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Masters Program in Public Health, Universitas Sebelas Maret

Meta-Analysis

Effects of Insecticide-Treated Nets and Stagnant Water on the Risk of Malaria: A Meta-Analysis

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ABSTRACT

Background: Malaria infection is a global public health problem that causes major morbidity worldwide. Stagnant water is one of the risk factors for malaria, insecticide-treated nets are one of the interventions that can prevent malaria. This study aims to estimate the magnitude of the effect of using insecticide-treated nets and stagnant water around the house on the risk of malaria.
Subjects and Method: This study was conducted using a systematic review and meta-analysis with PICO ie, Population: children. Intervention: insecticide-treated mosquito nets and stagnant water. Comparison: without insecticide-treated nets and no stagnant water. Result: incidence of malaria. By searching for articles in 3 databases namely PubMed, Google Scholar, Science Direct published from 2016 to 2023, by entering the following keywords insecticide-treated bed nets" OR "ITN" AND "stagnant water" OR "STAGNA" AND "Malaria" AND "Cross sectional" AND "Multivariate Analysis". Articles were selected using the PRISMA flow and data analysis using the Review Manager 5.3.
Results: There are 13 articles using a cross-sectional study design with a total sample of 5,793 children from Indonesia, Cameroon, Nigeria and Ethiopia which have gone through a systematic review and meta-analysis. Processed data showed that children who used insecticide-treated nets had a 0.65 times lower chance of contracting malaria compared to those who did not use insecticide-treated nets (aOR= 0.65; 95% CI= 0.41 to 1.01; p= 0.060). Children who live in an environment where there is stagnant water have a 4.10 times chance of getting malaria compared to children who live in an environment where there is no stagnant water and this is statistically significant (aOR= 4.10; 95% CI= 2.80 to 6.03; p < 0.001).
Conclusion: Insecticidal mosquito nets reduced the incidence of malaria, and stagnant water increased the incidence of malaria.

Keywords: insecticide-treated nets, stagnant water, STAGNA, children

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BACKGROUND

Malaria infection is still a global public health problem that causes morbidity worldwide (WHO, 2018). Malaria infection is spread by bite of female mosquitoes infected with Anopheles (Bate et al., 2016). *Plasmodium falciparum* is considered to the most common of all plasmodia in sub-Saharan Africa (SSA) (Bate et al., 2016). Other malaria parasites that cause disease in humans include *Plasmodium vivax,* *Plasmodium malaria*, and *Plasmodium ovale* (Eke et al., 2018)

Recent reports show that globally, around 214 million cases of malaria occur annually and 3.2 billion people are at risk of infection. 1.2 Furthermore, the report also shows that in 2017, there were 438,000 deaths from malaria globally. Of these, around 93% occur in the World Health Organization (WHO) Africa region, with Nigeria accounting for the highest burden at 19% (Bhatt et al., 2015). In Africa, malaria is responsible for around 20% to 30% of total admissions and around 30% to 50% of out-patient consultations (Faihurst et al., 2012). Previous studies have documented a high prevalence of malaria throughout Nigeria (Jemimah et al., 2019; Chukwuocha et al., 2016). This devastating disease affects the country's economic productivity, resulting in an estimated monetary loss of around 132 billion Naira (about US$700 million) in treatment, prevention and other indirect costs (Federal Ministry of Health, 2012).

Several methods are used to determine malaria prevalence and identify risk factors associated with malaria infection including health facility and community-based cross-sectional surveys. Previous studies conducted in Africa and Asia on factors related to malaria prevalence identified age, number of mosquito nets in the household, presence of forest cover, sex, altitude, household density and mud walls as key determinants (Haque et al., 2011). Similarly, in Ethiopia, insecticide net use (ITN), age, gender, wealth index, presence of stagnant water in settlements, distance from health facilities and materials used for roofing were identified as risk factors for malaria infection (Alemu et al., 2011).

The use of insecticide-treated nets due to stagnant water around the house is recommended so that it can be an intervention that can reduce the risk factors for malaria. This study aims to estimate the magnitude of the effect of using insecticide-treated nets and stagnant water around the house on the risk of malaria.

