PREVENTING MALARIA IN WESTERN KENYA THROUGH EDUCATIONAL INTERVENTIONS AND TREATMENT COMBINATION OF INDOOR RESIDUAL SPRAYING WITH INSECTICIDE TREATED MOSQUITO NETS: AN INTEGRATED REVIEW

A Scholarly Project

Submitted to the

Faculty of Liberty University

In partial fulfillment of the requirements for the

degree of Doctor of Nursing Practice

By

Banis Githinji

Liberty University

Lynchburg, VA

July 2021

PREVENTING MALARIA IN WESTERN KENYA THROUGH EDUCATIONAL INTERVENTIONS AND TREATMENT COMBINATION OF INDOOR RESIDUAL SPRAYING WITH INSECTICIDE TREATED MOSQUITO NETS: AN INTEGRATED REVIEW

A Scholarly Project

Submitted to the

Faculty of Liberty University

In partial fulfillment of the requirements for the

degree of Doctor of Nursing Practice

By

Banis Githinji

Liberty University

Lynchburg, VA

July 2021

Scholarly Project Chair Approval:

Dr. Odedina, DNP, FNP-C, PMHNP-BC Date: July 27th, 2021

Abstract

Over the years, several Malaria prevention strategies have been deployed in western Kenya with the aim of reducing malaria infection rates. However, those rates continue to be disproportionally higher in western Kenya compared to other regions of the country. The objective of this review is to determine factors that contribute to higher malaria infection rates in western Kenya compared to other regions in the country. The review will also examine past literature to determine if combining educational interventions with treatment interventions offers greater protection against malaria compared to treatment interventions alone. First, the project will compare the geographic and human characteristics of western Kenya to other regions. Second, the study will identify success barriers to previously deployed strategies. Third, the review will determine effects of combining interventions and develop educational and treatment interventions to strengthen current and future malaria prevention strategies and campaigns.

Keywords: malaria, western Kenya, malaria prevention, indoor residual spraying, insecticide treated nets, mosquitos, Insecticide-treated Nets (ITNs), Indoor Residual Spraying (IRS).

Table of Contents

SECTION ONE: INTRODUCTION

Malaria is a disease transmitted to humans through the bites of infected mosquitos. Malaria symptoms develop 10-15 days after a bite by a mosquito infected with the plasmodium parasite (Plewes et al., 2018). The parasite injected during feeding enters the circulatory system, replicates and infects red blood cells (Plewes et al., 2018). To eliminate infected red blood cells, splenic phagocytosis begins releasing cytokines which cause malaria symptoms including chills, fever, hypotension, headache, and perspiration (Plewes et al., 2018). Cytokines also inhibit the production of red blood cells further contributing to anemia and hypoxia. During the phagocytosis process, two cytokines, Interferon gamma (IFN-γ) and Tumor Necrosis Factor alpha (TNF alpha) are released (Plewes et al., 2018). These cytokines induce vasoconstriction in blood vessels in the brain and kidneys. As a result, vasoconstriction coupled with obstruction of blood vessels by infected red blood cells causes two fatal complications of malaria: cerebral malaria, and acute kidney injury. In cerebral malaria, obstruction of blood vessels results into cerebral edema and encephalopathy causing serious neurocognitive outcomes such as confusion, delirium, seizures, and coma (Plewes et al., 2018). Similar obstruction of blood vessels in the kidney coupled with hypovolemia results to tubular necrosis and kidney failure (Plewes et al., 2018).

The global rate of malaria related deaths has dropped, however, malaria rates in certain regions of sub-Sahara Africa remains a global health burden and a leading cause of death. In 2018, an estimated 429,000 malaria deaths were reported worldwide, and 92 percent of those deaths were in Africa (Kapesa et al., 2018). Malaria also accounts for 25 to 35 percent of outpatient visits, 20 to 45 percent of hospital admissions, and 15 to 35 percent of hospital deaths in endemic regions of sub-Saharan Africa (Kapesa et al., 2018).

Unfortunately, children and pregnant women are disproportionally affected by malaria. The World Health Organization (WHO,2019) reports that 67 percent of malaria deaths worldwide occur in children less than five years of age. It is estimated that 25 million pregnancies are at risk in Africa each year (Goshu & Yitayew, 2019). Due to immune changes related to pregnancy, malaria in pregnant women causes serious outcomes on the mother and the fetus. Some of the complications of malaria during pregnancy include, anemia, fetal demise, premature delivery, miscarriage, low birth weight, intrauterine growth retardation and maternal death (Goshu & Yitayew, 2019; Musoke et al.2015).

Although antimalarial drugs have been developed, malaria drugs sold in sub-Saharan Africa have been found to be counterfeit, falsified and potentially harmful to the consumer. An antimalarial drug quality review completed between 2001 and 2010 found that 35 percent of antimalarial drugs sold in sub-Saharan Africa failed chemical analysis (Renschler et al., 2015). The widespread counterfeiting may result from inadequate drug quality surveillance resulting from only three WHO qualified laboratories for drug quality testing in Sub-Saharan Africa (Renschler et al., 2015). Such limitations in regulations on drug production heighten risk for complications related to consumption of adulterated malaria drugs and stress the need to prioritize malaria prevention strategies over current pharmacological treatments.

Despite massive campaign efforts to increase mosquito net ownership and the availability of antimalarial drugs and malaria vaccines in sub-Saharan Africa, malaria rates remained stagnant between 2015 and 2017 (WHO, 2019). This is partially due to ineffective malaria treatments and vaccines available in Africa. For instance, the efficacy rate of the novel malaria vaccine, the RTS subunit vaccine, is only 30 to 50 percent. (Mbanefo & Kumar, 2020). Ongoing resistance to antimalarial drugs also creates barriers to long-term use of antimalarial drugs.

Therefore, a new approach to achieving malaria prevention goals such as transmission control measures, vector control, and education at community level must be prioritized.

The financial burden of malaria must also be recognized to best inform malaria control initiatives. Currently, mortality and morbidity related to malaria causes significant financial strain on already burdened healthcare systems. In endemic countries, malaria accounts for 40 percent of public health expenditure (Goshu & Yitayew, 2019). As of 2019, the global Malaria budget reached $3 billion (Atieli et al., 2011). In Kenya alone, the government spends about $34 million on malaria yearly in addition to donations from other countries (Atieli et al., 2011). In 2018, the Kenyan ministry of health proposed a five -year malaria prevention budget of $583 million as part of the Key Malaria Strategy (KMS) initiative (Lindblade & Kachur, 2020). The proposed amount is significant for a country with budget constraints and a weak healthcare system. Therefore, implementing malaria prevention strategies will have an impact on financial spending on a global and local scale.

The financial impact of malaria extends beyond the national government level to the community. The average cost of malaria treatment in Kenya, including provider visits and drugs, ranged from $11.24 to $287.81 (Sicuri et al., 2013). These costs pose significant financial burden on households with high and increasing poverty levels. Despite economic burden, it is also worth noting the productivity consequences of malaria on individuals. Asale et al., (2019) found that, in Ethiopia, an average of 6.3 workdays and 2.3 school days are lost each year in a household due to malaria. In Kenya, where 60 percent of the population falls below poverty line, these costs are detrimental and a deterrent to seek medical attention (Krishna et al., 2004). Thus, stressing the need for preventative measures in the face of costly malaria treatments is essential.

Background

Western Kenya remains highly endemic with a disproportionate burden of malaria infections compared to other regions of Kenya. Although ITN coverage has increased in Kenya, the Kenya National Bureau of Statistics (KNBS) reports that malaria is still the second most reported cause of death in Kenya after respiratory infections (Sultana et al., 2017). Currently, studies show that 70 percent of the people living in western Kenya are at risk of contracting malaria (Touray et al., 2020).

Western Kenya has a significantly higher malaria prevalence rate of 27 percent compared to the national average of 8 percent (Were et al. 2019). Malaria has also been the leading cause of mortality in infants and the cause of 20 percent deaths in children under the age of five in this region (Pathania, 2014). A variety of factors have been linked to increased malaria rates in western Kenya including climate, infrastructure, overpopulation, poverty, low malaria transmission literacy, cultural beliefs, and education. Other culture practices such as outdoor nighttime mourning, have been linked to increased exposure to mosquito bites, hence increased malaria rates (Ng'ang'a et al., 2021).

Emerging novel viruses such as the Covid-19 virus highlight the need to focus efforts on disease prevention. To do so, efforts must be made to identify environmental risk factors to ensure that appropriate mitigation strategies are in place. Environmental factors such as climate change must be evaluated since mosquito breeding is greatly influenced by climate change. According to Nabi and Qader (2018), rising temperatures resulting from global warming will likely change rain patterns and lengthen rainfall seasons, creating an unprecedented rise in sea levels that will result in flooding. Increased humidity and rain resulting from global warming will also present favorable conditions for mosquito breeding, further increasing risk for malaria

transmission in endemic regions. To this end, prompt action is needed to address environmental risk factors, reinforce education on mitigation measures, and identify additional prevention strategies to further reduce malaria rates in western Kenya.

Problem Statement

Insecticide-treated Nets (ITNs) and Indoor Residual Spraying (IRS) are the most used malaria prevention strategies in western Kenya. Introduction of ITNs and IRS has reduced malaria prevalence by 60 percent (Brown et al., 2016). ITN involves the use of an insecticide containing bed net to prevent mosquito bites. IRS on the other hand, involves spraying indoor walls and surfaces with insecticides to discourage mosquito resting. In addition to ITNs and IRS. other preventative strategies previously implemented in western Kenya include intermittent mass testing and treatment, prophylactic antimalarial treatment, mass mosquito trapping, coils, and malaria vaccines. Despite these interventions, malaria infection rates remain high in western Kenya compared to other regions.

ITNs remain the most used form of vector control worldwide and have been found to be both more effective and less costly compared to IRS. This is due to the fact that ITNs offer protection in two ways: (1) by protecting against the mosquito bite and (2) killing mosquitos that try to bite. In western Kenya, ITN use was found to reduce malaria transmission rate by 63 percent (Ng'ang'a et al., 2021). ITN use has also been shown to decrease childhood mortality in malaria endemic regions by 20 percent (Atieli et al., 2011). As a result, malaria eradication efforts have focused on increasing ITN ownership. Between 2004 and 2015, 50.2 million ITNs were distributed in western Kenya (Ng'ang'a et al. 2021).

Although improvement in ITN availability has been noted in western Kenya, ITN utilization remains low (Atieli et al., 2011; Zhou et al., 2014). For example, following the ITN

mass distribution in 2004 and 2015, ITN ownership increased to 85 percent compared to 18 percent in 2003 (Zhou et al., 2016). (Githinji et al., 2010) found that although 95 percent of the population owned a mosquito net, only 59 percent used the nets. Factors associated with low ITN usage included malaria transmission knowledge gaps, education level, misconception about ITN efficacy and health effects and perception that purchased bed nets are more effective than free ones (Ernst et al., 2016; Hamel et al., 2011).

In recent years, IRS with DDT has been recognized as an effective malaria control measure. DDT is one of the 12 recommended insecticides for IRS. However, DDT use has been banned in some countries including in the United States (US). Since the ban of DDT in the US in 1970, a global DDT ban was proposed but challenged due to lack of alternative cost-effective insecticides for malaria control (Rogan & Chen, 2005). Compared to other insecticides, DDT has been found to have the longest efficacy of six to 12 months (WHO,2017). A meta regression analysis of 13 studies in endemic regions in Africa, Asia, south and central America also found that DDT was more effective in reducing malaria incidence compared to other insecticides (Kim et al., 2012). Recent studies have found DDT to have lower risk for resistance compared to other insecticides used for IRS. The use of DDT has been challenged due to concerns about safety and pollution.

Risk associated with DDT ingestion has been reported but the long-term risks of DDT exposure are not well known. Although DDT health effects have been seen on animal models, researchers reviewed epidemiological data and found that DDT exposure was minimal and therefore, no cause for concern for human health (WHO,2017). Based on the potential risk to humans and the environment, organizations such as the United Nations Environmental Program (UNEP) have proposed reducing and eventually eliminate DDT use. However, proposals to ban

DDT use have been challenged in light of the need to maintain malaria control until cost effective measures are developed.

Compared to other insecticides, DDT is relatively more economical and therefore an ideal choice in developing countries. DDT also has longer efficacy because it requires two sprays a year compared to pyrethroids and carbamates which require between three to six sprays a year (WHO,2017). Less need for repeated spraying with DDT also decreases risk for resistance making it a favorable choice for vector control. Factors related to DDT cost and efficacy create barriers in introducing other costly alternatives in developing countries. The need to switch from DDT to other insecticides has further been challenged by the resurgence of malaria in countries where DDT has been replaced with other insecticides. In South Africa for instance, switching from DDT to pytheroids increased malaria infection rates due to mosquito resistance to pytheroid after three years (WHO,2017). Given the potential health and environmental risks associated with DDT use, the WHO has reserved DDT use only for IRS until other sustainable and cost-effective alternatives are available.

In 2006, WHO encouraged scaling up of IRS in malaria control programs. Introduction of IRS was shown to offer protection to 75 million people in Africa in 2009 (Kim et al., 2012). Promising effects of IRS led the development of campaigns to increase IRS spraying in Sub-Saharan Africa. Despite the direct effect of mosquito control, IRS is under-utilized in western Kenya. Gaps in IRS utilization and uptake are mainly due to cost, fear of harmful effects on humans, the environment, and the demanding logistics of spraying. Economic, societal, and demographic factors also play a role in malaria disparities in Kenya.

The overwhelming evidence on the benefits and effectiveness of ITNs and IRS in preventing malaria transmission underscore the need to examine the effect of combining ITN and

IRS to determine if combined intervention offers greater protection. To best guide malaria control efforts, identification of factors associated with ITN, and IRS nonuse is critical. Identifying reasons affecting ITN and IRS uptake will guide development of educational interventions to increase malaria transmission knowledge and clarify misconceptions to help increase intervention uptake. Additionally, identifying ITN ownership gaps in western Kenya will inform malaria control programs on where to prioritize ITN allocation to bridge coverage disparities and increase ITN usage in western Kenya.

