8, medchild$H22)) #age by fever
#    0   1   8
#0 465 169   0
#1 385 205   1
#2 359 227   6
#3 381 189   6
#4 390 139   6

plot(table(medchild$B8, medchild$S405A)) # age by malaria blood result
#   0  1  2  8
#0 12 28  8  6
#1 21 59  3 14
#2 12 63  5 12
#3  3 46  3 10
#4  8 36  1  4

cro(medchild$quint_com2, medchild$H22)

############################################################
# Effect of SEP (WI) on Fever without Mediator:
```

```
#univariate
x = glm(medchild$H22bin ~ factor(medchild$quint_com2),
family=binomial("logit"))
summary(x)
exp(x$coefficients)
exp(cbind(coef(x), confint(x)))
with(x, null.deviance - deviance)
with(x, df.null - df.residual)
with(x, pchisq(null.deviance - deviance, df.null - df.residual,
lower.tail = FALSE))
logLik(x)

#multivariate   (Mothers age as confounder)
y = glm(medchild$H22bin ~ factor(medchild$quint_com2) + medchild$V012,
family=binomial("logit"))
summary(y)
exp(cbind(coef(y), confint(y)))
with(y, null.deviance - deviance)
with(y, df.null - df.residual)
with(y, pchisq(null.deviance - deviance, df.null - df.residual,
lower.tail = FALSE))
logLik(y)

#multivariate   (Mothers age and houshold size as confounder)
y2 = glm(medchild$H22bin ~ factor(medchild$quint_com2) + medchild$V012 +
medchild$HV012, family=binomial("logit"))
summary(y2)
exp(cbind(coef(y2), confint(y2)))


#Explorative: same with given Wealth Index as exposure
ygiven = glm(medchild$H22bin ~ medchild$V190A + medchild$V012 +
medchild$HV012, family=binomial("logit"))
summary(ygiven)
exp(ygiven$coefficients)
exp(cbind(coef(ygiven), confint(ygiven)))

ygiven2 = glm(medchild$H22bin ~ factor(medchild$V190A) + medchild$V012 +
medchild$HV012, family=binomial("logit"))
summary(ygiven2)
exp(cbind(coef(ygiven2), confint(ygiven2)))

# association between Educational Attainment and Fever (no mediation)
#univariate
EAonFever = glm(medchild$H22bin ~ factor(medchild$V149),
family=binomial("logit"))
summary(EAonFever)
exp(EAonFever$coefficients)
exp(cbind(coef(EAonFever), confint(EAonFever)))

#multivariate   (Mothers age as confounder)
EAonFever2 = glm(medchild$H22bin ~ factor(medchild$V149)+ medchild$V012,
family=binomial("logit"))
summary(EAonFever2)
exp(EAonFever2$coefficients)
exp(cbind(coef(EAonFever2), confint(EAonFever2)))

#########################################################################
#######           MEDIATION with "medflex"-Package -  Command   #########
#########################################################################
# neImpute(  object,  formula,  data,  nMed = 1,  nRep = 5,  xSampling =#
```

```
# c("quantiles", "random"),                                                    #
#  xFit,  percLim = c(0.05, 0.95),  ...)                                       #
# formular= Y ~ X + M1 + M2 + M3 + C1 + C2                                     #
# impData <- neImpute(UPB ~ att + initiator * negaff + gender + educ +  #
# age,       + family = binomial("logit"), nMed = 2, data = UPBdata)    #
# neMod6 <- neModel(UPB ~ att0 + att1 + gender + educ + age,            #
#        + family = binomial("logit"), expData = impData, se = "robust")#
#################################################################################

#Model 1 - single mediation of education: SEP <-> education <->
age=confounder -> Fever
impData1 <- neImpute(H22bin ~ factor(quint_com2) + V149 + V012, family =
binomial("logit"), maxit=100, data = medchild )
head(impData1)
neMod1 <- neModel(H22bin ~ quint_com20+quint_com21  + V012, family =
binomial("logit"), expData = impData1)        #Bootstrap Standarderror