SUBJECTS AND METHOD

1. Study Design

The research design used was a meta-analysis study design, which is a systematic study to calculate several research results regarding the relationship between insecticide-treated nets and stagnant water on the incidence of malaria. The time of the study results is in the period 2016 to 2023. The search for articles is carried out for at least 1 month. Search for this article through databases, including: PubMed, Springer-link, Cochrane Database, Elsevier, Google Scholar, using the search keywords “insecticide-treated bed nets” OR “ITN” AND “stagnant water” OR “STAGNA” AND “Malaria” AND “Cross sectional” AND “Multivariate Analysis".

2. Steps of Meta-Analysis

The meta-analysis was carried out through 5 steps as follows:

1) Formulate research questions in PICO (Population, Intervention, Comparison, Outcome) format.
2) Searching for primary research articles from various electronic and non-electronic databases.
3) Screening and critical assessment of primary research articles.
4) Perform data extraction and synthesize effect estimates into RevMan 5.3.
5) Interpret and conclude the results.

3. Inclusion Criteria

The inclusion criteria for this study were full text English articles and a cross-sectional study design. The subject of the study was the incidence of malaria.

4. Exclusion Criteria

Exclusion criteria from this study were the size of the results of the study were not complete or did not clearly describe the results, the year of publication was more than 10 years since this study was conducted, the intervention and study population were different.

5. Operational Definition of Variables

Article search was carried out by considering the eligibility criteria determined using the PICO model. Population: children with malaria. Intervention: insecticide-treated mosquito nets and stagnant water. Comparison: no insecticide-treated mosquito nets and no stagnant water. Outcome: incidence of malaria.

Malaria: is a febrile condition caused by a protozoan parasite that attacks red blood cells. This parasite is transmitted by mosquitoes in many tropical/ subtropical areas.

The use of insecticide-treated nets: is an action taken to prevent mosquitoes from entering the bed area.

Stagnant water: is a condition there are a stagnant water around the house.

6. Study Instruments

This review will be analyzed systematically using meta guidelines, namely Preferred Reporting Items for Systematic Reviews and Meta Analysis (PRISMA) and using the Critical Appraisal Skills Program for cross-sectional study (CASP).

7. Data Analysis

The data in this study were analyzed using the Review Manager application (RevMan 5.3). Forest plots and funnel plots are used to determine the effect size and heterogeneity of the data. Data processing is carried out based on variations between studies, namely the fixed effect model or the random effect model.

RESULTS

The primary article search in this study used databases, namely Google Scholar, PubMed, and Science Direct. The process of screening articles according to the research criteria can be seen in the PRISMA flowchart (Figure 1). The initial search process obtained 1,427 then after going through a screening process, 1,077 articles were obtained which were considered as primary articles of this study, and 14 articles were included in this meta-analysis. The articles obtained came from 2 continents, namely Asia (Indonesia), Africa (Cameroon, Nigeria, Ethiopia).

