Prevalence of Malaria among underfives in Chiengi and Puta Districts of Luapula Province, Zambia.

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Abstract

Background

Malaria is the predominant driver of morbidity and mortality in Zambia, particularly among children under the age of 5. This disease ranks first in both outpatient and inpatient records, highlighting its prevalent impact on public health. Malaria has such an adverse socioeconomic impact that it significantly exacerbates poverty and underdevelopment. Therefore, this study aimed to investigate the prevalence of malaria and related factors in children under five years of age in the Chiengi and Puta Districts.

Methods

A descriptive cross-sectional survey was carried out in the Chiengi and Puta districts, which are malaria endemic areas. Using a pretested structured questionnaire, every head of a randomly selected household male or female present from July 1, 2022 – July 30, 2022 was interviewed about ownership of an insecticide-treated mosquito net (ITN), actual usage, coverage of indoor residual spraying, sociodemographic factors, and the presence of malaria parasites in the underfive population, which was determined using a malaria rapid diagnostic test (mRDT).

Results

A total of 318 participants were recruited from the Puta Rural Health Centre and Chiengi District Hospital. The children’s overall mean standard deviation (SD) age was 2.35 (1.53) years, 50.3% were female (160/318), and 49.7% were male (158/318). The prevalence of malaria was 59.1% (188/318), with the Puta Rural Health Centre accounting for 61.3% and the Chiengi District Hospital accounting for 48.1%. Among the 56% of households that recorded possession and usage of the ITN, the prevalence of malaria was 4.3%.

Conclusions

The use of insecticide-treated nets was found to be the most dominant risk factor for malaria infection. Enhancing accessibility to comprehensive malaria interventions is essential for disrupting transmission at the community level, particularly when targeting at-risk age groups. Thus, it is crucial to raise awareness within the community regarding the proper utilization of insecticide-treated bed nets (ITNs).

1.0 Introduction

Malaria is the most important parasitic disease in humans. Approximately 5% of the world’s population is infected. Malaria remains one of the major threats to public health and economic development in Africa.
It is estimated that three million deaths result from malaria worldwide, with Africa having more than 90% of this burden (1).

Malaria can cause outpatient, inpatient, or admissions of children younger than five years of age at health facilities in Zambia (2). The high burden of malaria in Zambia is because 4.5-5 million new malaria cases are reported annually. The annual incidence rate is 10–100/1,000 people, and this number doubles for children younger than five years of age (3).

The malaria parasite is a mosquito-transmitted protozoan. Plasmodia are sporozoan parasites of red blood cells transmitted to animals (mammals, birds, reptiles) by the bite of mosquitoes. There are four species of *Plasmodium* (*P. falciparum, P. vivax, P. ovale* and *P. malariae*) that can cause malaria in humans and lead to disease (4). In sub-Saharan Africa, most malaria episodes are caused by *P. falciparum*, which is the agent of the most severe and fatal malaria disease. The transmission of the *Plasmodium* parasite occurs mainly from person to person through the bite of a female *Anopheles* mosquito. Rarely can transmission occur through accidents, such as transfusion, inoculation of infected blood from one person to another, or transfer through the placenta from an infected mother to her unborn child. The malaria parasite has a unique life cycle adapted to humans over the years. The life cycles of all *Plasmodium* species transmitted to humans are the same, with three reproductive phases.

Sporozoites are introduced into the blood when an infected mosquito bites a human. The sporozoites then move on to the liver, where during the next stage, a single cycle of asexual reproduction, known as the hepatic schizogony or preerythrocytic phase, occurs in human liver cells over the course of five to seven days, during which merozoites are produced (4). The term "sporogony" refers to the first stage of the female mosquito life cycle, which includes a single cycle of sexual reproduction and results in the development of sporozoites that infect humans. At 24°C, sporogony occurs in *P. falciparum* and *P. malariae* after 9 and 21 days, respectively. When liver cells rupture and infiltrate red blood cells, merozoites reach the bloodstream. The erythrocytic cycle, also known as the third or final phase, comprises numerous cycles of asexual reproduction that take place in red blood cells and persist for approximately 48 hours for *P. falciparum, P. ovale*, and *P. vivax* but 72 hours for *P. malariae*. During each cycle, this phase generates fresh merozoites, which penetrate fresh red blood cells and restart the erythrocytic cycle. However, some of these merozoites differentiate into male and female gametocytes through an unidentified mechanism; these gametes are subsequently ingested by blood-sucking female anopheles to begin the next sporogony cycle.