#Model 2: SEP <-> (education + modern housing <-> Age )-> Fever
impData2 <- neImpute(H22bin ~ factor(quint_com2) + V149+modernhousing +
V012, family = binomial("logit"),maxit=100, nMed=2, data = medchild )
head(impData2)
neMod2 <- neModel(H22bin ~ quint_com20+quint_com21 + V012, family =
binomial("logit"), expData = impData2)

#Model 3: SEP - education + (sleptbednet2) Children u5 slept under LLIN->
# Fever with ordered categories for slepbednet
impData3 <- neImpute(H22bin ~ factor(quint_com2) +V149 + sleptbednet2  +
V012, family = binomial("logit"),maxit=100, nMed=2, data = medchild )
head(impData3)
neMod3 <- neModel(H22bin ~ quint_com20+quint_com21  + V012, family =
binomial("logit"), expData = impData3)

#Mediation  SEP <-> education + Prenatal care facility <-> Age --> Fever
impData4 <- neImpute(H22bin ~ factor(quint_com2) +V149+ prenatal + V012,
family = binomial("logit"), maxit=100, nMed=2, data = medchild)
head(impDat4)
neMod4 <- neModel(H22bin ~ quint_com20+quint_com21  + V012, family =
binomial("logit"), expData = impData4)

# Mediation with all 4Mediators
# SEP-> EA + Housing + LLIN use + prenatal care -> Fever
impDatall <- neImpute(H22bin ~ factor(quint_com2) +
V149+modernhousing+sleptbednet2+prenatal+ V012,  family =
binomial("logit"), maxit=100, nMed=4, data = medchild )
head(impDatall)
neModall <- neModel(H22bin ~ quint_com20+quint_com21 + V012,
                    family = binomial("logit"), expData = impDatall)

################## Results #################
summary(neMod1)
summary(neMod2)
summary(neMod3)
summary(neMod4)
summary(neModall)

#EFFECT DECOMPOSITION
summary(neEffdecomp(neMod1))
summary(neEffdecomp(neMod2))
summary(neEffdecomp(neMod3))
summary(neEffdecomp(neMod4))
summary(neEffdecomp(neModall))
```

```
# ANOVA
library(car)
Anova(neMod1)
Anova(neMod2)
Anova(neMod3)
Anova(neMod4)
Anova(neModall)

#  Odds ratios:
logistic.display(neMod1)
logistic.display(neMod2)
logistic.display(neMod3)
logistic.display(neMod4)
logistic.display(neModall)

medchild_backup  <- medchild
write.csv(medchild,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesi
s/Analysis/Results/medchild.csv", row.names = FALSE)

cro(medchild$H22bin)
xtabs(medchild$H22bin ~ medchild$quint_com2)
xtabs(medchild$H22bin ~ medchild$V149)
```

iv. Calculation descriptive results

```
### Results - Descriptive Tables ###
### Theresa Habermann 08.04.2021 ###
### based on dataframes: medchild, hh_all
library(dplyr)
install.packages()
library(sjlabelled)
library(expss)

# Table 1: Characteristics of study participants of MIS2019 in Ghana
# mean age child B19,  mean age mother V012, % female children B4, EA
describe(medchild$B19) #age children in months

descr_medchild<- describe(medchild)
write.csv(descr_medchild,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Maste
rthesis/Analysis/Results/descr_medchild3.csv", row.names = TRUE)
get_label(medchild) # import labels to variable names manually
descr_medchild
cro(medchild$quint_com2, (mean(medchild$B19)))
cro((colMeans(medchild$B19)), medchild$quint_com2)

#mean age of children in WI-quintiles
describe(medchild$B19[medchild$quint_com2==1])
describe(medchild$B19[medchild$quint_com2==2])
describe(medchild$B19[medchild$quint_com2==3])
describe(medchild$B19[medchild$quint_com2==4])
describe(medchild$B19[medchild$quint_com2==5])

#mean age of mothers in WI-quintiles
describe(medchild$V012[medchild$quint_com2==1])
describe(medchild$V012[medchild$quint_com2==2])
describe(medchild$V012[medchild$quint_com2==3])
describe(medchild$V012[medchild$quint_com2==4])
describe(medchild$V012[medchild$quint_com2==5])
```