Purpose of the Project

The focus of this project is to assess human, environmental, and economic factors contributing to higher malaria rates in western Kenya to guide the development of malaria prevention strategies specific to that region. First, the review explored the use of ITNs and IRS in the region to determine effectiveness and identify gaps in implementation and utilization. Understanding gaps in utilization of current interventions clarified the need to integrate educational interventions to improve malaria literacy and ensure sustainability of interventions. The review also explored the benefits of combining IRS with ITN to determine if combining interventions offered greater protection compared to using the interventions separately. To further strengthen these interventions, the review also surveyed literature on previously deployed malaria education to determine if integrating educational interventions could increase ITN and IRS use in this region.

Clinical Question

In western Kenya, does education and treatment combining Indoor Residual Spraying (IRS) with Insecticides-treated Nets (ITNs) provide more protection from malaria infection compared to the use of ITNs and IRS without education?

SECTION TWO: LITERATURE REVIEW

Literature Search

To conduct this review, three databases—Google scholar, PubMed, and the Cochrane Library—were used to obtain literature. Specific key words were used to obtain articles addressing malaria prevention strategies in western Kenya. Key search words used to obtain literature included “malaria prevention,” “malaria in western Kenya,” “malaria mortality,” “malaria coverage,” “insecticide-treated nets,” “indoor spraying,” and “indoor spraying with insecticide-treated nets”. To enhance the quality of this review, the author consulted a librarian at the National Institute of Health (NIH) to assist with the literature search. The author also completed training on navigating Covidence and EndNote at the NIH.

The database search generated 2,754 articles; 711 duplicate articles were removed, and the remaining 2,043 articles were included in the screening. References from all 2,043 articles were placed on EndNote and transferred to Covidence, a screening and extraction tool that is used to streamline articles and data quality. Using Covidence, title and abstract screening was completed, and 1,892 studies were removed as they did not meet the inclusion and exclusion criteria. A thorough full text screening was done on the remaining 151 articles; 126 articles were excluded, as they did not provide useful content. Critical appraisal of the remaining 25 studies was completed using Critical Appraisal Skills (CASP) checklist and included in the review

Inclusion Criteria

Due to the vast amount of available literature related to malaria, inclusion and exclusion criteria were used to narrow the search. Inclusion criteria included peer reviewed articles published in English in the past ten years and studies focusing on the following interventions of interest: malaria literacy, malaria transmission, malaria misconception, ITN ownership and use,

IRS use, and the combined use of ITNs with IRS. Only articles addressing malaria morbidity, malaria prevention, malaria campaigns, and malaria education were included in the review. Due to the limited number of articles on educational interventions deployed in western Kenya, the search on educational interventions was expanded to include studies conducted in endemic regions in Uganda, Ethiopia, and Kenya. The decision to include Uganda and Ethiopia in this review was made based on a scan of literature revealing malaria knowledge gaps, malaria mortality rates and geographic characteristics similar to western Kenya.

Exclusion Criteria

To prevent missing relevant findings, a scan of literature predating 10 years was done. The researcher found that studies older than 10 years did not address the clinical question and therefore not relevant. Hence, the review excluded articles older than 10 years to ensure that findings were current and relevant. Using the Melynk level of evidence, articles were assessed for level of evidence and articles with level seven evidence were excluded from the review. Articles addressing the use of coils, skin repellent sprays, and malaria vaccines and medications were also excluded from the review because they did not align with the purpose of this study. To best serve the population of interest, studies conducted in non-endemic regions of western Kenya, Uganda and Ethiopia were also excluded. The review also excluded articles with a sample size of less than 200, which is too small to generalize findings.

Critical Appraisal

The critical appraisal process is an essential step in the literature review because it guides the inclusion and exclusion process to ensure that selected articles are applicable and relevant to the phenomenon of interest (Moran et al., 2020). Critical appraisal requires the researcher to thoroughly review literature to ensure that aim, population, and outcomes are clearly stated. The

appraisal process is also useful in assessing risk of bias and to identify deviations, missing evidence, and inconsistencies. By thoroughly appraising the literature, the researcher will determine the value, relevance, and applicability of findings.

The critical appraisal of literature in this project was completed using the CASP checklist. The checklist was used to assess the design, methodology, and quality of the studies. The articles were assessed for bias and missing or incomplete data. Using the CASP checklist, the researcher evaluated outcomes of interventions to determine if they matched interventions of interest. Findings were examined to ensure they align with the aim of the review. The CASP checklist was also used to determine if the population presented in the studies accurately represented the people of western Kenya to ensure results are relevant and generalizable.

To further enhance the critical appraisal process, a leveling matrix was used to examine essential aspects of the selected articles, such as study design, level of evidence, sample population, limitations, and outcome of findings. The leveling matrix allowed the researcher to compare study designs of individual and group studies by level of evidence. Additionally, the leveling matrix was also used to identify themes, compare the sample size, setting and interventions, and link interventions to outcomes.

Synthesis

Although numerous efforts have been made to increase treatment interventions through ITN coverage and antimalarial drug campaigns, the review highlights that utilization gaps still exist due to knowledge limitation on malaria transmission. The reviews included in this study consistently found low knowledge on malaria transmission while at the same time finding high knowledge of malaria symptoms. Majority of the studies found a link between education level and malaria transmission knowledge. Those with higher educational levels—at least secondary

level education—were found to have better knowledge of malaria transmission compared to those without such education. Although studies evaluating outcomes of malaria education on ITN and IRS uptake were limited, one study reviewed malaria teaching in western Kenya between 2004 and 2010 and found a 93 percent increase in malaria literacy as a consequence of that teaching (Zhou et al., 2020). These findings highlight the potential of integrating malaria education as a standard practice in malaria control initiatives.

The review found reoccurring themes on ITN ownership and utilization gaps. A survey in a rural area in western Kenya that aimed to assess ITN ownership and usage highlights gaps in utilization, noting that although 95 percent of the sample owned a mosquito net only 59 percent of them slept under the net (Githinji et al., 2010). Studies evaluating ITN coverage after mass distribution campaigns in western Kenya found decreased coverage after one year. This drop in coverage was attributed to loss, ITNs being used for other purposes such as fishing and population growth (Zhou et al., 2014). Additional factors linked to ITN adoption and utilization gaps included knowledge deficit regarding malaria transmission and distribution disparities during free ITN distribution campaigns resulting to higher ITN ownership in lowlands compared to highlands. Despite higher ITN coverage in lowlands, low usage was found in the lowlands compared to highlands. Reasons for ITN nonuse varied based on geographic, social, and economic challenges. Additional factors linked to ITN nonuse included education level, occupation, and social-economic status. Among these factors, education level was consistently linked to ITN nonuse in western Kenya, Uganda, and Ethiopia. Coupled with ownership gaps, the factors linked to ITN nonuse were found to be barriers to the success of malaria control programs.

Compared to ITN, the volume of literature addressing IRS use in western Kenya was smaller. Available studies in western Kenya reported the benefits of IRS; however, studies in other countries showed mixed results. Despite the reported benefits of IRS in western Kenya, IRS uptake was also low due to fear of health risks and logistics barriers related to IRS spraying. Some of the logistics barriers include privacy concerns by allowing sprayers to enter the homes, inconvenience of leaving the home before and after spraying and moving items from the home during spraying (Ediau et al., 2013).

ITN coverage disparities during free ITN distribution campaigns were consistently reported resulting to higher ITN ownership in some regions compared to others. In addition to social factors, geographic factors influencing higher malaria infection rates in western Kenya were identified. The geographic factors include proximity to water bodies, temperature, altitude and drainage infrastructure, humidity, lakes, deforestation, climate change, and a long rainy season. Collectively these factors were found to increase mosquito distribution in these regions, hence increasing malaria rates and other mosquito borne diseases such as Dengue fever, Zika virus and West Nile Virus.

Conceptual Framework

Conceptual Frameworks are used to broaden the researcher's knowledge on the phenomenon of interest by enabling the researcher to conceptualize the area of interest in order to gain a systematic view of the phenomenon in relationship to identified variables (Chism, 2019). This review will use the Health Belief Model (HBM) to design educational interventions to promote behavior change in western Kenya residents. The HBM was developed in the 1950s to address behavior that impacts health and to aid in designing and evaluating health behavior

interventions (Orji et al., 2012). The HBM consists of four variables: (1) perceived susceptibility, (2) perceived severity, (3) perceived benefits, and (4) perceived barriers.

The HBM variables were used to identify specific behaviors preventing intervention usage and adoptions in western Kenya. Concepts from HBM were also used to develop educational material to clarify misconceptions and highlight the benefits of using preventative strategies. By identifying perceptions and beliefs preventing ITN and IRS adoption, the researcher was able to develop specific educational interventions to address barriers in utilization and adoption. The HBM asserts that perceived susceptibility determines behavior and responses. Therefore, educating the people of western Kenya about malaria risk factors and highlighting potential complications could increase ITN and IRS use and influence change in attitudes and perceptions regarding malaria.

Integrating the HBM model could also guide in developing educational interventions that are culturally centered to enhance adoption of ITNs and IRS and promote behavior change. Further, the HBM model can be used to address perceived cost and accessibility barriers to ITN and IRS uptake. Additionally, education on environmental risk factors such as stagnant water bodies and poor drainage systems should also be included to increase responsibility in ensuring that the environment is free of mosquito breeding grounds.

SECTION THREE: METHODOLOGY

Design

The integrated review included experimental, non-experimental, and observational studies. The review also included studies utilizing collection tools such as surveys, interviews, and case studies, and experiments. Experimental studies with a random sampling of participants

were also included in the review. Included articles were appraised to link interventions to outcomes and assessed for quality of evidence.

Measurable Outcomes

To guide literature selection, variables were identified to serve as measurable outcomes and to assess effectiveness of interventions. Identifying variables ensured that the selected literature aligns with the aim of the study. To inform the review, variables were identified as either dependent or independent. Independent variables included malaria transmission literacy and malaria infection rates. Dependent variables included malaria transmission education and IRS with ITN use. To measure the outcome of interventions, malaria infection rates were compared before and after interventions; by conducting surveys and interviews before and after teaching, malaria literacy was assessed. IRS and ITN use was also assessed before and after teaching to determine if increasing malaria literacy had an effect on ITN and IRS use.

Setting

Due to the disproportionate impact of malaria in western Kenya compared to other regions of the country, the review focused on determining factors that contribute to higher malaria rates in this region. Therefore, the review summarized research conducted within the last ten years on malaria impact and prevention efforts in western Kenya. Although there was adequate literature on malaria transmission, prevention, and risk factors, there was limited research on educational interventions. Hence, the search on educational interventions was expanded to include settings in Uganda and Ethiopia. According to Stern et al. (2011), Uganda and Ethiopia share similar altitude, climate, and temperatures with western Kenya and are highly endemic. By expanding the search in these regions, the researcher was able to compare the outcomes of studies focusing on ITN use with and without educational interventions.

Population

Research covered in this review included studies on children, pregnant women, young adults and elderly adults living in western Kenya. To enhance the quality of the review, studies with sample sizes of 200 and below were excluded. This also ensured that the findings could be generalized to a larger population. Considering the detrimental risk of malaria to pregnant women and the fetus, pregnant women were also included in this study. Although the link between female-headed household and higher malaria infection rates has been found, gender specifications and household size of subjects were not considered in this study as the aim is to increase malaria literacy of all persons living in western Kenya, regardless of gender.

Ethical Considerations

The study was approved by the Institutional Review Board. The researcher also completed the Collaborative Institutional Training Initiative (CITI).

Data Collection

The studies included in the review utilized the following data collection methods: surveys, interviews, and data mining from community hospitals and clinics. In all the studies included, data collection was completed by trained community health workers, health practitioners and researchers. Studies were assessed to ensure that demographic information, study setting, study methodology and method of analysis were captured. The researcher also ensured that pertinent data relating to level of education, ITN ownership, ITN usage, IRS spraying, number of malaria infections in lifetime and malaria transmission knowledge was captured, analyzed, and interpreted. Experimental studies involving collection of blood specimen to test malaria were also assessed to ensure that consent and the handling of samples was done

appropriately. Blood sampling tools used were assessed to ensure they comply with Kenya malaria guidelines.

Tools

The review followed recommendations from Whittermore and Knafl (2005) to complete a rigorous data analysis; according to them, an integrative review assesses the current state of a phenomenon to identify gaps and deficiencies by including both experimental and non-experimental studies. This allows the researcher to gain in-depth perspective on an idea to develop feasible interventions that would have a direct impact.

The review followed the five stages of an integrative review defined by Whittermore and Knafl (2005): (1) problem formulation stage, (2) a literature search stage, (3) a data evaluation stage, (4) a data analysis stage, and (5) a presentation stage. To aid in formulating the problem, the researcher devised a PICO question below:

Patient/Problem/Phenomenon of Interest: Increased malaria infection rates in western Kenya compared to other regions in Kenya.

Intervention: Educational interventions and treatment of combination of Indoor Residual Spraying (IRS) with Insecticides Treated Nets (ITNs).

Comparison: Insecticides Treated Nets alone or Indoor Residual Spraying (IRS) without education.

Outcome: Decrease in malaria infection rates in western Kenya.

The PICO guided the search strategy to incorporate treatment and educational interventions. The PICO question also aided in identifying key terms to include in the literature to narrow search to western Kenya.

The review also used a literature-leveling matrix to organize the literature and compare articles. The leveling matrix allowed the researcher to compare articles on sample size, aim, interventions, outcomes, and limitations. This process also helped in selecting articles that were relevant to the study and determining the efficacy of interventions based on outcomes.

Interventions

The review assessed the effectiveness of interventions to prove or disprove the hypothesis that combining ITN and IRS with educational interventions offers the greatest protection compared to the use of each intervention alone. The review also assessed educational interventions to identify the most effective ones to increase malaria literacy. By assessing the effect of combining ITN with IRS, the review was able to determine that combining ITN with IRS was more effective than using each intervention alone. Evaluating interventions and outcomes helped identify gaps in implementation and further prove that integrating educational interventions has potential to increase and sustain ITN and IRS use.