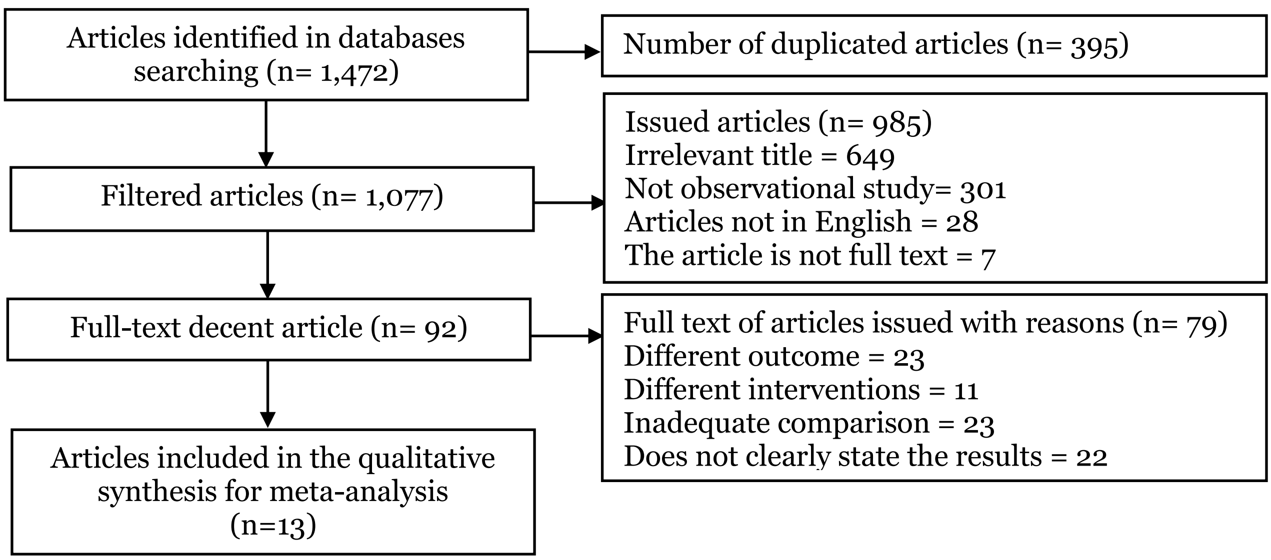

Figure1. PRISMA Flow Diagram

Figure 2. The cross-sectional study area of effects of insecticide-treated nets and stagnant wateron the risk of malaria

The assessment of the quality of the study was carried out quantitatively, in which this study used a quality assessment of the study with a cross-sectional design based on the Critical Appraisal Skills Program for cross-sectional study (CASP) in 2014. The results of the assessment of the quality of the study based on CASP can be seen in Table 1.

Table 2 and table contains brief descripttions of 13 articles relating to the effect of insecticide treated nets and stagnant water on the incidence of malaria in children.

Table 1. Critical appraisal checklist for cross-sectional studies in meta-analysis

Primary Study	Criteria of Questions												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Ibrahim et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	24
Leonard et al. (2016)	2	2	2	0	1	2	2	2	2	2	0	2	19
Ahmed et al. (2021)	2	2	2	0	1	2	2	2	2	2	0	2	19
Haji et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	2	24
Mekuria et al. (2022b)	2	2	2	2	2	2	2	2	2	2	2	2	24
Abossie et al. (2020a)	2	2	2	2	2	2	2	2	2	2	2	2	24
Haiti et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	2	24
Leonard et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	2	24
Tsegaye et al. (2021)	2	2	2	0	1	2	2	2	2	2	0	2	19
Awosulu et al. (2021)	2	2	2	2	2	2	2	2	2	2	2	2	24
Duguma et al. (2022b)	2	2	2	2	2	2	2	2	2	2	2	2	24
Debash et al. (2022)	2	2	2	0	1	2	2	2	2	2	0	2	19
Amanuel and Tadesse (2023)	2	2	2	2	2	2	2	2	2	2	2	2	24

Description of the question criteria:

1 = Do the research objectives clearly address the focus/problem of the research?

2 = Is the research method (research design) suitable for answering the research question?

3 = Is the research subject selection method clearly written?
4 = Does the sampling method give rise to bias (selection)?
5 = Does the research sample take represent the designated population?
6 = Was the sample size based on pre-study considerations?
7 = Is the measurement method achievable?
8 = Are the research instruments valid and reliable?
9 = Was statistical significance assessed?
10 = Was a confidence interval given for the main outcome?
11 = Are there any confounding factors that have not been taken into account?
12 = Are the results applicable to your research?

Description of the answer score:
0 = No
1 = Hesitate
2 = Yess

Table 2. Description of cross-sectional studies of the effects of insecticide-treated nets and stagnant wateron the risk of malaria

Author (year)	Country	Sample size	P	I	C	O
Ibrahim et al. (2022)	Nigeria	330	Child with fever	Use insecticide-treated mosquito nets	Do not use insecticide-treated mosquito nets	Incidence of malaria
Leonard et al. (2016)	Cameroon	292	Child	Use insecticide-treated mosquito nets	Do not use insecticide-treated mosquito nets	Incidence of malaria
Ahmed et al. (2021)	Ethiopia	356	Child	Use insecticide-treated mosquito nets	Do not use insecticide-treated mosquito nets	Incidence of malaria
Haji et al. (2016)	Ethiopia	830	Children <16 years	Use insecticide-treated mosquito nets	Do not use insecticide-treated mosquito nets	Incidence of malaria
Mekuria et al. (2022)	Ethiopia	532	Children in Ilu Galan, Ethiopia	Use insecticide-treated mosquito nets	Do not use insecticide-treated mosquito nets	Incidence of malaria
Abossie et al. (2020a)	Ethiopia	271	Child <5 years	Use insecticide-treated mosquito nets	Do not use insecticide-treated mosquito nets	Incidence of malaria
Haiti et al. (2017)	Indonesia	176	Child	Use insecticide-treated mosquito nets	Do not use insecticide-treated mosquito nets	Incidence of malaria
Tsegaye et al. (2021)	Ethiopia	585	Child <5 years	There are puddles around the house	No water pond around the house	Incidence of malaria
Awosulu et al. (2021)	Nigeria	380	Child infected with *Plasmodium falciparum*	There are puddles around the house	No water pond around the house	Incidence of malaria