The clinical manifestations of malaria are dependent on the previous immune status of the host. In areas of intense *P. falciparum* malaria transmission, asymptomatic parasitaemia is common in adults. Severe malaria is not common in this age group; it is mostly confined to the first years of life and becomes progressively less frequent with increasing age. The majority of childhood malaria infections present with fever and malaise and respond rapidly to appropriate antimalaria treatment.

Symptoms of malaria include high fever and a variety of other symptoms, such as headache, body pains, and nonspecific vomiting (4). The severity of malaria ranges from asymptomatic (mainly in semi-immune
populations) to severe and fatal. Severe anemia is a common manifestation of severe malaria in semi-immune children and is responsible for long-term developmental impairments and a high mortality rate in children. Some days after inoculation of the sporozoites, the first symptom was a typical fever. There is a fever peak every 48 hours \((P. falciparum)\) (5). A fever peak appears as a result of the synchronized bursting of blood schizonts. Through asexual division of the parasite, the infected erythrocytes burst and release endotoxins into the blood. The endotoxins are mostly Interleukin-1 and TNF-alpha, which can lead to high fever. Other signs of acute malaria include headache, myalgia (muscle pain) and diarrhea. Malaria-infected children may be asymptomatic, or they may also exhibit vomiting and hypoglycemia (5).

In patients infected with \(P. falciparum\), the sequestration of infected erythrocytes leads to more complications, especially in children. On their surface, infected erythrocytes have special receptors. These conditions lead to adherence to other erythrocytes and to the epithelium of the blood vessels. This prevents removal of the parasite in the spleen. Sequestration leads to cerebral malaria, respiratory distress, and generalized organ failure. Anemia is another important complication in malaria-infected patients (4). Malaria is considered the most consequential parasitic infection in humans. There are as many as 350–500 million clinical episodes per year worldwide (1), and while most estimates of mortality caused by malaria lie at approximately 1 million deaths per year (1), some calculations reach as high as 3 million (3). Almost all of these deaths occur in children (6) living in malaria-endemic countries in sub-Saharan Africa (SSA) (7), where 25% of all childhood deaths before the age of five (approximately 800,000 young children are attributable to malaria) (3). Additionally, more than 15% of those children who survive cerebral malaria suffer neurological deficits (8), which include weakness, spasticity, blindness, speech problems and epilepsy. Where such children are poorly managed and do not have access to specialized educational facilities, these deficits may interfere with future learning and development.

Children under the age of five years are at highest risk for malaria because they have not yet acquired protective immunity. People with semi-immune conditions are infected but do not develop severe disease as a rule. In stable transmission areas, newborns are protected by the IgM antibodies of their mother and through breastfeeding. After three months, children are more susceptible to infection by the parasite. In high transmission areas, this disease lasts until the age of 3–5 years. In areas with seasonal transmission, the transmission period can last 10 years. Without reinfection, acquired immunity can disappear within a matter of years (9). Furthermore, children under five years of age experience the greatest malaria burden because they are often superinfected with other parasites and/or often suffer from nutritional deficiencies. These effects lead to a weakened immune system, which leads to increased susceptibility to malaria. Moreover, malaria infection and malnutrition are reasons for an increasing anemia burden in children (10). It is universally accepted that malaria is a disease of public health importance worldwide. The disease causes the greatest suffering and impoverishment among poor people, particularly in Africa.

In 2001, the World Health Organization (WHO) identified malaria as the eighth most significant contributor to the global disease burden, measured by disability-adjusted life years (DALYs), with Africa experiencing the second-highest impact (11). Indeed, the highest incidence of malaria is found among the most impoverished segments of society. This is due to their inability to afford protection from malaria,
including improved housing and a clean environment. Additionally, they are particularly susceptible to the consequences of inadequate diagnosis and treatment (12). Annually, the global occurrence of malaria encompasses a range of 300 to 500 million infections, leading to approximately 1 million deaths attributed to malaria. Approximately 90% of these deaths occur in sub-Saharan Africa, and the majority of them occur among women and children. Most of the estimated more than one million malaria deaths every year occur in children up to 5 years old who live in areas where P. falciparum is strongly transmitted, especially in sub-Saharan Africa (13). Malaria also presents major obstacles to the social and economic development of affected countries (14).