SECTION FOUR: DATA ANALYSIS

Highlands vs. Lowlands

Geographic differences in highland and lowland regions of western Kenya play a role in malaria incidence. The lowland region is adjacent to Lake Victoria and is relatively hot and dry (Matsushita et al., 2019). Due low altitudes, of 1200 m above sea level, the lowlands experience higher temperatures and humidity hence longer rainy seasons compared to highlands. Historically, Lowlands have been associated with higher malaria prevalence of 26.7 percent compared to 3.1 percent in the highlands (Coalson et al., 2020). As a result, majority of malaria control efforts are targeted in these areas. By contrast, highland areas are located in higher altitude of 1,500 m above sea level and have moderate climate with average temperatures of 68

degrees Fahrenheit. (Matsushita et al., 2019: Stern et al., 2011). Prior to 19th century, there was no malaria burden in the highlands (Matsushita et al., 2019). However, in recent years malaria prevalence in the highlands has been fluctuating due to increased mosquito distribution caused by climate change.

Malaria Knowledge Gaps

In the studies included in this review, malaria knowledge was determined based on understanding of the mode of transmission, signs and symptoms, complications and knowledge on prevention methods.

Cross sectional studies in western Kenya, Uganda and Ethiopia found consistent malaria transmission knowledge gaps linked to inappropriate ITN use. A Ugandan study found that 74 percent of respondents had low knowledge on malaria transmission (Musoke et al., 2015). Additionally, studies in Ethiopia found similar knowledge gaps on malaria transmissions (Birhanu et al., 2017; Goshu & Yitayew, 2019; Gobena et al., 2013). Misconception that malaria risk was only during rainy season was consistently reported in western Kenya (Ernst et al., 2016). Assessing knowledge gaps in malaria transmission is essential to aid development of educational interventions to strengthen current and future malaria control strategies. To investigate malaria knowledge gaps, Birhanu et al. (2017) interviewed caretakers in 798 households and found that although the majority of the respondents accurately described the use of ITNs, a proportion of the caretakers reported that personal hygiene, eating hot pepper, and avoiding fruits such as mangos and avocado also prevented malaria. Other respondents linked malaria transmission to cold weather, human contact, drinking cold and contaminated water, and eating corn (Musoke et al., 2015; Gobena et al., 2013). These misconceptions on malaria

transmission and prevention methods stress the need for malaria education in malaria endemic regions.

ITN Ownership and Usage

ITN distribution disparities were found in highlands and lowland regions of western Kenya. Free ITN distribution has increased overall ITN coverage in western Kenya; however, studies show that coverage is inconsistent in certain areas. Following a mass ITN distribution campaign in western Kenya, only eight percent of nets were distributed in the highlands compared to 36 percent in the lowlands (Coalson et al., 2020). In most cases ITN distribution was prioritized to pregnant women and children during mass campaigns. Those who did not receive ITNs cited inability to afford commercial ITNs due to competing demands for food, shelter, and school fees (Coalson et al., 2020). In addition to economic barriers, distance to mass ITN distribution campaigns sites, clinics, and stores are also barriers to ITN ownership (Larson et al., 2014; Ng'ang'a et al., 2021). Disparities in distribution coupled with ITN access limitations ultimately decreased interest in ITN usage and ownership.

The review identified notable differences in ITN ownership and usage in the lowlands compared to the highlands. Higher ownership in the lowlands was attributed to more focus on free ITN mass distribution in the lowlands compared to the highlands. Although ITN ownership is higher in lowlands, ITN usage was found to be higher in the highlands. Studies in western Kenya found that the number of people sleeping under nets in the lowlands was significantly lower compared to the highlands (Ernst et al., 2016; Atieli et al., 2011; Hamre et al., 2020; Larson et al., 2014). Prudhomme O'Meara et al. (2011) also noted that ITN ownership is generally higher in communities near health facilities and roads. Highlands are located in higher altitudes far from ITN distributions sites such as clinics and health care facilities. Poor road

infrastructure limits access to remote highland areas during mass campaign distributions. As a result, significant differences in ITN coverage in the highlands and the lowlands remain a barrier to the goal of malaria control.

Despite higher ITN coverage in the lowlands, greater knowledge gaps on malaria transmission and risk were noted in the lowlands compared to the highlands. Respondents in the highlands were more likely to be educated and have more assets compared to those in the lowlands. Studies in western Kenya, Uganda, and Ethiopia consistently found a link between education, social-economic factors, occupation, malaria transmission knowledge, and ITN usage (Coalson et al., 2020; Ernst et al., 2016; Larson et al., 2014; Musoke et al., 2015; Ng'ang'a et al., 2021). Consistent findings in the difference in educational levels in the lowlands and highlands of western Kenya were reported. The majority of the people in the highlands of western Kenya reported at least a primary school education, whereas the majority of the lowland population reported no education (Atieli et al., 2011; Ernst et al., 2016; Ndwiga et al., 2014). Cross sectional studies in Ethiopia evaluating malaria knowledge also found higher ITN usage among pregnant women with higher education and in households with an educated head of the house (Fuge et al., 2015; Goshu & Yitayew, 2019). A systematic review that included 42 studies identified other reasons for ITN nonuse, including heat discomfort, difficulty hanging nets, lack of space, house structure, and lack of tools such as nails and hooks to hang the nets (Salam et al., 2014).

In western Kenya, ITN ownership has increased from 18 percent in 2003 to 85 percent in 2015 (Zhou et al., 2020). Despite this increase, there have been consistent gaps in ITN usage and ownership. Similar studies in Uganda found consistent gaps in ITN usage despite ownership. A cross sectional study in Uganda enrolled 369 participants and found that 84 percent of them owned ITNs but only 66 percent used the ITNs (Taremwa et al., 2017). Reasons for ITN nonuse

vary based on cultural and demographic context. In the lowlands, where ITN coverage was higher, reasons for nonuse included belief that ITNs are sprayed with chemicals that cause cancer, fear that insecticides affect fertility, perception that ITNs were ineffective, perception that malaria risk is only during rainfall, and limited understanding about malaria transmission (Atieli et al., 2011; Ernst et al., 2016; Ng'ang'a et al., 2021; Santos et al., 2019; Zhou et al., 2020). Interestingly, in areas with combined ITN and IRS and high ITN coverage decreased ITN use was noted due to perception of reduced malaria risk (Rek et al., 2020; Hamel et al., 2011). Thus, suggesting the need to include educational interventions to encourage continued ITN use.

Majority of malaria control efforts have been focused on increased ITN ownership but have neglected education on ITN use. Despite the consistent link between malaria and ITN misconception and ITN nonuse, the review found few available studies in western Kenya focusing on malaria education. Interestingly, the involvement of community and religious leaders in educating heads of households about the efficacy of ITNs and IRS increased use compared to such efforts by health workers (Taremwa et al., 2017; Wadunde et al., 2018).

Involvement of community leaders offers great benefit in clarifying misconceptions and educating the community about malaria and ITN usage. Musoke et al. (2015) noted that malaria education by community health workers significantly increased malaria knowledge in children from 76.6 percent to 90 percent and 65.7 percent to 73 percent in pregnant women. Deploying community health workers at distribution sites increased ITN utilization in children from 51 percent to 64.7 percent and from 24 percent to 78 percent in pregnant women (Musoke et al., 2015). Based on these findings, the benefits of involving community health workers in malaria education strategies cannot be disputed. A systematic review by Salam et al. (2014) also found that multifaceted educational interventions involving role playing, poetry recitals, songs, and

dramatizations are effective in increasing ITN usage. In Uganda, behavior education interventions were found to increase malaria prevention knowledge from 76.6 percent to 90 percent (Mugisa & Muzoora, 2012). In a quasi-experimental study, Abamecha et al. (2021) reported increased ITN use by 39 percent after deploying a malaria education workshop. The findings highlight the need to integrate malaria education to increase intervention uptake.

IRS Spraying With DDT

Although studies argue that IRS spraying is generally safe, it is worth noting that newer studies on animal models have reported long-term health effects of IRS with Dichloro-Diphenyl-Trichloroethane (DDT) (Kim et al., 2012). DDT exposure has been associated with preterm birth, cancer, male infertility and liver issues (Rogan & Chen, 2005). Maternal exposure to DDT has been linked to urogenital birth defects in newborn males (Bornman et al., 2009). Studies in California, South Africa, and Spain have also found a link between DDT exposure and increased risk for obesity (Coker et al., 2018; La Merrill et al., 2020; Valvi et al., 2012). Based on these findings, community concerns regarding IRS cannot be refuted considering there are few Randomized Control Trials (RCTs) available to conclusively determine the effects of IRS on humans and the environment. Additionally, there are no standard guidelines IRS timing and risk associated with repeated IRS.

The review found mixed evidence on IRS timing and the efficacy of repeated spraying. Gimnig et al. (2016), found decreased mosquito density after two rounds of spraying and no change after one round, whereas Pryce et al. (2018) noted decreased density after one round. A cross sectional study in Uganda found greater mosquito reduction in areas that received six rounds of spraying compared to regions with three rounds (Steinhardt et al., 2013). It is worth highlight that some of the studies discussed above used different insecticide for IRS. Some of the

studies used pyrethroid based sprays while others used DDT. Therefore, findings should be interpreted with caution given that DDT based sprays are known to have higher efficacy compared to other available sprays (Kim et al., 2012). Additional factors that should be considered include transmission rate, mosquito density prior to spraying and time of spraying. This data suggests that standardized IRS guidelines are needed to increase confidence in uptake.

IRS Knowledge Gaps

IRS has been found to reduce vector prevalence by over 50 percent (Abong'o et al., 2020). However, social, geographic, and economic barriers affect IRS uptake. Interviews to assess IRS willingness consistently found that fear of health effects and questions about IRS efficacy were the two most reported reasons for IRS refusal (Wadunde et al., 2018; Taremwa et al., 2017; Musoke et al., 2015). Ediau et al. (2013) surveyed 314 participants and found that most of the participants feared that IRS would cause cancer and respiratory illness. Of the 314 participants, 244 also reported concerns that IRS would contaminate food and houses and pollute the environment. Age was also linked to IRS uptake. Wadunde et al., (2018) found that those over the age of 35 years were more likely to use IRS largely due to lived experience and the belief that IRS is an essential malaria control strategy. This finding highlights the need to target malaria education to younger populations.

Additional factors affecting IRS uptake included education level, religion, and social-economic status. Respondents older than 22 years with at least a primary school education and middle or higher social-economic status were more likely to use IRS compared to respondents younger than 22 years with no education (Taremwa et al., 2017). Differences in IRS perception vary based on location. In Uganda, negative perceptions were higher in rural areas compared to urban areas (Ediau et al., 2013). This difference in perception was linked to education level,

access to media, and IRS education. At the time of the study, IRS promotion campaigns had not been done in rural areas, hence IRS knowledge and perception in rural regions was relatively lower compared to the urban regions where IRS promotion campaigns had been done prior to the study (Ediau et al., 2013). These differences in IRS perception further highlight the need for IRS education in rural areas to increase IRS uptake. Regarding IRS education, Ediau et al. (2013) found that community health workers, clinicians, and religious leaders were preferred sources of health education on IRS.

ITN Knowledge Gaps

Studies assessing malaria knowledge and ITN efficacy knowledge consistently report knowledge gaps regarding malaria transmission. In western Kenya, education, perceived risk, and misconceptions about malaria transmission are consistently reported as factors influencing ITN ownership and usage (Birhanu et al., 2017; Ernst et al., 2016). Studies in Uganda and Ethiopia also found high knowledge regarding malaria symptoms but overall low knowledge regarding malaria transmission and the role of ITNs (Birhanu et al., 2017; Taremwa et al., 2017). A study by Taremwa et al. (2017) found that knowledge regarding malaria signs and symptoms prompted care seeking behaviors but did not increase ITN use. In Uganda and Ethiopia there was high knowledge regarding malaria symptoms but overall low knowledge regarding malaria transmission and the role of ITNs (Birhanu et al., 2017; Taremwa et al., 2017). These findings indicate that high ITN ownership and knowledge of malaria signs and symptoms do not translate to ITN usage.

Similar to IRS use, education level has been found to affect ITN use. Consistent links between education and ITN use are found in Ethiopia and Uganda. In western Kenya, respondents with at least a primary education are more likely to use ITNs compared to those

without education (Ng'ang'a et al., 2021). This further underscores the role of education in malaria intervention uptake and the need to focus interventions on less educated populations.

The review found overwhelming evidence that ITN ownership does not guarantee proper use. In western Kenya, despite owning a net, respondents reported using nets only during rainfall season because perceived malaria risk was higher during rainy seasons compared to dry seasons (Larson et al., 2014; Ng'ang'a et al., 2021). Inconsistent patterns in ITN use based on seasons was noted to be higher in the lowlands compared to the highlands, highlighting wider knowledge gaps in proper ITN use in the lowlands (Atieli et al., 2011).

Combining ITNs with IRS

Few Randomized Control Trials (RCTs) are available to conclusively determine added benefits of combining ITNs with IRS, and available non-randomized control trials on the combined use of ITNs with IRS have shown mixed results. For instance, one study compared outcomes of a group using ITNs with IRS with a cohort group using ITNs alone and found no added benefit with the combined interventions (Corbel et al., 2012; Protopopoff et al., 2008). On the other hand, studies in western Kenya have demonstrated declined malaria prevalence with combined interventions in certain regions based on ITN coverage and transmission rate. Gimnig et al. (2016) used IRS in areas with high ITN coverage and found a significant decline in malaria *parasitemia* in the region with IRS coverage (6.4 percent) compared to the areas without IRS (16.7 percent). In comparing outcomes from a district that used both IRS and ITN with a district that used ITN alone, Gaudence et al. (2018) found malaria transmission was reduced from 53 percent to 12 percent in the district that received both ITNs and IRS.

A similar study by Fullman et al. (2013) also found that combining IRS and ITNs reduced malaria risk by 31 percent in high transmission areas and 53 percent in medium

transmission areas. This reduction in high transmission areas was linked to higher ITNs and IRS use and higher knowledge on proper ITN hanging and IRS spraying techniques. It is also important to note that the group in the highlands also had higher education levels and wealth compared to the group in lowland areas. Interestingly, despite overall malaria reduction in medium transmission areas, combined interventions did not reduce childhood mortality (Fullman et al., 2013).