Author (year)	Country	Sample size	P	I	C	O
Duguma et al. (2022b)	Ethiopia	412	Child	There are puddles around the house	No water pond around the house	Incidence of malaria
Debash et al. (2022)	Ethiopia	633	Child <5 years	There are puddles around the house	No water pond around the house	Incidence of malaria
Ahmed et al. (2021)	Ethiopia	356	Child <5 years	There are puddles around the house	No water pond around the house	Incidence of malaria
Amanuel and Tadesse (2023)	Ethiopia	640	Child in Shashogo district, southern Ethiopia	There are puddles around the house	No water pond around the house	Incidence of malaria
Ibrahim et al. (2022)	Nigeria	330	Child with fever.	There are puddles around the house	No water pond around the house	Incidence of malaria

Table 3. Data of the effect insecticide-treated nets on the incidence of malaria in children

Author (Year)	aOR	95%CI	
		Lower Limit	Upper Limit
Ibrahim et al. (2022)	2.98	1.09	6.69
Leonard et al. (2016)	0.25	0.07	0.95
Ahmed et al. (2021)	0.22	0.06	0.61
Haji et al. (2016)	0.69	0.56	0.85
Mekuria et al. (2022)	0.61	0.37	1.11
Abossie et al. (2020a)	1.24	0.17	8.97
Haiti et al. (2017)	0.50	0.23	1.08

The forest plot in Figure 3 shows that ITN is effective in reducing malaria incidence, and is statistically almost significant. Children who used insecticide-treated mosquito nets were 0.65 times less likely to develop malaria than those who did not use insecticide-treated mosquito nets (aOR= 0.65; 95% CI= 0.41 to 1.01; p= 0.060).

The forets plot in Figure 3 also shows the estimated effect between studies with high heterogeneity (I^2= 59%), so that the calculation of effect estimation uses the Random Effect Model (REM) approach.

Figure 4 shows the funnel plot results from the influence of insecticide-treated nets, the figure shows no publication bias.

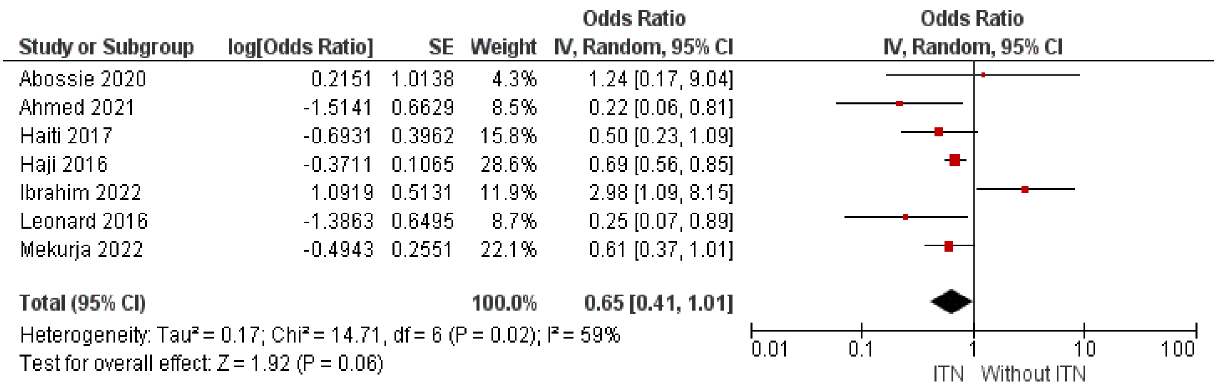

Figure 3. Forest plot of the Effect insecticide-treated nets on the incidence of malaria in children