Malaria has significant measurable direct and indirect costs and has recently been shown to be a major constraint on economic development. The direct costs of malaria include a combination of personal and public expenditures on both prevention and treatment. Personal expenditures encompass the money spent by individuals or families on items such as insecticide-treated mosquito nets (ITNs), fees for doctors, antimalarial drugs, transportation to health facilities, and financial support for the patient and, at times, a family member accompanying them during hospital stays. Public expenditures include spending by the government on maintaining health facilities and health care infrastructure, publicly managed vector control, education, and research. In certain nations with a significant malaria burden, the disease could constitute up to 40% of public health expenditures. The indirect expenses related to malaria encompass the reduced productivity or income resulting from illness or death. This can be articulated as the expenses incurred due to missed workdays or absenteeism in formal employment, along with the valuation of unpaid household work performed by both men and women. In instances of death, the indirect cost encompasses the discounted future lifetime earnings of the deceased individuals (15).

This study concentrated on the Chiengi and Puta districts, which are situated in the Luapula Province of Zambia. These regions are recognized as areas prone to malaria epidemics and are characterized by an overall prevalence of malarial infection of 50% (12).

2.0 Materials and Methods

2.1 Study Design

This was a community-based prospective cross-sectional study that was conducted in Chiengi District and Puta District from 1 July 2022 to 30 July 2022.

2.2 Study site

The study was conducted in Chiengi and Puta Districts, which harbor Chiengi Hospital and Puta Rural Health Centre. Chiengi Hospital is a referral hospital for more than 15 health facilities in the District of Luapula Province.

2.3 Study Frame
All the underfive Children with parents or legal guardians in Chiengi and Puta Districts apparently with no symptoms of malaria and without a history of taking antimalarial in the previous week were recruited in this study.

2.4.1 Inclusion criteria

All underfive children without a history of taking antimalarial agents in the previous week and with no symptoms of malaria were included in the study. Consent was obtained from the child's parents or legal guardian.

2.4.2 Exclusion criteria

All underfive children with malaria symptoms, a history of taking antimalarial agents in the previous week and those with nonconsenting guardians were excluded from this study.

2.5 Study Variables

Economic variables such as income from buying an ITN were our independent variable, while malaria status was the dependent variable.

2.6 Sampling and sample size

A convenience sampling method was used. This means that only children under five years of age who satisfied the inclusion criteria were recruited, for an estimated sample size of 318.

2.7 Data analysis

The data analysis was performed using SPSS Version 23.0. SPSS was used to generate frequency tables, charts and graphs. The data are presented as percentages and means and were analyzed using Microsoft Word and Excel.

2.8 Ethics considerations

Permission to conduct this research was obtained from Chiengi First Level Hospital and Puta RHC Management. Ethical approval was granted by the University of Zambia School of Medicine Research Ethics Committee (UNZASOMUREC) reference number 14-06-2022 and the National Health Research Authority (NHRA) reference number NHRA00010/05/10/2023. Participation in this study was strictly voluntary. This study did not affect patient management during the period of study. Patients were not remunerated. All the information obtained was kept confidential and for research purposes only. Participants were free to withdraw from the study at any time and with no penalty. All the investigations were performed by qualified personnel. The only anticipated risk to the patient was minimal discomfort during blood collection. Written consent was obtained from every legal guardian of the participants.

3.0 Results
3.1 Sociodemographic and Gender of Study Participants

A total of 318 participants were recruited from the Puta Rural Health Centre and Chiengi District Hospital. The children's overall mean standard deviation (SD) age was 2.35 (1.53) years, 50.3% were female (160/318) and 49.7% were male (158/318), as shown in Table 1.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Frequency n = 318</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group (Months)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–24</td>
<td>83</td>
<td>26.1</td>
</tr>
<tr>
<td>25–48</td>
<td>50</td>
<td>15.7</td>
</tr>
<tr>
<td>49–60</td>
<td>185</td>
<td>58.2</td>
</tr>
<tr>
<td>Sex respondents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>158</td>
<td>49.7</td>
</tr>
<tr>
<td>Female</td>
<td>160</td>
<td>50.3</td>
</tr>
</tbody>
</table>

Interestingly, most participants were malaria-positive (188/318; 59.1%), while the rest were malaria negative (130/318; 40.9%).