A systematic review aimed to determine the benefit of adding IRS in areas with ITN coverage found conflicting evidence in adding IRS in areas with high ITN usage but noted substantial benefits in adding IRS in areas with low ITN usage (Sherrard-Smith et al., 2018). This finding is consistent with a study in the western Kenya region that found a 62 percent reduction in new malaria infection in lowlands, where ITN usage was low, after adding IRS (Hamel et al., 2011). Conversely, Gimnig et al. (2016) also reported increased malaria *parasitemia* in those using ITNs but not IRS and vice versa, which further highlights the potential benefit of combined interventions.

Due to mixed research findings, actual benefits of combining ITNs with IRS have not been well established. Sherrard-Smith et al. (2018) suggest that the efficacy of combining ITNs with IRS varies based on transmission rate and mosquito density. It is worth noting that the review did not find any available RCT's comparing the efficacy of combining ITNs with IRS. However, the available, cross-sectional studies revealed contradicting findings on the efficacy of combining and adding IRS to ITNs. Significant differences in efficacy varied in high and low transmission areas, however, these findings were not consistent. For instance, Kim et al., (2012) found that adding IRS to ITNs in areas of high malaria transmission reduces malaria prevalence at higher rates compared to areas of low transmission.

Another secondary data analysis of 17 countries in endemic regions in Africa, Asia and south America found that combining ITNs with IRS was only effective in medium transmission areas but not in low transmission areas whereas another systemic review reported malaria reduction in high transmission areas and no reduction in low transmission areas with combined interventions (Sherrard-Smith et al. 2018). These findings highlight the need for RCTs to compare the effectiveness of combining ITNs with IRS in high, medium, and low transmission areas to inform malaria control efforts on which areas to prioritize combined interventions. This will also reduce wastage of resources by preventing unnecessary implementation of combined interventions.

SECTION FIVE: DISCUSSION

Dissemination

Maximizing the benefits of malaria prevention interventions requires strategic effort to increase intervention coverage and education to increase malaria knowledge. The review highlights knowledge, ownership, and utilization barriers that must be addressed to meet malaria control in western Kenya. Although some effort has been made to increase coverage of both IRS and ITNs through mass distribution campaigns and donor programs, educational interventions to increase knowledge on malaria transmission remain limited. Education focused on narrowing knowledge gaps on malaria transmission will ultimately increase IRS and ITN use.

Educational Interventions

Studies evaluating malaria knowledge consistently report that higher levels of knowledge of the benefits of ITNs increased usage. Arogundade et al. (2011) found that knowledge regarding modes of preventing malaria increased use of ITN compared to knowledge on malaria symptoms. This finding suggests that focusing educational interventions on increasing literacy

on malaria prevention strategies is more effective than education on malaria symptoms alone. To further strengthen educational interventions, clarification of misconceptions about IRS and ITN is needed. Among the factors regarding the nonuse of ITNs and IRS, lack of knowledge regarding ITN hanging techniques and misconceptions about the efficacy of ITNs, and IRS remain a barrier. Some studies report that misinformation about IRS efficacy and effects of IRS on fertility and health were found to be common reasons for IRS refusal. Additional factors impacting ITN use include education level, high number of mosquitos, and low indoor temperatures (Atieli et al., 2011).

Misconceptions and knowledge deficits on IRS health risks and efficacy must be addressed to increase IRS uptake. Additional factors of IRS refusal such as age, economic status, and level of education must be considered when developing educational interventions. It is also imperative to focus teaching on heads of households in light of the paternalistic culture in western Kenya. Additional research is needed to bridge evidence gaps on the impact of educating heads of households compared to educating women and children. This knowledge is needed to guide community health workers and clinicians to determine the target audience for malaria education.

Knowledge deficits on malaria transmission and doubts about the efficacy of malaria control interventions contribute to low usage of IRS and ITNs. Therefore, a focus to increase malaria transmission knowledge must be prioritized to drive IRS and ITN uptake. The literature highlights factors associated with ITN and IRS uptake such as misconceptions based on age, cultural beliefs, transmission rates, and setting. These factors must be considered when developing educational interventions to ensure that interventions are culturally sensitive. Demographic and societal differences as well as local challenges such as health access,

infrastructure, economic barriers, and other health risks must also be considered to ensure that they are applicable to the setting and population. Therefore, health workers, funders, and donors must engage both community leaders and the community as a whole to gain insight on specific local challenges and barriers.

Studies consistently found that those without a primary school education were less likely to afford commercially sold ITNs. This is because education level often determines occupation and economic status. Economic barriers limit the ability to purchase and replace ITNs and thus constitute a significant barrier to achieving malaria control goals in many regions. Considering the reported link between education level and ITN and IRS access and uptake, educational interventions should be focused on less educated people. To address financial barriers, there have been numerous campaigns to increase ITN coverage in western Kenya; however, distribution disparities affect ownership. There are also no known initiatives in western Kenya to replace worn and torn ITNs for those who cannot afford commercially sold ITNs.

Although the benefits of community health workers in increasing malaria knowledge and promoting ITN utilization is well noted, this review found that mistrust of community health workers in certain areas was a barrier to the acceptance of malaria interventions. For instance, in the Ugandan study, IRS uptake increased with the engagement of local leaders compared to health workers (Wadunde et al., 2018). This is because community leaders are trusted and well known by community members. Similar studies in Ethiopia also found that educational interventions involving community health workers increased overall malaria knowledge.

There is also sufficient evidence that engaging community health workers in community education programs offers added benefit in ITN and IRS uptake. These findings suggest that involving community health workers and community leaders in malaria education programs has

the potential to increase ITN and IRS usage. Therefore, studies to assess the impact of including both community leaders and community health workers versus community health workers alone should be further undertaken to better improve malaria education outcomes. A Ugandan study found increase in ITN uptake after deploying medical students to endemic regions to coordinate malaria prevention teaching (Ndira et al., 2015). Although the practice of involving medical students in malaria programs has not been well studied, it has the potential to strengthen malaria control programs and should be explored further.

Combined ITNs and IRS

Mixed results on the effects of combining ITNs and IRS were found in this review. While some studies reported a significant decrease in malaria prevalence with combined ITN and IRS use, other studies found no significant benefit in combining these interventions. However, there is clear evidence that combining ITN and IRS in the lowlands of Kenya offers greater protection compared to the highlands. Concerns about resource wastage with combining interventions in areas with limited resources also suggest a greater need to limit combined interventions to the lowlands. To best maximize resources, additional research to determine the actual impact of combining these interventions over time is needed. Given the economic challenges in the lowlands, further research is needed to identify ways to sustain combined ITN and IRS use.

The need for educational interventions to advance malaria knowledge to strengthen uptake is critical in sustaining malaria prevention goals. With reduced malaria prevalence after mass distribution of ITNs, their use consistently decreased due to the perception of reduced malaria risk. Similar trend, decrease in IRS use, was noted a year following IRS campaigns. These findings highlight the need for continued education on malaria transmission risk and the proper use of ITNs and IRS to promote continued use of these interventions.

Implication for Practice

Future malaria control programs in western Kenya must join efforts with donors and the Kenyan government to develop an integrative approach focused on bridging disparities in ITN coverage, promoting IRS use in the lowlands, and increasing community knowledge of malaria transmission. When deploying malaria prevention interventions, it is important to consider that uptake may differ based on previous control efforts in the region. Disparities in distribution from previous distribution campaigns may affect community response during future campaigns. Additionally, misconceptions about the efficacy of free nets compared to purchased nets may also impact response. To address these potential challenges, a thorough analysis of previous interventions must be assessed to identify gaps, successes, and failures. Gaps in distribution, usage and ownership must be determined beforehand to develop strategies to mitigate these challenges. For instance, disparities in ITN distribution during mass campaigns have been shown to decrease interest in ITN usage among those who did not receive the nets.

Future distribution campaigns must strategize efforts to promote equal distribution in affected regions. Increasing ITN coverage along with education on proper use will help increase ownership and usage. To sustain malaria control goals, integrated efforts to develop ITN replacement programs are needed. Given mixed findings regarding the benefit of combining IRS and ITN, overall community benefit must be assessed to prevent resource wastage in economically burdened regions. Ultimately, research to assess direct measurement of transmission with combined ITN and IRS versus each intervention alone is needed to inform malaria control programs. Given the rising rates of insecticide resistance, it is worth giving some thought to the potential barriers future research may face because the value of research results may be compromised if insecticide resistance occurs.

Despite the potential benefits of IRS in vector control, it is crucial to consider insecticide resistance as a potential challenge in IRS use and to identify IRS agents with fewer cases of resistance. In addition to resistance challenges, IRS is cost intensive and requires training and timed spraying to achieve optimal mosquito reduction. In countries with burdened resources and competing demands, feasibility of maintaining timely spraying scheduled and employing trained spraying teams to service home can be challenging. Therefore, sustainability factors must also be considered in decision making regarding IRS implementation.

Concerns about long-term effects of IRS should also be addressed as they are barriers to uptake. Historically, most insecticides have risk factors and adverse effects and therefore, the concern of IRS exposure is valid and should be taken into account when implementing future malaria control interventions. Although most reviews report that IRS spraying is generally safe, newer studies have identified health risks related to DDT. Thus, longitudinal studies to assess long-term effects are needed to provide clear insight into the long-term effects of IRS spraying; the risks and benefits of all available insecticides must be assessed to determine those insecticides with the highest safety efficacy. These studies should also evaluate health and environmental risks associated with multiple sprayings to help develop standardized IRS spraying guidelines.

Ongoing climate change driven by global warming has the potential to further increase malaria infections globally. Considering that mosquitos thrive in warm humid environments, the effects of global warming will likely create new breeding grounds for mosquitos. In addition, deforestation resulting from climate change is likely to widen mosquito distribution to new locations. Not only will this increase malaria infection rates, but also other mosquito borne diseases such as Dengue fever, Zika virus, and West Nile virus. The potential health effects of

mosquito migration to other countries could be catastrophic considering the current shortage of malaria prevention resources. Distribution of mosquitos to non-endemic areas will likely increase rates of mosquito borne disease, further burdening already stressed healthcare systems.

The effects of climate change on malaria transmission and other vector borne diseases are a public health concern. Strategies to address climate change must be prioritized by all nations, given the potential health and environmental risks. Given the potential risk for change in mosquito distribution, efforts to improve malaria surveillance are needed to monitor trends and identify distribution patterns. Strong surveillance will help researchers identify hot spots and detect epidemics to guide allocation of malaria prevention resources. Ultimately, climate change control coupled with surveillance tools has the potential to prevent—or at least severely limit—the spread of malaria and other vector borne illnesses.

Conclusion

This review highlights three crucial points: (1) association between level of education and ITN uptake, (2) ITN ownership does not guarantee usage and (3) effectiveness of interventions varies based on location and transmission rate. The findings assert the need to prioritize interventions to increase malaria knowledge. The review offers sufficient evidence that education increases ITN utilization and IRS uptake but does not provide sufficient evidence that combined ITNs with IRS offers greater protection than ITN or IRS used alone. However, the review offers great insight on ITN ownership and IRS gaps that limit malaria control success. It also highlights important social and geographic factors that affect ITN and IRS uptake further hindering success of malaria control interventions.

The identified challenges and barriers to uptake and utilization of malaria interventions highlight the need to reevaluate implementation of current malaria interventions. To achieve best

outcomes, efforts to improve malaria transmission knowledge and decrease ITN coverage disparities are critical. Although there were limited studies assessing efficacy of Malaria education on ITN or IRS use, the review highlights the link between malaria knowledge and ITN use, therefore, ITN distribution campaigns should consider integrating malaria education in the distribution efforts to increase sustained utilization.

Regarding the effectiveness of combining IRS and ITN use, there were limited studies addressing the effectiveness of combined interventions and the available studies showed mixed results. Therefore, the review cannot conclusively answer the problem question, does combining ITN with IRS offer greater protection compared to each intervention alone? Based on the findings of the review, combining ITNs with IRS can be cost and resource intensive. There are also potential logistical and technical demands that must be anticipated when considering combing ITN with IRS. Some of the demands include, hiring experienced IRS sprayers, maintaining consistent spraying schedules, monitoring insecticide resistance, and replacing damaged ITNs. These demands challenge the practicality of sustaining combined IRS and ITNs in western Kenya considering the current economic state. Future studies must also consider economic, geographic, and societal challenges to ensure feasibility and applicability. To prevent resource wastage, different types of studies are needed to inform decision making regarding combining IRS with ITN. The need for experimental and investigative studies to measure the added benefit of adding IRS to ITNS and determine long term benefits of combing interventions is undebatable. Additional randomized control studies comparing outcomes of combining intervention as opposed to using ITN or IRS used alone are needed. These studies along with a cost benefit analysis of combining the interventions will be essential in guiding future malaria control efforts.