```
table1 <- cro(medchild[c(4,5,6,7,8,9,14,15,16,17,
23,24,26,34,35,57,58,59,61,62,63,64,82, 83,84, 85, 86,87, 88,96,103,112,
113,114,115,116,117)])
table1_prop <- cro_cpct(medchild[c(4,5,6,7, 8,9,14,15,16,17,
23,24,26,34,35,57, 58,59,61,62,63,64,82, 83,84, 85, 86,87, 88,96,103,112,
113,114,115,116,117)])
write.csv(table1,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthesis/
Analysis/Results/table1.csv", row.names = TRUE)
write.csv(table1_prop,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterth
esis/Analysis/Results/table1_prop.csv", row.names = TRUE)
cro(medchild$H46A)

#Table 1 by WI
table1_wi <- cro((medchild$quint_com2),
(medchild[c(4,5,6,7,8,9,14,15,16,17,
23,24,26,34,35,57,58,59,61,62,63,64,82, 83,84, 85, 86,87, 88,96,103,112,
113,114,115,116,117,128)]))
table1_wi_prop <- cro_cpct((medchild$quint_com2),
(medchild[c(4,5,6,7,8,9,14,15,16,17, 23,24,26,34,35,57,
58,59,61,62,63,64,82, 83,84, 85, 86,87, 88,96,103,112,
113,114,115,116,117,128)]))
write.csv(table1_wi,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthes
is/Analysis/Results/table1_wi2.csv", row.names = TRUE)
write.csv(table1_wi_prop,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Maste
rthesis/Analysis/Results/table1_wi2_prop.csv", row.names = TRUE)

#Table1 by Fever event
table1_fe <- cro((medchild$H22), (medchild[c(4,5,6,7,8,9,14,15,16,17,18,
23,24,26:34,57,58,61,62,63,64,80, 82, 83,84, 85, 86,87, 88,92,
96,103,112, 113,114,115,117,128)]))
table1_fe_prop <- cro_cpct((medchild$H22),
(medchild[c(4,5,6,7,8,9,14,15,16,17,18, 23,24,26:34,57,58,61,62,63,64,80,
82, 83,84, 85, 86,87, 88,92, 96,103,112, 113,114,115,117,128)]))
write.csv(table1_fe,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthes
is/Analysis/Results/table1_fe.csv", row.names = TRUE)
write.csv(table1_fe_prop,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Maste
rthesis/Analysis/Results/table1_fe_prop.csv", row.names = TRUE)

table1_fe_2 <- cro((children$H22), (children[c(117:121, 126, 146:148,
152:154, 156, 159, 160, 161, 172, 173, 176:179, 184:185, 194, 263,
307)]))
table1_fe_2_prop <- cro_cpct((children$H22), (children[c(117:121, 126,
146:148, 152:154, 156, 159, 160, 161, 172, 173, 176:179, 184:185, 194,
263, 307)]))
write.csv(table1_fe_2,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterth
esis/Analysis/Results/table1_fe_2.csv", row.names = TRUE)
write.csv(table1_fe_2_prop,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Mas
terthesis/Analysis/Results/table1_fe_2_prop.csv", row.names = TRUE)

#Table 2: Characteristics of households assets of MIS2019 in Ghana
# Table 2. Descriptive Tables PCA - Assets distribution
# set_caption("Table 2. Number of Households with Household Assets")
get_label(hh_rural)
table2 <- cro((household$HV025), (household[c(53, 55:68, 73:75,80:85,
87:96, 99, 119:129)]))
write.csv(table2_rur,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterthe
sis/Analysis/Results/table2_rur2.csv", row.names = TRUE)
table2_prop <- cro_cpct((household$HV025), (household[c(53, 55:68,
73:75,80:85, 87:96, 99, 119:129)]))
write.csv(table2_prop,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Masterth
esis/Analysis/Results/table2_rur2prop.csv", row.names = TRUE)
```

```
cro(household$HV025),household$)