3.2 Prevalence of Malaria among Under Five Children at Chiengi District Hospital

At Chiengi District Hospital, the majority of study participants tested negative for malaria, accounting for 51.9% (27 out of 52) of the participants, while the remaining 48.1% (25 out of 52) tested positive. In contrast, at the Puta Rural Health Centre, a different pattern emerged, with a significant majority of children testing positive (61.3%; 163 out of 266), while 38.7% (103 out of 266) tested negative. Further details of these results are illustrated in the figure below.
Table 2
Clinical characteristics of the study participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Frequency n = 318</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prevalence of malaria among underives at Chiengi Hospital</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaria Positive</td>
<td>25</td>
<td>48.1</td>
</tr>
<tr>
<td>Malaria Negative</td>
<td>27</td>
<td>51.9</td>
</tr>
<tr>
<td><strong>Prevalence of malaria among underives at Puta Rural Health Centre</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaria Positive</td>
<td>163</td>
<td>61.3</td>
</tr>
<tr>
<td>Malaria Negative</td>
<td>103</td>
<td>38.7</td>
</tr>
<tr>
<td><strong>Overall Prevalence of malaria infection among the underive in the two study sites</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaria Positive</td>
<td>188</td>
<td>59.1</td>
</tr>
<tr>
<td>Malaria Negative</td>
<td>130</td>
<td>40.1</td>
</tr>
</tbody>
</table>

### 3.3 Clinical characteristics of the study participants

Table 3 shows the clinical characteristics of the study participants.

#### Table 3
To determine the factors associated with the incidence of malaria among under Fives in the Chiengi and Puta districts

<table>
<thead>
<tr>
<th>Variable</th>
<th>Results</th>
<th>Malaria Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total n (%)</td>
<td>Positive n (%)</td>
</tr>
<tr>
<td>Possession of an ITN</td>
<td>Yes</td>
<td>241 (75.8)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>77 (24.2)</td>
</tr>
<tr>
<td>Sleeping under an ITN</td>
<td>Yes</td>
<td>136 (42.8)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>182 (57.2)</td>
</tr>
<tr>
<td>Source of income for the head of the family</td>
<td>Formal employment</td>
<td>69 (21.7)</td>
</tr>
<tr>
<td></td>
<td>Informal</td>
<td>204 (64.2)</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>45 (14.2)</td>
</tr>
</tbody>
</table>
4.0 Discussion

Malaria is a public health problem among children under 5 years old at both study sites. The study revealed that the overall malaria incidence was 59.1%. The study also aimed to determine the major determinant factor for a high incidence of malaria, even though only a few studies were performed. This finding was higher than the findings of a prior study in Ethiopia; the prevalence of malaria was 22.8% in children under five years of age in Arsi Negele, Ethiopia (16). This was a retrospective study, and the results were more limited and did not reveal determining factors. The present study is similar to another study conducted in Malawi in which the prevalence increased 37% compared with that in previous years; however, many interventions were administered to children under 5 years old (17). On the other hand, a study conducted in villages around Lake Langano in the Oromia region of Ethiopia reported a significantly elevated malaria incidence of 66.4% (18). This difference is attributed to the seasonal variation in the high prevalence of malaria parasites at the study site, as was the case in our study, which was conducted during a major malaria transmission season. Additionally, the prevalence of HELLP syndrome was higher than that reported in a study in India, which was 36.6% in children under 5 years old in malaria endemic forest villages (19). However, the variation in parasite species might be due to the rapid diagnostic test (RDT) used in the present study, as we did not consider species other than Plasmodium falciparum.

The present study investigated the sociodemographics, household structure and availability of bed nets for the participants, but these factors were not significantly associated with malaria infection; these findings agreed with those of other studies conducted in Uganda. However, there is a lack of knowledge about mosquito breeding sites and modes of transmission for some of the participants in Uganda, similar to the findings of previous studies in Uganda 20, although this study did not assess participant knowledge (16).