References

Abamecha, F., Sudhakar, M., Abebe, L., Kebede, Y., Alemayehu, G., & Birhanu, Z. (2021). Effectiveness of the school-based social and behaviour change communication interventions on insecticide-treated nets utilization among primary school children in rural Ethiopia: a controlled quasi-experimental design. *Malaria Journal*, *20*(1). https://doi.org/10.1186/s12936-020-03578-x

Abate, A., Degarege, A., & Erko, B. (2013). Community knowledge, attitude and practice about malaria in a low endemic setting of Shewa Robit Town, northeastern Ethiopia. *BMC Public Health*, *13*(1). https://doi.org/10.1186/1471-2458-13-312

Abong'o, B., Gimnig, J. E., Torr, S. J., Longman, B., Omoke, D., Muchoki, M., ter Kuile, F., Ochomo, E., Munga, S., Samuels, A. M., Njagi, K., Maas, J., Perry, R. T., Fornadel, C., Donnelly, M. J., & Oxborough, R. M. (2020). Impact of indoor residual spraying with pirimiphos-methyl (Actellic 300CS) on entomological indicators of transmission and malaria case burden in Migori County, western Kenya. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-61350-2

Arogundade, E. D., Adebayo, S. B., Anyanti, J., Nwokolo, E., Ladipo, O., Ankomah, A., & Meremikwu, M. M. (2011). Relationship between care-givers' misconceptions and non-use of ITNs by under-five Nigerian children. *Malaria Journal*, *10*(1), 170. https://doi.org/10.1186/1475-2875-10-170

Asale, A., Kussa, D., Girma, M., Mbogo, C., & Mutero, C. M. (2019). Community based integrated vector management for malaria control: Lessons from three years' experience (2016–2018) in Botor-Tolay district, southwestern Ethiopia. *BMC Public Health*, *19*(1). https://doi.org/10.1186/s12889-019-7606-3

Atieli, H. E., Zhou, G., Afrane, Y., Lee, M.-C., Mwanzo, I., Githeko, A. K., & Yan, G. (2011). Insecticide-treated net (ITN) ownership, usage, and malaria transmission in the highlands of western Kenya. *Parasites & Vectors*, *4*(1). https://doi.org/10.1186/1756-3305-4-113

Birhanu, Z., Yihdego, Y. Y., & Yewhalaw, D. (2017). Caretakers' understanding of malaria, use of insecticide treated net and care seeking-behavior for febrile illness of their children in Ethiopia. *BMC Infectious Diseases*, *17*(1). https://doi.org/10.1186/s12879-017-2731-z

Bornman, R., De Jager, C., Worku, Z., Farias, P., & Reif, S. (2009). DDT and urogenital malformations in newborn boys in a malarial area. *BJU International*, *106*(3), 405–411. https://doi.org/10.1111/j.1464-410x.2009.09003.x

Brown, Z. S., Kramer, R. A., Ocan, D., & Oryema, C. (2016). Household perceptions and subjective valuations of indoor residual spraying programmes to control malaria in northern Uganda. *Infectious Diseases of Poverty*, *5*(1). https://doi.org/10.1186/s40249-016-0190-1

Chism, L. A. (2019). *The Doctor of Nursing practice: A guidebook for role development and professional issues*. Jones & Bartlett Learning.

Choi, L., Pryce, J., & Garner, P. (2019). Indoor residual spraying for preventing malaria in communities using insecticide-treated nets. *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.cd012688.pub2

Coalson, J. E., Santos, E. M., Little, A. C., Anderson, E. J., Stroupe, N., Agawo, M., Hayden, M., Munga, S., & Ernst, K. C. (2020). Insufficient ratio of long-lasting insecticidal nets to household members limited universal usage in Western Kenya: A 2015 cross-sectional study. *The American Journal of Tropical Medicine and Hygiene*, *102*(6), 1328–1342. https://doi.org/10.4269/ajtmh.19-0119

Coker, E., Chevrier, J., Rauch, S., Bradman, A., Obida, M., Crause, M., Bornman, R., & Eskenazi, B. (2018). Association between prenatal exposure to multiple insecticides and child body weight and body composition in the VHEMBE South African birth cohort. *Environment International*, *113*, 122–132. https://doi.org/10.1016/j.envint.2018.01.016

Corbel, V., Akogbeto, M., Damien, G. B., Djenontin, A., Chandre, F., Rogier, C., Moiroux, N., Chabi, J., Banganna, B., Padonou, G. G., & Henry, M.-C. (2012). Combination of malaria vector control interventions in pyrethroid resistance area in Benin: a cluster randomised controlled trial. *The Lancet Infectious Diseases*, *12*(8), 617–626. https://doi.org/10.1016/s1473-3099(12)70081-6 District, Uganda. *African Health Sciences*, *15*(2), 401. https://doi.org/10.4314/ahs.v15i2.13

Ediau, M., Babirye, J. N., Tumwesigye, N. M., Matovu, J. K. B., Machingaidze, S., Okui, O., Wanyenze, R. K., & Waiswa, P. (2013). Community knowledge and perceptions about indoor residual spraying for malaria prevention in Soroti district, Uganda: a cross-sectional study. *Malaria Journal*, *12*(1). https://doi.org/10.1186/1475-2875-12-170

Ernst, K. C., Hayden, M. H., Olsen, H., Cavanaugh, J. L., Ruberto, I., Agawo, M., & Munga, S. (2016). Comparing ownership and use of bed nets at two sites with differential malaria transmission in western Kenya. *Malaria Journal*, *15*(1). https://doi.org/10.1186/s12936-016-1262-1

Fuge, T. G., Ayanto, S. Y., & Gurmamo, F. L. (2015). Assessment of knowledge, attitude and practice about malaria and ITNs utilization among pregnant women in Shashogo District, Southern Ethiopia. *Malaria Journal*, *14*(1). https://doi.org/10.1186/s12936-015-0755-7

Fullman, N., Burstein, R., Lim, S. S., Medlin, C., & Gakidou, E. (2013). Nets, spray or both? The effectiveness of insecticide-treated nets and indoor residual spraying in reducing malaria

morbidity and child mortality in sub-Saharan Africa. *Malaria Journal*, *12*(1). https://doi.org/10.1186/1475-2875-12-62

Gaudence, K. T., Mwenechanya, R., & Choongo, K. (2018). Impact of insecticide-treated nets and indoor residual spraying on malaria case prevalence in Geita and Nyang'hwale districts of Tanzania. *Journal of Applied and Natural Science*, *10*(1), 236–240. https://doi.org/10.31018/jans.v10i1.1610

Gimnig, J. E., Otieno, P., Were, V., Marwanga, D., Abong'o, D., Wiegand, R., Williamson, J., Wolkon, A., Zhou, Y., Bayoh, M. N., Lobo, N. F., Laserson, K., Kariuki, S., & Hamel, M. J. (2016). The effect of indoor residual spraying on the prevalence of malaria parasite infection, clinical malaria, and anemia in an area of perennial transmission and moderate coverage of insecticide treated nets in Western Kenya. *PLOS ONE*, *11*(1). https://doi.org/10.1371/journal.pone.0145282

Githinji, S., Herbst, S., Kistemann, T., & Noor, A. M. (2010). Mosquito nets in a rural area of Western Kenya: ownership, use and quality. *Malaria Journal*, *9*(1). https://doi.org/10.1186/1475-2875-9-250

Gobena, T., Berhane, Y., & Worku, A. (2013). Women's knowledge and perceptions of malaria and use of malaria vector control interventions in Kersa, eastern Ethiopia. *Global Health Action*, *6*(1), 20461. https://doi.org/10.3402/gha.v6i0.20461

Goshu, Y. A., & Yitayew, A. E. (2019). Malaria knowledge and its associated factors among pregnant women attending antenatal clinic of Adis Zemen Hospital, North-western Ethiopia, 2018. *PLOS ONE*, *14*(1). https://doi.org/10.1371/journal.pone.0210221

Hamel, M. J., Marwanga, D., Kariuki, S., Gimnig, J., Slutsker, L., Were, V., Laserson, K. F., Otieno, P., Bayoh, N., & Williamson, J. (2011). The Combination of Indoor Residual

Spraying and Insecticide-Treated Nets Provides Added Protection against Malaria Compared with Insecticide-Treated Nets Alone. *The American Journal of Tropical Medicine and Hygiene*, *85*(6), 1080–1086. https://doi.org/10.4269/ajtmh.2011.10-0684

Hamre, K. E., Ayodo, G., Hodges, J. S., & John, C. C. (2020). A mass insecticide-treated bed net distribution campaign reduced malaria risk on an individual but not population level in a highland epidemic-prone area of Kenya. *The American Journal of Tropical Medicine and Hygiene*, *103*(6), 2183–2188. https://doi.org/10.4269/ajtmh.19-0306

Kapesa, A., Kweka, E. J., Atieli, H., Afrane, Y. A., Kamugisha, E., Lee, M.-C., Zhou, G., Githeko, A. K., & Yan, G. (2018). The current malaria morbidity and mortality in different transmission settings in Western Kenya. *PLOS ONE*, *13*(8). https://doi.org/10.1371/journal.pone.0202031

Kim, D., Kramer, R., & Fedak, K. (2012). Reduction of malaria prevalence by indoor residual spraying: A meta-regression analysis. *The American Journal of Tropical Medicine and Hygiene*, *87*(1), 117–124. https://doi.org/10.4269/ajtmh.2012.11-0620

Krishna, A., Kristjanson, P., Radeny, M., & Nindo, W. (2004). Escaping poverty and becoming poor in 20 Kenyan villages. *Journal of Human Development*, *5*(2), 211–226. https://doi.org/10.1080/1464988042000225131

La Merrill, M. A., Krigbaum, N. Y., Cirillo, P. M., & Cohn, B. A. (2020). Association between maternal exposure to the pesticide dichlorodiphenyltrichloroethane (DDT) and risk of obesity in middle age. *International Journal of Obesity*, *44*(8), 1723–1732. https://doi.org/10.1038/s41366-020-0586-7

Larson, P. S., Minakawa, N., Dida, G. O., Njenga, S. M., Ionides, E. L., & Wilson, M. L. (2014). Insecticide-treated net use before and after mass distribution in a fishing community along

Lake Victoria, Kenya: successes and unavoidable pitfalls. *Malaria Journal*, *13*(1). https://doi.org/10.1186/1475-2875-13-466

Lindblade, K. A., & Kachur, S. P. (2020). Opportunities for Subnational Malaria Elimination in High-Burden Countries. *The American Journal of Tropical Medicine and Hygiene*, *103*(6), 2153–2154. https://doi.org/10.4269/ajtmh.20-1342

Magaço, A., Botão, C., Nhassengo, P., Saide, M., Ubisse, A., Chicumbe, S., & Zulliger, R. (2019). Community knowledge and acceptance of indoor residual spraying for malaria prevention in Mozambique: a qualitative study. *Malaria Journal*, *18*(1). https://doi.org/10.1186/s12936-019-2653-x

MALARIA DEATH RATE BY COUNTRY. World Life Expectancy. (2021). https://www.worldlifeexpectancy.com/cause-of-death/malaria/by-country/.

Matsushita, N., Kim, Y., Ng, C., Moriyama, M., Igarashi, T., Yamamoto, K., Otieno, W., Minakawa, N., & Hashizume, M. (2019). Differences of Rainfall–Malaria Associations in Lowland and Highland in Western Kenya. *International Journal of Environmental Research and Public Health*, *16*(19), 3693. https://doi.org/10.3390/ijerph16193693

Mbanefo, A., & Kumar, N. (2020). Evaluation of malaria diagnostic methods as a key for successful control and elimination programs. *Tropical Medicine and Infectious Disease*, *5*(2), 102. https://doi.org/10.3390/tropicalmed5020102

Moran, K. J., Burson, R., & Conrad, D. (2020). *The Doctor of Nursing practice project: A framework for success*. Jones & Bartlett Learning.

Mugisa , M., & Muzoora , A. (2012). Behavioral change communication strategy vital in malaria prevention interventions in rural communities: Nakasongola district, Uganda. *The Pan African Medical Journal.*

Musoke, D., Karani, G., Ssempebwa, J. C., Etajak, S., Guwatudde, D., & Musoke, M. B. (2015). Knowledge and practices on malaria prevention in two rural communities in Wakiso

Nabi, S. A., & Qader, S. S. (2018). Is global warming likely to cause an increased incidence of malaria? *Libyan Journal of Medicine*, *4*(1), 18–22. https://doi.org/10.3402/ljm.v4i1.4799

Ndira, S., Ssebadduka, D., Niyonzima, N., Sewankambo, N., & Royall, J. (2015). Tackling malaria, village by village: a report on a concerted information intervention by medical students and the community in Mifumi, Eastern Uganda. *African Health Sciences*, *14*(4), 882. https://doi.org/10.4314/ahs.v14i4.16

Ndwiga, T., Kei, R. M., & Dancan, O. W. (2014). Utilization of insecticide treated bed nets among mothers attending MCH/FP in Webuye District Hospital, Bungoma County, Kenya. *Open Journal of Preventive Medicine*, *04*(06), 470–480. https://doi.org/10.4236/ojpm.2014.46055

Ng'ang'a, P. N., Aduogo, P., & Mutero, C. M. (2021). Long lasting insecticidal mosquito nets (LLINs) ownership, use and coverage following mass distribution campaign in Lake Victoria basin, Western Kenya. *BMC Public Health*, *21*(1). https://doi.org/10.1186/s12889-021-11062-7

Okumu, F. O., & Moore, S. J. (2011). Combining indoor residual spraying and insecticide-treated nets for malaria control in Africa: a review of possible outcomes and an outline of suggestions for the future. *Malaria Journal*, *10*(1). https://doi.org/10.1186/1475-2875-10-208

Orji, R., Vassileva, J., & Mandryk, R. (2012). Towards an effective health interventions design: An extension of the Health Belief Model. *Online Journal of Public Health Informatics*, *4*(3). https://doi.org/10.5210/ojphi.v4i3.4321

Pathania, V. (2014). The impact of malaria control on infant mortality in Kenya. *Economic Development and Cultural Change*, *62*(3), 459–487. https://doi.org/10.1086/675382

Protopopoff, N., Van Bortel, W., Van Herp, M., Baza, D., Marcotty, T., Maes, P., Coosemans, M., & D'Alessandro, U. (2008). Spatial Targeted Vector Control Is Able to Reduce Malaria Prevalence in the Highlands of Burundi. *The American Journal of Tropical Medicine and Hygiene*, *79*(1), 12–18. https://doi.org/10.4269/ajtmh.2008.79.12

Prudhomme O'Meara, W., Smith, N., Ekal, E., Cole, D., & Ndege, S. (2011). Spatial distribution of bednet coverage under routine distribution through the public health sector in a rural district in Kenya. *PLoS ONE*, *6*(10). https://doi.org/10.1371/journal.pone.0025949

Pryce, J., Richardson, M., & Lengeler, C. (2018). Insecticide-treated nets for preventing malaria. *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.cd000363.pub3

Rek, J., Musiime, A., Zedi, M., Otto, G., Kyagamba, P., Asiimwe Rwatooro, J., Arinaitwe, E., Nankabirwa, J., Staedke, S. G., Drakeley, C., Rosenthal, P. J., Kamya, M., Dorsey, G., & Krezanoski, P. J. (2020). Non-adherence to long-lasting insecticide treated bednet use following successful malaria control in Tororo, Uganda. *PLOS ONE*, *15*(12). https://doi.org/10.1371/journal.pone.0243303