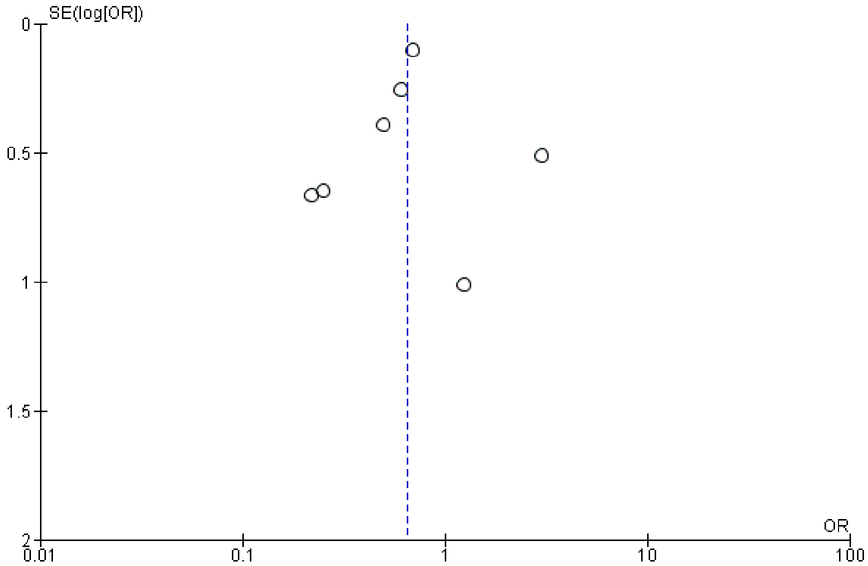

Figure 4. Funnel plot of the Effect insecticide-treated nets on the incidence of malaria in children

Table 5. Effect of stagnant water on the incidence of malaria in children

Author (Year)	aOR	95 % CI Lower limit	95 % CI Upper limit
Tsegaye et al. (2021)	4.00	1.90	8.10
Awosulu et al. (2021)	3.69	1.89	7.22
Duguma et al. (2022b)	4.00	1.14	14.60
Debash et al. (2022)	5.22	2.92	9.33
Ahmed et al. (2021)	8.99	5.08	15.90
Amanuel & Tadesse (2023)	1.76	0.79	3.42
Ibrahim et al. (2022)	3.36	2.13	5.30

The forest plot in Figure 5 shows that stagnant water has an effect on increasing the incidence of malaria. Children who live in environments with stagnant water have a 4.10 times chance of getting malaria compared to children who live in environments where there are no stagnant water and are statistically significant (aOR= 4.10; 95% CI= 2.80 to 6.03; p < 0.001).

The forest plot in Figure 5 also shows the estimated effect between studies with high heterogeneity (I²= 53%), so the calculation of effect estimate uses the Random Effect Model (REM) approach.

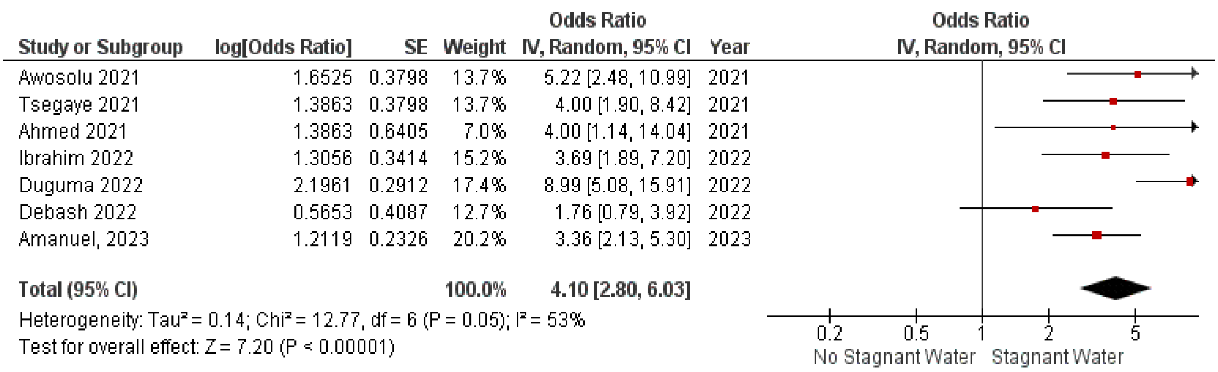

Figure 5. Forest plots the Effect of stagnant water on the incidence of malaria in children

The funnel plot in Figure 6 shows that the distribution of effect estimates is more to the left of the average vertical line, which indicates publication bias. Because there are more effect estimates in the funnel plots to the left of the vertical line as opposed to the average effect estimates in the forest plots to the right, publication bias tends to understate the true effect.