# table 2 PCA used assets
table2_assets <- cro((hh_all$HV025), (hh_all[c(3:16, 26:121)]))
write.csv(table2_assets,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/Master
thesis/Analysis/Results/table2_assets.csv", row.names = TRUE)
table2_assets_prop <- cro_cpct((hh_all$HV025), (hh_all[c(3:16, 26:121)]))
write.csv(table2_assets_prop,"C:/Users/Theresa/Documents/BNITM_KEEP/MBC/M
asterthesis/Analysis/Results/table2_assets_prop.csv", row.names = TRUE)

cro(medchild$quint_com2, medchild$prenatal)
cro_cpct(medchild$quint_com2, medchild$prenatal)
cro(medchild$H22bin, medchild$prenatal)
cro_cpct(medchild$H22bin, medchild$prenatal)

cro(medchild$quint_com2, medchild$B19)
cro_cpct(medchild$prenatal)

describe(household$HV012)
describe(household$HV012[household$HV025==1])
describe(household$HV012[household$HV025==2])
describe(household$HV014)

#description of malaria and anemia level by fever and WI
cro_cpct(medchild$H22bin, medchild$HW57)
cro_cpct(medchild$H22bin, medchild$S405A)
cro_cpct(medchild$quint_com2, medchild$HW57)
cro_cpct(medchild$quint_com2, medchild$S405A)
```

Please note:

- the numbering of tables in this syntax is not in line with the actual table numbering within this thesis. The needed descriptives were extracted to excel for easier formatting and were further calculated if needed.
- Not all calculated tables are presented in the thesis, as some were created for understanding of the underlying data in an explorative way and not relevant for answering the research question.

E Supplement of results

Annex Table 2: Addition for Table 4 (expression of housing material across HWI)

Expression of housing material across individuals		Total		HWI quintile									
		n	%	Lowest		Second		Middle		Fourth		Highest	
				n	%	n	%	n	%	n	%	n	%
Floor improved	no	302	10.1	98	32.5	77	25.5	50	16.6	33	10.9	44	14.6
	yes	2702	89.9	558	20.7	543	20.1	529	19.6	553	20.5	519	19.2
Wall improved	no	796	26.5	231	29.0	198	24.9	140	17.6	122	15.3	105	13.2
	yes	2208	73.5	425	19.3	422	19.1	439	19.9	464	21.0	458	20.7
Roof improved	no	154	5.1	59	38.3	28	18.2	22	14.3	21	13.6	24	15.6
	yes	2850	95.9	597	21.0	592	20.8	557	19.5	565	19.8	539	18.9

Annex Table 3: Effect of HWI on fever event – binary logistic regression

		Unadjusted				adjusted			
		β	**SE**	**z**	**p**	**β**	**SE**	**z**	**p**
HWI	intercept	-0.83	0.09	-9.70	<0.001	-0.47	0.19	-2.44	0.01
	2	0.12	0.12	1.01	0.31	0.13	0.12	1.04	0.30
	3	0.04	0.13	0.32	0.75	0.05	0.13	0.37	0.71
	4	0.23	0.12	1.87	0.06.	0.24	0.12	1.98	0.05*
	5	-0.02	0.13	-0.18	0.85	-0.03	0.13	-0.22	0.83
Mother's age		-	-	-	-	-0.01	0.01	-2.11	0.03
		OR	**95% CI**	χ^2	**df**	**aOR**	**95% CI**	χ^2	**df**
HWI	intercept	0.44	0.37; 0.51	5.396	4	0.63	0.43; 0.91		
	2	1.13	0.89; 1.44			1.14	0.89; 1.44		
	3	1.04	0.81; 1.33			1.05	0.82; 1.34		
	4	1.26	0.99; 1.60			**1.28**	**1.00; 1.62**		
	5	0.98	0.76; 1.25			0.97	0.76; 1.25		
Mother's age		-	-	-	-	0.99	0.98; 0.99		

Declaration of independent work

I hereby declare that I wrote this thesis without any assistance and used only the aids listed. Any material taken from other published and unpublished works, either as a quote or idea have been indicated under ‘References’. This thesis, with the same content or has not been submitted. The thesis has never been submitted to an examination office with the same content or essential parts before.

Hamburg, 18th August 2021

[redacted]

Theresa Habermann