Renschler, J. P., Walters, K. M., Newton, P. N., & Laxminarayan, R. (2015). Estimated under-five deaths associated with poor-quality antimalarialls in Sub-Saharan Africa. *The American Journal of Tropical Medicine and Hygiene*, *92*(6_Suppl), 119–126. https://doi.org/10.4269/ajtmh.14-0725

Rogan, W. J., & Chen, A. (2005). Health risks and benefits of bis(4-chlorophenyl)-1,1,1-trichloroethane (DDT). *The Lancet*, *366*(9487), 763–773. https://doi.org/10.1016/s0140-6736(05)67182-6

Salam, R. A., Das, J. K., Lassi, Z. S., & Bhutta, Z. A. (2014). Impact of community-based interventions for the prevention and control of malaria on intervention coverage and health outcomes for the prevention and control of malaria. *Infectious Diseases of Poverty*, *3*(1), 25. https://doi.org/10.1186/2049-9957-3-25

Sherrard-Smith, E., Griffin, J. T., Winskill, P., Corbel, V., Pennetier, C., Djénontin, A., Moore, S., Richardson, J. H., Müller, P., Edi, C., Protopopoff, N., Oxborough, R., Agossa, F., N'Guessan, R., Rowland, M., & Churcher, T. S. (2018). Systematic review of indoor residual spray efficacy and effectiveness against Plasmodium falciparum in Africa. *Nature Communications*, *9*(1). https://doi.org/10.1038/s41467-018-07357-w

Sicuri, E., Vieta, A., Lindner, L., Constenla, D., & Sauboin, C. (2013). The economic costs of malaria in children in three sub-Saharan countries: Ghana, Tanzania and Kenya. *Malaria Journal*, *12*(1), 307. https://doi.org/10.1186/1475-2875-12-307

Steinhardt, L. C., Yeka, A., Lavoy, G., Dorsey, G., Nasr, S., Kamya, M., Sserwanga, A., Wiegand, R. E., Filler, S., Wanzira, H., & Rubahika, D. (2013). The Effect of Indoor Residual Spraying on Malaria and Anemia in a High-Transmission Area of Northern Uganda. *The American Journal of Tropical Medicine and Hygiene*, *88*(5), 855–861. https://doi.org/10.4269/ajtmh.12-0747

Stern, D. I., Gething, P. W., Kabaria, C. W., Temperley, W. H., Noor, A. M., Okiro, E. A., Shanks, G. D., Snow, R. W., & Hay, S. I. (2011). Temperature and Malaria Trends in Highland East Africa. *PLoS ONE*, *6*(9). https://doi.org/10.1371/journal.pone.0024524

Sultana, M., Sheikh, N., Mahumud, R. A., Jahir, T., Islam, Z., & Sarker, A. R. (2017). Prevalence and associated determinants of malaria parasites among Kenyan children. *Tropical Medicine and Health*, *45*(1). https://doi.org/10.1186/s41182-017-0066-5

Taremwa, I. M., Ashaba, S., Adrama, H. O., Ayebazibwe, C., Omoding, D., Kemeza, I., Yatuha, J., Turuho, T., MacDonald, N. E., & Hilliard, R. (2017). Knowledge, attitude and behaviour towards the use of insecticide treated mosquito nets among pregnant women and children in rural Southwestern Uganda. *BMC Public Health*, *17*(1). https://doi.org/10.1186/s12889-017-4824-4

Touray, A. O., Mobegi, V. A., Wamunyokoli, F., & Herren, J. K. (2020). Diversity and multiplicity of P. falciparum infections among asymptomatic school children in Mbita, Western Kenya. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-62819-w

Valvi, D., Mendez, M. A., Martinez, D., Grimalt, J. O., Torrent, M., Sunyer, J., & Vrijheid, M. (2012). Prenatal oncentrations of olychlorinated biphenyls, DDE, and DDT and overweight in children: A prospective birth cohort study. *Environmental Health Perspectives*, *120*(3), 451–457. https://doi.org/10.1289/ehp.1103862

Wadunde, I., Mpimbaza, A., Musoke, D., Ssempebwa, J. C., Ediau, M., Tuhebwe, D., Adoke, Y., & Wanyenze, R. K. (2018). Factors associated with willingness to take up indoor residual spraying to prevent malaria in Tororo district, Uganda: a cross-sectional study. *Malaria Journal*, *17*(1). https://doi.org/10.1186/s12936-017-2163-7

Were, V., Buff, A. M., Desai, M., Kariuki, S., Samuels, A. M., Phillips-Howard, P., ter Kuile, F. O., Kachur, S. P., & Niessen, L. W. (2019). Trends in malaria prevalence and health related socioeconomic inequality in rural western Kenya: results from repeated household

malaria cross-sectional surveys from 2006 to 2013. *BMJ Open*, *9*(9). https://doi.org/10.1136/bmjopen-2019-033883

Whittemore, R., & Knafl, K. (2005). The integrative review: Updated methodology. *Journal of Advanced Nursing*, *52*(5), 546–553. https://doi.org/10.1111/j.1365-2648.2005.03621.x

World Health Organization. (2017, January 5). *The use of DDT in malaria vector control. WHO position statement*. World Health Organization. https://www.who.int/malaria/publications/atoz/who_htm_gmp_2011/en/.

World Health Organization. (2019). *The "World malaria report 2019" at a glance*. World Health Organization. https://www.who.int/news-room/feature-stories/detail/world-malaria-report-2019.

Zhou, G., Afrane, Y. A., Dixit, A., Atieli, H. E., Lee, M.-C., Wanjala, C. L., Beilhe, L. B., Githeko, A. K., & Yan, G. (2013). Modest additive effects of integrated vector control measures on malaria prevalence and transmission in western Kenya. *Malaria Journal*, *12*(1), 256. https://doi.org/10.1186/1475-2875-12-256

Zhou, G., Hemming-Schroeder, E., Gesuge, M., Afrane, Y. A., Lee, M.-C., Atieli, H. E., Githeko, A. K., & Yan, G. (2020). Gaps between Knowledge and Malaria Treatment Practices after Intensive Anti-Malaria Campaigns in Western Kenya: 2004–2016. *The American Journal of Tropical Medicine and Hygiene*, *102*(6), 1358–1365. https://doi.org/10.4269/ajtmh.19-0907

Zhou, G., Lee, M.-C., Githeko, A. K., Atieli, H. E., & Yan, G. (2016). Insecticide-Treated Net Campaign and Malaria Transmission in Western Kenya: 2003–2015. *Frontiers in Public Health*, *4*. https://doi.org/10.3389/fpubh.2016.00153

Zhou, G., Li, J. S., Ototo, E. N., Atieli, H. E., Githeko, A. K., & Yan, G. (2014). Evaluation of universal coverage of insecticide-treated nets in western Kenya: field surveys. *Malaria Journal*, *13*(1), 351. https://doi.org/10.1186/1475-2875-13-351

Appendix A

Literature Review Leveling Matrix 1

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Article 1 The current malaria morbidity and mortality in different transmission settings in Western Kenya. (Kapesa et al., 2018)	The study aims to understand the degree of malaria morbidity and mortality in Western Kenya.	The study included three areas with varying transmission rates. The areas included Marani (epidemic prone), Iguhu (mesoendemic) and Kombewa (hyperendemic).	Surveys	The study found that mortality rates were higher among children <5 years in high infection transmission setting and among ≥15 years in low and moderate transmission settings.	Level 4: Cross sectional	The study obtained comparison data from only four hospitals in the region; therefore, findings cannot be generalized.	Yes, the study gives insight on malaria prevalence rates in children.
Article 2 Correlation Between Malaria-Specific	To identify the effect of preexisting immunity on the efficacy	118 participants between age 6 months to 65 years were enrolled in the study, 59 from each group.	Experimental	The study found that preexisting immunity can affect the	Level 1: RCT	The study was limited by the small number of P. falciparum	Yes, the study provides significant insight on

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Antibody Profiles and Responses to Artemisinin Combination Therapy for Treatment of Uncomplicated Malaria in Western Kenya. (Odhiambo et al., 2019)	of the different ACT regimens. The study compared 2 ACT regimens, the Artemether-Lumefantrine (AL) and Artesunate-Mefloquine (ASMQ),			efficacy of different ACT regimes. Additionally, ASMQ was found to clear infection faster than, AL.		antigens analyzed; therefore, findings are not generalizable to all antigens.	the effectiveness of ACT regimes. This insight is useful in guiding interventions
Article 3 Indoor and outdoor malaria vector surveillance in western Kenya: Implications for better	To assess vector feeding behavior and their influence on indoor and outdoor malaria	10,864 female Anopheles mosquitoes comprising were collected in western Kenya. The mosquitos composed of 4 types; the An. gambiae s.l. , An. funestus s.l., Anopheles	Observational	The study found that the transmission method varied by type pf mosquito. Anopheles gambiae s.s. showed an	Level V: Cross sectional study	The study did not address the role of secondary vectors in malaria transmission. Thus, findings may be inaccurate.	Yes, the study gives some insight on transmission methods of different mosquito species.

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
understanding of residual transmission. (Degefa et al., 2017)	transmission in western Kenya.	coustani and Anopheles phronesis		increasing tendency to feed on cattle. Anopheles arabiensis was highly zoophagic, whereas An. funestus showed anthropophagic behavior.			
Article 4 Remotely Sensed Environmental Conditions and Malaria Mortality in Three Malaria Endemic Regions in Western	To investigate relationship between Malaria spread and weather conditions and identify early weather	Three endemic areas with a population of 280,000 people were followed over a period of 9 years between 2003 to 2012	Questionnaires	The study found that rainfall was the most consistent predictive pattern to malaria transmission areas in western Kenya.	Level 4: uncontrolled cohort study	Death reports and symptoms were self-reported thus affecting validity of results.	Yes, the study offered valuable insight on the relation between weather condition and malaria transmissio

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Kenya. (Sewe et al., 2016)	warning signs including temperature, and precipitation .						n. This information is useful in developing preventativ e measures.
Article 5 Dynamic malaria hotspots in an open cohort in western Kenya. (Platt et al., 2018)	To determine malaria hotspot locations and measure spatial and temporal stability of malaria hotspots.	8300 compounds in Bungoma east province comprising 12,602 households. Each household was more than 2.5 Kilometers from the nearest river.	Observational	The study found that Malaria hotspots change in six-month intervals and rarely recur in the same area. The study also found that human movement to and from areas with varying levels of malaria	Level 3: case control	Symptoms of malaria were defined by self-report; therefore, recall bias could have affected accuracy of results	Yes, the study offers insight on the impact of local migration on malaria transmissio n

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
				exposure resulted into importation parasite, thus resulting into varying parasite genotype.			
Article 6 Epidemiological risk factors for clinical malaria infection in the highlands of Western Kenya (Essendi et al., 2019).	To determine individual and household factors influencing malaria infection among individuals in the highlands of Western Kenya.	906 participants, 302 symptomatic residents and 604 control participants ages five months old to 45 years.	Surveys and interviews	The study found a link between educational status, occupation and house structure and malaria infection risk in western Kenya.	Level 3: case–control study	The sample size is too small and not representative of the general population.	Yes, the study provides foundational information regarding malaria risk factors specific in the western Kenya region. This insight will guide

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
							intervention .
Article 7 The Effect of Indoor Residual Spraying on the Prevalence of Malaria Parasite Infection, Clinical Malaria and Anemia in an Area of Perennial Transmission and Moderate Coverage of Insecticide Treated Nets in Western Kenya.	To assess the impact of adding an IRS program in areas with high ITN coverage. The study also aims to determine influence of IRS on mosquito density in an area of intense perennial malaria transmission and moderate	Sample size consisted of 2,439 subjects. 1,016 of participants were in the non-IRS group and 1,423 subjects in the IRS group	Surveys	The study found that combining IRS and ITNs in western Kenya compared with ITN use alone significantly with reduced the prevalence of malaria infection and increased hemoglobin levels and reduced anemia	Level 3: Cross-sectional	The study design was non-randomized; therefore, validity of findings could be flawed.	Yes, the study offered insight on the efficacy of combining ITNs and IRS in controlling Malaria.

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
(Gimnig et al., 2016)	ITN coverage						
Article 8 Insecticide-Treated Nets and Protection against Insecticide-Resistant Malaria Vectors in Western Kenya (Ochomo et al., 2017)	To assess if insecticide resistance altered the effectiveness of ITNs in malaria endemic counties of western Kenya	1,000 children ages 1-6.	A non-experimental, descriptive survey	The study found that insecticide resistance rates, especially to pyrethroids, have increased significantly in areas where ITNs and indoor residual spraying are the common practice of vector control.	Level 6: Descriptive design	The study failed to consider insecticide resistance in *An. funestus* mosquitoes	Yes, the study offered insight on the need for measures to monitor insecticide resistance to aid malaria control initiatives.
Article 9 Comparing ownership and use of bed nets at two sites	To understand how cultural, social and environment	105 participants, 53 men and 52 women ages 18–30 years old	Cross-sectional survey	The study found that limited access to bed nets was a leading	Level 4: A cross-sectional study	The study relied on self-report regarding bed net use.	Yes, the study offers insight on cultural and social

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
with differential malaria transmission in western Kenya (Ernst et al., 2016)	al factors of bed net use may vary between areas with high and low transmission rates.			barrier to bed net use. Additional barriers included education, perception and limited knowledge about transmission			barriers to best net use.
Article 10 Plasmodium Falciparum parasitemia and clinical malaria among school children living in high transmission setting in	To investigate the burden of Plasmodium Falciparum infection, clinical malaria and anemia among children.	2,346 school children aged 5–15 years	Cross section surveys	The study found that the prevalence of Plasmodium Falciparum infection was higher in males than females while the risk of clinical malaria was higher in	Level 1: Randomized trial	The children selected were from schools that were purposively selected based on accessibility. Therefore, findings do not represent entire population.	Yes, the study offers insight on the impact of malaria infection in children.

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
western Kenya. (Kepha et al., 2016)				females compared to males.			