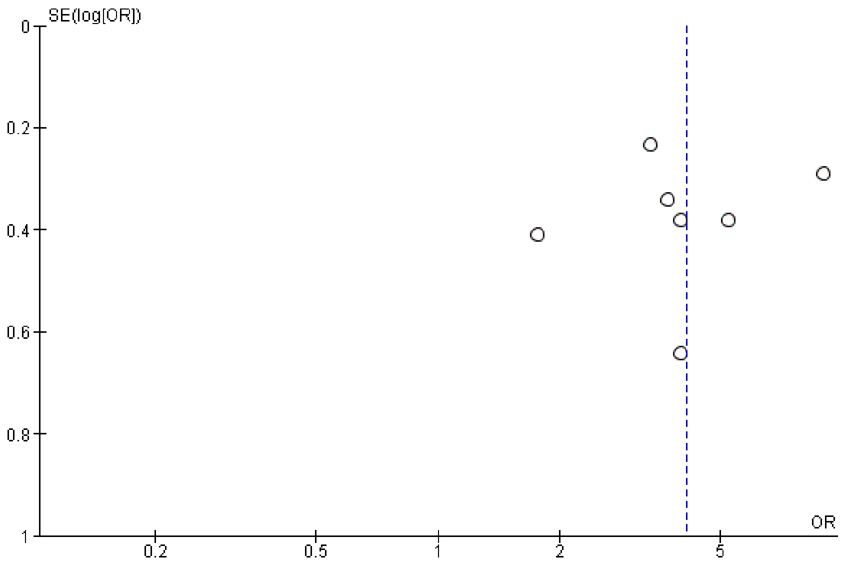

Figure 6. Funnel plots the Effect of stagnant water on the incidence of malaria in children

DISCUSSION

1. Insecticide-treated nets

The chance of malaria infection was higher among children living near standing water near their homes than among children living near standing water. This finding is also in line with previous research conducted in Southern Ethiopia. In this study, the overall prevalence of malaria was 3.9% which is lower than studies conducted in other countries such as Ghana, Malawi, Uganda, and in different parts of Ethiopia such as in Tselemt district of northern Ethiopia, Jima city, and in the BG region 13.9%. Children who use ITNs have a lower risk of malaria infection compared to those who use ITNs who do not use ITNs. This finding is in contrast to a study conducted in Uganda where the odds among children who had used ITN increased significantly by 1.33 times compared to those who had not.

A cross-sectional study of a population of children presenting to health facilities with suspected malaria showed that 20% of those with symptoms had confirmed infection, whereas the asymptomatic prevalence rate of Plasmodium infection among pregnant women was 2.74% (95%CI = 1.26 to 5.14) and 3.05% (95% CI= 1.47 to 5.54) using Giemsa-stained blood smear microscopy and RDT. The findings reveal that not using ITNs effectively increases the chances of developing malaria infection during pregnancy. Of the factors associated with malaria infection, household ownership of ITN was found to be protective against malaria. The protective effect of ITN use demonstrated in our study adds to the many facts supporting the efficacy and effectiveness of ITNs for protection against malaria (Lengeler, 2004). It is clear that proper use of ITN will prevent mosquito bites which in turn prevent malaria infection. However, this requires further elaboration, because ownership of an ITN alone does not guarantee its utilization and there is a lack of a relationship between ITN use and malaria infection (Deressa et al., 2014).

According to WHO's malaria control and elimination strategy, access to all interventions improves malaria reduction, in particular, implementing better case management, and increasing durable insecticide nets (LLINs) and indoor residual spraying (IRS) and early diagnosis and treatment and environmental management. However, the coverage and utilization of ITN is high, IRS is still not widely implemented and is known as one of the main vector control measures in research participant households. The study results in need to increase IRS coverage, and other interventions together with ITN to reduce the burden and transmission of malaria especially for high-risk population groups (Abossie et al., 2020b).

The findings of a study conducted by Mekuria et al. (2022a), showed that 72.2% of households used the ITN the night before the day of data collection. This finding is consistent with results from Arbaminch city in southern Ethiopia (71%), 18 Addressa District in northern Ethiopia (73%), 21 Harari state, Ethiopia (73.3%),22 Burkina Faso (70%), 14 and Nigeria (75.4%). This is because all of the above studies including this study were conducted in malaria endemic areas which might force households to use ITNs for fear of contracting malaria. However, the findings of this study are higher than the 2016 Ethiopian DHS findings where 16.6% of households used ITNs. This difference can be explained by the differences in the regions covered by the EDHS study providing reports for areas with lower malaria risk and higher malaria risk. higher combined into one, whereas this study was conducted in a malaria endemic area. The findings of this study fall short of those obtained from a study conducted among settlers in southwest Ethiopia which found 80% of households used mosquito nets the night before the study.