According to WHO malaria control and elimination strategies, access to all interventions enhances the incidence of malaria, mainly through the implementation of improved case management, the scaling up of long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS), and early diagnosis, treatment and environmental management. However, coverage and utilization of the ITN were high; nevertheless, the IRS has not been widely implemented and is known as one of the major vector control measures used by the households of study participants. The study results suggest the need to increase the coverage of IRS and other interventions together with ITNs to reduce the burden and transmission of malaria, particularly for high-risk groups of the population.

Among the study participants in Uganda, 72.0% knew that the suitable breeding site for mosquitoes was stagnant water (16). Several studies have shown that malaria vector density and living in close proximity to water bodies, such as rivers and streams, could be important factors influencing malaria transmission (16). The present study did not look at breeding sites for malaria. It was also suggested that there are noteworthy correlations between age, sex, and marital status and malaria incidence. However, the results
of the present study contradicted these findings by revealing no significant associations between age or sex and place of residence.

ITN availability was observed among 75.8% of the participants.

Despite considering the use of insecticide-treated nets (ITNs) as a protective measure, the prevalence of malaria among individuals using ITNs was not significantly different from that among individuals not using these agents. However, it is not always consistently linked to a reduced malaria incidence. The utilization of ITNs is recognized as an effective tool for controlling malaria vectors and preventing transmission. This study revealed that children who slept under ITNs had a 9.65-fold lower risk of testing positive for malaria than did those who did not use ITNs. These findings align with those of a study in the Hadiya zone, which concluded that individuals not using bed nets were more likely to be infected (16). Moreover, another study showed that individuals who did not use mosquito nets at night were more likely to have malaria than were those who did use mosquito nets at night (20).

A two-year prospective cohort study conducted in the Arba Minch Zuria district, Ethiopia, revealed that the utilization rate of insecticide-treated nets (ITNs) reached 69%. However, the usage of these tools among children under the age of 5 was notably low (21). Similarly, there was a substantial access rate for insecticide-treated nets (ITNs) among parents/caregivers, reaching 93.3%. However, the use of ITNs in children under the age of 5 was not significantly prevalent (21). However, 55.0% of the children who slept under the ITN were significantly protected from malaria infection compared to 55.0% of the children who did not sleep under the ITN in this study.

**Conclusion and Recommendations**

Malaria infection is highly prevalent in children under 5 years old, particularly those aged between 37 and 59 months old, in the “Chiengi and Puta” districts. The use of ITNs was found to be the most common risk factor for malaria infection. Improved access to all malaria interventions is needed to interrupt transmission at the community level, with a special focus on the at-risk group. The prevalence of malaria infection among children under 5 years old, particularly those aged 37 to 59 months, is a significant concern in the Chiengi and Puta districts. The dominant risk factor identified is the insufficient use of insecticide-treated nets (ITNs). To address this issue effectively, it is crucial to intensify the distribution and promotion of ITNs, ensuring that they are readily available and that the community is educated on their proper use. Additionally, expanding malaria testing and treatment services, launching community-wide health education campaigns, and implementing targeted interventions for at-risk age groups are vital steps. Community engagement, regular surveillance, and collaboration with international organizations and NGOs are essential components of a comprehensive strategy to combat malaria in these districts. A long-term commitment to building sustainable solutions and strengthening healthcare infrastructure is also emphasized.

**Abbreviations**
Declarations

Acknowledgments

The success of this work would not have been possible without the dedication and diligence of the entire research team involved. I would like to thank the Almighty Jehovah God for his never-ending love and presence throughout the study period. Last, I would also like to appreciate and thank the Puta RHC and Chiengi District Hospital laboratory members for the help provided throughout the study.

Conflict of interest

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Statement of Ethical approval
The study was conducted under a protocol that was reviewed and approved by the University of Zambia School of Medicine Ethics Review Committee (UNZASOMUREC) and the National Health Research Authority (NHRA). Informed consent was obtained from all individual participants included in the study.

**Statement of informed consent**

All study participants were informed about the study's objectives and procedures, and written informed consent was obtained. The privacy and confidentiality of the participants were ensured by using codes instead of names on the data collection forms, and the data were stored in a password-protected Excel sheet, which was accessible only to the principal and coinvestigators.

**Authors’ and contributions**

W. conceived the study, conducted the initial analysis and wrote the first draft. D. conducted the formal analysis and reviewed and edited the final manuscript. A, E, and M performed the data curation and reviewed the manuscript. Modern Ntalasha supervised the conduct of the study.

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