Appendix B

Literature Leveling Matrix Table 2

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Article 1 Indoor residual spraying for preventing malaria in communities using insecticide-treated nets. (Choi et al., 2019)	To determine the added effect of combining Indoor Residual Spraying (IRS) with Insecticide-Treated Nets (ITNs) in communities using ITNs.	Individuals living in high endemic in Ethiopia and Tanzania. Included six RCT	Literature review	Combining ITNs with IRS decreased malaria prevalence compared to using only ITNs	Level 1: Systematic review	There were only six RCT studies available for this review	Yes, considering the level of evidence of this study, incorporating evidence found in this study would likely yield good outcomes.

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Article 2 Insecticide-treated nets for preventing malaria (Pryce et al., 2018)	To assess the effectiveness of ITNs in preventing and reducing malaria mortality and morbidity rates	275,000 adults and children were included	Literature review	The review concluded that the use of ITNs reduced severity of malaria by 40%	Level 1: Systematic review	The review did not consider insecticide resistance as a variable considering that some studies were conducted in high insecticide resistance areas.	Yes, the study supports the use of ITNs in malaria prevention noting that ITNs reduced the rate of malaria by 50 percent and severity by 40 percent.
Article 3 Insecticide space spraying for preventing malaria transmission	To evaluate the impact of spraying spaces with insecticides to reduce on malaria transmission.	Review of studies conducted in Haiti an India between 1972 and 1984, both studies included a total of 33,560 adults.	Literature review	The study found a reduction of malaria rates after a month of spraying, and the reduction rate increased	Level 1: Systematic review	The review only included two studies and both studies were performed over 30 years ago. Therefore, the certainty	Yes, the study offers some insight on the benefit of space spraying, but the evidence is not strong considering

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
(Pryce et al., 2018)				after a year of spraying. No impact was noted within the first month.		of the evidence for both studies is very low	that only two RCTs were reviewed. Although there is evidence that spraying may have impact on reducing malaria rates, it would yield better outcomes if combined with other interventions such as ITNs.
Article 4 Strategies to increase the	To evaluate effectiveness of increasing ITN coverage to aid Malaria prevention strategies.	10 studies were included in the review. The sample size of all ten studies	Literature review	The study found no impact in that those who	Level 1: Systematic review	The authors note that there was missing data in the	Yes, the study provides insight on significance

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
ownership and use of insecticide-treated bed nets to prevent malaria (Polec et al., 2015)		totaled 27,083 people.		received free ITNs compared to those who purchased them. The researcher identified that limited knowledge of use for those who received free ITNs resulted into irregular use and therefore did not impact malaria reduction.		reviews which forced them to use only available data.	of educating the targeted population on the proper ways to use ITNs to achieve desired outcome.
Article 5 The Effect of Indoor	The study aimed to understand the impact of IRS and ITN in high transmission verses low transmission areas.	Baseline household surveys were conducted in two districts,	Surveys	The study found that the prevalence of malaria	Level 4: case control	Data may be inaccurate because some of the subjects	Yes, the study provides evidence that the use

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Residual Spraying on the Prevalence of Malaria Parasite Infection, Clinical Malaria and Anemia in an Area of Perennial Transmission and Moderate Coverage of Insecticide Treated Nets in Western Kenya. (Gimnig et al., 2016)		one district was a high malaria transmission district while the other one was a low Malaria transmission district.		reduced form 16.7 percent to 6.4 percent after two rounds or IRS use in both regions, no change was noted after one round of IRS.		used both IRS and ITNs; therefore, it was difficult for the researchers to isolate the actual effects of IRS in those who used ITNs and IRS concurrently.	of IRS has potential to reduce malaria rates in both low and high endemic regions. This supports universal use of IRS irrespective of geographic location.

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Article 6 Impact of insecticide-treated nets and indoor residual spraying on malaria case prevalence in Geita and Nyang'hwale districts of Tanzania (Gaudence et al., 2018).	The objective of this study is to assess the difference in impact when ITNs and IRS are used together versus when IRS is used alone.	807,619 residents in Geita District and 148,320 in Nyang'hwale district. 435,719	Surveys	The malaria prevalence rates in the region that received both the IRS and ITNs reduced from 53 percent to 12 percent. However, the region, with only IRS, saw an increase in malaria cases from 103,788 to 123,337	Level 3: cross sectional	The study included both pyrethroid IRS and non-pyrethroid IRS and failed to consider pyrethroid resistance, which could have impacted the effectiveness of IRS hence impacting overall findings.	Yes, the reported decrease of malaria from 53 percent to 12 percent provides adequate foundation on the benefits of combining ITNs with IRS.
Article 7	The goal of the study was to measure the effectiveness of ITNs by measuring changes	Malaria test positivity rate data was obtained from	Quantitative data analysis	The study found modest decline in	Level 4: Cohort study	The study lacks a control group for	Yes, the study offers insight on variables,

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Measures of Malaria Burden after Long-Lasting Insecticidal Net Distribution and Indoor Residual Spraying at Three Sites in Uganda: A Prospective Observational Study (Katureebe et al., 2016).	in key malaria indicators after initiating universal ITN campaigns in 3 sub counties in Uganda.	hospitals and clinics in three sub counties including, the county of Walu-kuba, Kihii and Nagongera. The reported cases of malaria were as follows: Walu- kuba - 42,833, Kihihi - 28,790, and Nagongera - 38,690		malaria cases with use of ITNs alone and significant decline with combined use of ITNs with IRS. The researchers also found that cost of IRS and the need of repeated use affected sustainability of use and was a key element to consider in malaria campaigns.		comparison and causal inferences. The study does not outline indicators measured or considered.	such as cost and type of IRS to consider when planning malaria campaigns.

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Article 8 Community knowledge and acceptance of indoor residual spraying for malaria prevention in Mozambique: A qualitative study (Magaço et al., 2019).	The objective of this study was to evaluate factors related to the IRS uptake and reasons for IRS use refusal in malaria burden Mozambique communities.	61 people were interviewed, and 12 focus groups were conducted.	Interviews	The study found belief in limited IRS efficacy as the most common reason for refusal. Additional barriers to IRS acceptance included: past negative experiences from previous campaigns, political and historical factors as well as preference for ITNs over IRS.	Level 6: qualitative study	The study interviewed a small sample of 61 people. These sample does not represent the entire population.	Yes, the study provides insight on IRS refusal to consider in malaria prevention strategies.

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
Article 9 Equity in long-lasting insecticidal nets and indoor residual spraying for malaria prevention in rural South-Central Ethiopia (Hailu et al., 2016).	To evaluate the socioeconomic factors and inequity in distribution of malaria prevention strategies.	The study was conducted in 13 villages in Ethiopia. 31,284 individuals from 6,069 households were included in the study.	Self-reported questionnaire	The study found higher ITN ownership the wealthy compared to the poor. Additionally, the study also found even bigger gaps in IRS uptake in the wealthy and the poor. This was mainly due to cost and limited access to IRS.	Level 6: Descriptive	The study lacked a control group.	Yes, the study provides relevant insight on social-economic factors to consider when developing malaria prevention strategies.
Article 10 Digital Insecticide-	To describe implementation barriers of a digital Insecticide-treated nets (ITNs) mass	The study included a total of 14,423,998 people.	Cross sectional	The study found that political engagement, commitment	Level 6: Descriptive	Data may be inaccurate because the study was briefly	Yes, the study offers relevant insight on the need to

Article Title, Author, etc. (Current APA Format)	**Study Purpose**	**Sample (Characteristics of the Sample: Demographics, etc.)**	**Methods**	**Study Results**	**Level of Evidence (Use Melnyk Framework)**	**Study Limitations**	**Would Use as Evidence to Support a Change? (Yes or No) Provide Rationale.**
treated nets (ITNs) mass distribution campaign in the particular context of covid-19 pandemic in Benin: Lessons learned and challenges. (Aikpon et al., 2020).	distribution campaign in Benin. The study also hoped to inspire the development of digital malaria prevention strategies to supplement malaria control efforts during lockdowns due to crisis such as Corona Virus 19 (Covid-19) pandemic.			, and financial support contributed to the success of the program despite Covid-19 challenges. The researcher adds that government involvement in the campaign facilitated adaptation of unforeseen changes in protocol related to Covid-19.		interrupted by the Covid-19 pandemic.	develop digital malaria prevention strategies that can be used during pandemics and global crisis.

Appendix C

Literature Leveling Matrix 3 (Included Articles)

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
Nets, spray or both? The effectiveness of insecticide-treated nets and indoor residual spraying in reducing malaria morbidity and child mortality in sub-Saharan Africa	(Fullman et al., 2013)	17 countries in sub-Saharan Africa.	Secondary data analysis	ITN with IRS	Combined ITNs and IRS use reduced malaria risk in medium and high transmission areas. 53% in medium transmission areas and 31% in low. No impact in low transmission areas. Combined interventions did not reduce childhood mortality.	-ITN more protective in areas with high and medium transmission while IRS was most protective in areas with medium and low transmission -Combined ITN with IRS more protective in medium transmission areas.
Factors associated with willingness to take up indoor residual spraying to prevent malaria in Tororo district, Uganda: a cross-sectional study	(Wadunde et al., 2018)	Uganda	Descriptive cross sectional	IRS uptake	Low willingness to use IRS among household heads	-Age was a factor in in willingness to use IRS. Those over age of 35 years were more willing to take up IRS largely due to lived experience and the belief that IRS is an essential malaria control

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
						strategy. Need for IRS education to target younger populations. -Community and religious leaders are preferred sources of IRS information.
Caretakers' understanding of malaria, use of insecticide treated net and care seeking-behavior for febrile illness of their children in Ethiopia	(Birhanu et al., 2017)	Ethiopia	Cross sectional	ITN use and Malaria knowledge	Only 66% of 720 participants identified mosquito bite as the cause of malaria. Low knowledge of malaria transmission linked to less ITN usage.	Low malaria transmission knowledge (66%) Low knowledge on the role of IRS ITN use and access gaps identified
Comparing ownership and use of bed nets at two sites with differential malaria transmission in western Kenya	(Ernst et al., 2016)	Western Kenya	Cross sectional	ITN ownership	70 percent ITN ownership in lowlands compared 59.5 percent in highlands. Higher infection rate in lowlands compared to highlands. Belief that treated ITN affect fertility	ITN access barrier was the leading cause of use. -Belief that ITNs should only be used during rainy season.

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
The Effect of Indoor Residual Spraying on the Prevalence of Malaria Parasite Infection, Clinical Malaria and Anemia in an Area of Perennial Transmission and Moderate Coverage of Insecticide Treated Nets in Western Kenya	(Gimnig et al., 2016)	Western Kenya	Observational	Adding IRS to ITNs	Minimal impact on malaria prevalence after 1 round of with pyrethroid IRS, strongest impact after 2 rounds Using both ITN and IRS most effective when implemented in areas with moderate to high transmission and moderate ITN coverage	
Reduction of Malaria Prevalence by Indoor Residual Spraying: A Meta-Regression Analysis	(Kim et al., 2012)	All malaria endemic areas in Africa, South Asia, central and south America	Meta regression analysis	IRS efficacy	IRS is more protective in areas with high transmission after several rounds when DDT containing IRS is used Unrecognized long-term health effects related to DDT use	
Knowledge, attitude and behavior towards the use of insecticide treated mosquito nets among pregnant women and children in rural Southwestern Uganda	(Taremwa et al., 2017)	Uganda	descriptive cross-sectional study	ITN knowledge	85 percent own net but only 66.1 percent use them consistently. ITN use influenced by socio-cultural expectations and cultural beliefs about symptoms and misconceptions about malaria	

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
					98 % recognize signs and symptoms of malaria Other reasons for nonuse perceived concerns about health effects of the chemical.	
Insecticide-treated net use before and after mass distribution in a fishing community along Lake Victoria, Kenya: successes and unavoidable pitfalls	(Larson et al., 2014)	Western Kenya	Cross sectional	ITN use, ownership and knowledge	ITN use was associated with education level and occupation. On the other hand, ITN ownership was associated with multiple factors including cost, distance to distribution sites, socioeconomic status, and targeted distribution region. High coverage found in areas closer to the lake, the lowlands compared to high areas.	
The Combination of Indoor Residual Spraying and Insecticide-Treated Nets Provides Added Protection against Malaria Compared with Insecticide-Treated Nets Alone	(Hamel et al., 2011)	Western Kenya	Nonrandomized cohort	Combined ITN with IRS	Protective efficacy of combining ITN with IRS was 61 percent compared to ITN use alone. Significant decrease in clinical malaria in children between 6 months and 4 years of age. Decreased parasite density in the group with both ITN and IRS	

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
					Decreased ITN use on the group with combined ITN and IRS due to perception that of reduced malaria risk. Thus, suggesting the need to include educational interventions to encourage continued ITN use.	
Insufficient Ratio of Long-Lasting Insecticidal Nets to Household Members Limited Universal Usage in Western Kenya: A 2015 Cross-Sectional Study	(Coalson et al., 2020)	Western Kenya	cross-sectional survey	ITN ownership and usage	During mass ITN distribution campaign, only 8 percent of people in the highlands received a net compared to 36 percent in the lowlands. Insufficient ownership found in large households	
Long lasting insecticidal mosquito nets (LLINs) ownership, use and coverage following mass distribution campaign in Lake Victoria basin, Western Kenya	(Ng'ang'a et al., 2021)	Western Kenya	Cross sectional	ITN ownership and use	Malaria is the most frequently occurring illness in western Kenya Distance to health facility where ITN can be attained was reported to affect ITN ownership Cultural practices – mourning outdoors at night increase exposure to mosquito bites ITN use vary based on level of education and seasonal patterns	

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
Malaria knowledge and its associated factors among pregnant women attending antenatal clinic of Adis Zemen Hospital, North-western Ethiopia, 2018	(Goshu & Yitayew, 2019)	Ethiopia	Cross sectional	Malaria knowledge	Educated mothers with high income were more knowledgeable on malaria knowledge compared to non-educated mothers. Education, income and residence (urban vs rural) factors associated with malaria knowledge 91 percent has high knowledge of malaria symptoms but only 74 percent has knowledge on malaria transmission. Definition of Malaria knowledge cause of malaria signs and symptoms mode of transmission complications preventative mechanisms	
Knowledge and practices on malaria prevention in two rural communities in Wakiso District, Uganda	(Musoke et al., 2015)	Uganda	Cross sectional	Knowledge and practices of malaria prevention	64 percent had decreased knowledge of malaria prevention Malaria knowledge was associated with age, education status, employment and income level. Inadequate knowledge linked to inappropriate use of intervention Perceived health risks of IRS	