The discrepancy between this study and the southwestern Ethiopian study could be explained by the time gap between this study and the southwestern Ethiopian study as long as the distribution of ITNs occurred before the study was conducted. Another reason for the differences between the 2 studies may be due to differences in the sociodemographic and socioeconomic profiles of the study population (Mekuria et al., 2022).

2. Stagnant Water

A total of 7 primary study articles met the criteria, 6 from Ethiopia and 1 from Nigeria. This study shows that standing water around the house is significant in influencing the increase in the incidence of malaria. Forest plots show that standing water around the house can increase the incidence of malaria by 4.10 times compared to no standing water (OR= 4.10; 95% CI= 2.80 to 6.03: p= 0.87). This is in line with previous research (Ahmed et al., 2021) which stated that standing water around the house is a factor that can cause malaria. Based on the study overall prevalence of malaria is 3.9% which is lower than studies conducted in other countries such as Ghana, Malawi, Uganda and in differrent parts of Ethiopia such as North Tselemt District. Ethiopia, the city of Jima and the BG region is 13.9 %. This difference may be due to differences in malaria control and prevention programs.

The existence of a pool of water near the house is a higher chance of malaria infection among children who live near a pool of water near the house. This finding is also in line with previous studies conducted in Southern Ethiopia and Dembia. This can be explained by the fact that they are more likely to be bitten by mosquitoes, because the area is suitable for mosquito breeding around their homes (Ahmedÿ et al., 2021).

Puddles can be classified into several groups based on their size, duration of standing water (permanent or temporary) and type of reservoir. Groups of large stagnant water that are temporary or permanent include swamps, lakes, rice fields, rainwater puddles, puddles, irrigation ditches in rice fields, ditches or sewage drains. Small groups of standing water include holes in trees, water tanks, buckets, container dispensers, wells and bathtubs (Triwahyuni et al., 2020).

Plasmodium falciparum and P. Vivax were the two species identified in the blood of children, contributing to 57.1% and 38.5% of infections, respecttively. In this study, similar to a study conducted in the Wogera district, Ethiopia, the number of children with fever and Plasmodium infection decreased with increasing age. This may be because these children live in endemic areas of stable malaria transmission and can infect mosquitoes.

The majority of infected children had moderate parasite densities followed by low and high parasite densities, respectively 71%, 16% and 12.9% of malaria positive children. To prevent and reduce malaria infection, several intervention activities such as distribution of insecticide-treated nets (ITNs), indoor residual spraying (IRS), artemisinin-based combination therapy (ACT) and dissemination of health information have been carried out in Ethiopia. Nonetheless, malaria remains a serious public health problem in endemic areas, particularly among children under five years of age. Ethiopia is implementing a malaria elimination program with the aim of eliminating the disease by 2030. To assess program progress, the prevalence and determinants of malaria among vulnerable groups must be evaluated over time and in different regions (Debashid et al., 2022).

Epidemics of malaria are greatest in the highlands or suburban highlands of Ethiopia, especially 1,000 to 2,000 meters above sea level. Malaria cases number 2.9 million annually, with 4,4782,000 deaths and morbidity and mortality rates increase rapidly during the outbreak. Malaria remains a major public health problem despite significant successes and progress in improving public health and reducing the burden of disease. Ethiopia is still a country that is known to have a very high burden of malaria and especially in the study area (the people of Mizan-Aman city and its surroundings) many suffer from this disease which is detrimental to health. (Duguma et al., 2022a).

AUTHOR CONTRIBUTION

Dinda Nur Asri Mutiara Ramadhani and Yovita Galuh Eka Ariska who contributed in articles search. Anggun Fitri Handayani and Yovita Galuh Eka Ariska who contributed to data analysis. Siti Damayanti who contributed to writing publication manuscript. Bhisma Murti and Anggun Fitri Handayani who contributed to supervisor in manuscript writing.

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CONFLICT OF INTEREST

There is no conflict of interest in this study.

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