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
Insecticide-Treated Net Campaign and Malaria Transmission in Western Kenya: 2003–2015	(Zhou et al., 2016)	Western Kenya	Cross sectional	ITN ownership		
Women's knowledge and perceptions of malaria and use of malaria vector control interventions in Kersa, eastern Ethiopia	(Gobena et al., 2013)	Ethiopia	Cross sectional	ITN, IRS and Malaria knowledge	Only 56 % associated malaria with mosquito bite	
Spatial Distribution of Bednet Coverage under Routine Distribution through the Public Health Sector in a Rural District in Kenya	(Prudhomme O'Meara et al., 2011)	Western Kenya	Cross sectional	ITN ownership	Despite free ITN distribution in ante natal clinics, ITN ownership was not found to be higher in pregnant women when compared to non-pregnant women. Factors associated with ITN ownership included wealth, occupation, distance to healthcare facility, distance to nearest road.	
Benefits of the school based social and behavior change communication interventions on ITN	(Abamecha et al., 2021).	Ethiopia	Quasi experimental	ITN and malaria knowledge	Malaria education advanced malaria knowledge, attitude, self-efficacy and risk perception	

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
utilization among primary school students in rural Ethiopia: a controlled quasi-experimental design					Following based malaria education workshop, ITN use was 39 percent higher in the group that received malaria education.	
Community knowledge, attitude, and practice about malaria in a low endemic setting of Shewa Robit Town, northeastern Ethiopia	(Abate et al., 2013)	Ethiopia	Cross sectional	Malaria prevention knowledge	Misconceptions about malaria transmission through personal contact, flies, cold weather and personal hygiene. Malaria knowledge linked with higher use of malaria prevention tools.	
Evaluation of universal coverage of insecticide-treated nets in western Kenya: field surveys	(Zhou et al., 2014)	Western Kenya	Cross sectional	ITN coverage	ITN coverage gaps appear after distribution due to, loss, being used for other purposes such as fishing and population growth. Existing ITN coverage gaps.	
Non-adherence to long-lasting insecticide treated bed net use following successful malaria control in Tororo, Uganda	(Rek et al., 2020)	Uganda	Case control	Assess ITN adherence after malaria transmission is reduced	High nonadherence due to reduced malaria risk perception	

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
Modest additive effects of integrated vector control measures on malaria prevalence and transmission in western Kenya	(Zhou et al., 2013)	Western Kenya	Mixed design	To assess added benefit of adding IRS to ITN	Adding IRS reduced mosquito density, but it was seasonal. Reduced malaria risk in ITN and IRS houses compared to houses with ITN or IRS alone. Group with combined ITN with IRS showed 79 percent malaria risk reduction whereas the ITN and IRS group had a 40 percent and 58 percent reduction risk, respectively.	
Insecticide-treated net (ITN) ownership, usage, and malaria transmission in the highlands of western Kenya	(Atieli et al., 2011)	Western Kenya	Cross sectional	ITN ownership and use	ITN use in rainy seasons 62% compared to dry seasons 49.6% Education level associated with ITN ownership and use	
Community knowledge and perceptions about indoor residual spraying for malaria prevention in Soroti	(Ediau et al., 2013)	Uganda	Cross sectional	IRS knowledge	Those with a high school education or higher has higher IRS knowledge 66 % perceived IRS to have negative health effects	

Title	Intext	Country	Study type	Intervention of interest	Themes /Outcomes	Unexpected Findings
district, Uganda: a cross-sectional study					IRS uptake hindered by privacy concerns of allowing sprayers to enter their homes and the inconvenience of leaving the home before and after spraying and moving items from the home during spraying.	
Behavioral change communication strategy vital in malaria prevention interventions in rural communities: Nakasongola district, Uganda	(Mugisa & Muzoora , 2012)	Uganda	Cross sectional	Malaria knowledge	Behavior education interventions increased malaria prevention knowledge from 76.6 % to 90%.	
Combining indoor residual spraying and insecticide-treated nets for malaria control in Africa: a review of possible outcomes and an outline of suggestions for the future	(Okumu & Moore, 2011)	All endemic regions	Systematic review	ITN with IRS	Mixed evidence on the added benefits of combining ITNs with IRS	

Appendix D

IRB Approval Letter

IRB #: IRB-FY20-21-858
Title: PREVENTING MALARIA IN WESTERN KENYA THROUGH EDUCATIONAL INTERVENTIONS AND TREATMENT COMBINATION OF INDOOR RESIDUAL SPRAYING WITH INSECTICIDE TREATED MOSQUITO NETS: AN INTEGRATED REVIEW
Creation Date: 4-25-2021
End Date:
Status: Approved
Principal Investigator: Banis Githinji
Review Board: Research Ethics Office
Sponsor:

Study History Submission Type Initial

Key Study Contacts

Review Type

Exempt

Decision

Research

Contact Contact Contact

No Human Subjects

fodedina@liberty.edu bngithinji@liberty.edu bngithinji@liberty.edu

---

Member Member Member

Folashade Odedina Banis Githinji
Banis Githinji

Role Co-Principal Investigator Role Principal Investigator Role Primary Contact

---

Appendix E

CITI Training Certificate

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI PROGRAM)

COMPLETION REPORT - PART 1 OF 2
COURSEWORK REQUIREMENTS*

* NOTE: Scores on this Requirements Report reflect quiz completions at the time all requirements for the course were met. See list below for details. See separate Transcript Report for more recent quiz scores, including those on optional (supplemental) course elements.

- **Name:** Banis Githinji (ID: 9918448)
- **Institution Affiliation:** Liberty University (ID: 2446)
- **Institution Email:** bngithinji@liberty.edu

- **Curriculum Group:** Biomedical Research - Basic/Refresher
- **Course Learner Group:** Biomedical & Health Science Researchers
- **Stage:** Stage 1 - Basic Course
- **Description:** Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in biomedical research with human subjects.

- **Record ID:** 41035862
- **Completion Date:** 22-Feb-2021
- **Expiration Date:** 22-Feb-2024
- **Minimum Passing:** 80
- **Reported Score*:** 84

REQUIRED AND ELECTIVE MODULES ONLY	DATE COMPLETED	SCORE
Belmont Report and Its Principles (ID: 1127)	17-Feb-2021	3/3 (100%)
Recognizing and Reporting Unanticipated Problems Involving Risks to Subjects or Others in Biomedical Research (ID: 14777)	22-Feb-2021	5/5 (100%)
Liberty University (ID: 15111)	18-Feb-2021	No Quiz
Populations in Research Requiring Additional Considerations and/or Protections (ID: 16680)	18-Feb-2021	4/5 (80%)
History and Ethics of Human Subjects Research (ID: 498)	22-Feb-2021	4/5 (80%)
Basic Institutional Review Board (IRB) Regulations and Review Process (ID: 2)	22-Feb-2021	4/5 (80%)
Informed Consent (ID: 3)	22-Feb-2021	4/5 (80%)
Social and Behavioral Research (SBR) for Biomedical Researchers (ID: 4)	22-Feb-2021	4/4 (100%)
Records-Based Research (ID: 5)	22-Feb-2021	3/3 (100%)
Genetic Research in Human Populations (ID: 6)	22-Feb-2021	5/5 (100%)
Research and HIPAA Privacy Protections (ID: 14)	22-Feb-2021	4/5 (80%)
Conflicts of Interest in Human Subjects Research (ID: 17464)	22-Feb-2021	2/5 (40%)

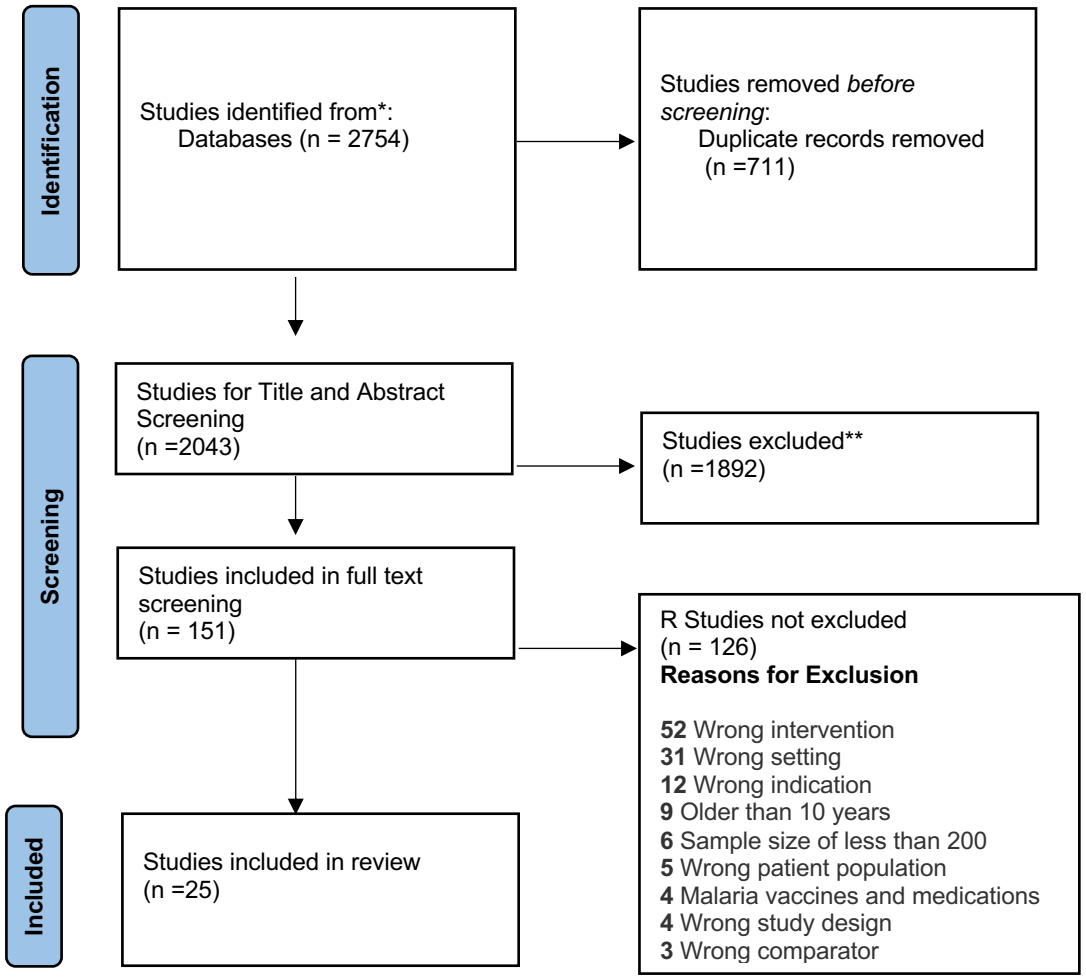
For this Report to be valid, the learner identified above must have had a valid affiliation with the CITI Program subscribing institution identified above or have been a paid Independent Learner.

Verify at: www.citiprogram.org/verify/?kade566ff-4e6f-4b9b-98cf-6fdc7439c253-41035862

Collaborative Institutional Training Initiative (CITI Program)
Email: support@citiprogram.org
Phone: 888-529-5929
Web: https://www.citiprogram.org

Appendix F

PRISMA Flow Diagram



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

Appendix G

Study Characteristics

Study design	Methodology	Country	Sample Size	ITN	IRS	ITN with IRS	ITN Knowledge	IRS Knowledge	Malaria Knowledge	Results
Meta-analysis	Surveys	17 countries in sub-Saharan Africa.				x				Varied
Descriptive cross sectional	Surveys	Uganda	640		x			x		Low knowledge
Cross sectional	Interview	Ethiopia	709	x					x	Low knowledge
Qualitative	Surveys	Western Kenya	3,255	x			x			Low knowledge
Cross sectional	Surveys	Western Kenya	30 clusters		x					Mixed
Meta-analysis	Literature review All malaria endemic regions in Africa, Southeast Asia, Central America, and		n/a		x					Varied

Study design	Methodology	Country	Sample Size	ITN	IRS	ITN with IRS	ITN Knowledge	IRS Knowledge	Malaria Knowledge	Results
	South America									
Descriptive cross-sectional study	Questionnaire	Uganda	382				x		x	Low knowledge ITN use
Cross sectional	Observational	Western Kenya	12098	x			x			Low use
Nonrandomized control trial	Experimental	Western Kenya	1804			x				Decreased malaria
Cross-sectional	Survey	Western Kenya	4419	x			x			Ownership disparities
Cross sectional	Questionnaire	Western Kenya	753	x						Low use
Cross sectional	Interview	Ethiopia	236						x	Moderate knowledge 74%
Cross sectional	Survey	Uganda	376				x	x		Low knowledge
Cross sectional	Survey	Western Kenya	300	x						High ownership after distribution
Cross sectional	Interviews and Questionnaires	Ethiopia	2463	x	x	x	x	x	x	Low knowledge

Study design	Methodology	Country	Sample Size	ITN	IRS	ITN with IRS	ITN Knowledge	IRS Knowledge	Malaria Knowledge	Results
Retrospective analysis	Data analysis	Western Kenya	44,753 households	x						Low ownership
Quasi experimental	Questionnaire	Ethiopia	798				x			improved literacy
Cross sectional	Interview	Ethiopia	425						x	Low knowledge
Cross sectional	Surveys	Western Kenya	6878 households	x						Low usage despite high ownership ITN ownership 84 %, usage 75%
Case Control	Observational	Uganda	526	x						High non-adherence
Case Control	Survey	Western Kenya	560			x				Reduction based on season
Cross sectional	Survey	Western Kenya	600 households	x						Low use
Cross sectional	Questionnaire	Uganda	770					x		Low knowledge of 48%
Cross sectional	Survey	Uganda	16 villages						x	Improved malaria prevention knowledge

Study design	Methodology	Country	Sample Size	ITN	IRS	ITN with IRS	ITN Knowledge	IRS Knowledge	Malaria Knowledge	Results
Systematic Review	Literature review	All endemic countries	n/a			x				Mixed