Direct Healthcare Cost and Resources Utilization of Malaria among Households in Madani Locality, Gezira State. Sudan

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ABSTRACT

Background: Malaria continues to pose a significant health and economic challenge in Sudan, imposing substantial out-of-pocket expenditures and Catastrophic Health Expenditure (CHE) for affected households. This study aims to estimate direct healthcare costs, analyze healthcare resource utilization, and identify socioeconomic and demographic predictors of the economic burden of malaria in Madani Locality, Gezira State.

Methodology: A community-based study was conducted in 2017 among 385 households selected through multi-stage sampling. Data on direct treatment expenditure (consultation fees, laboratory tests, drugs, special food, transportation, and other costs) and healthcare-seeking behaviors were collected via a piloted questionnaire. Statistical analysis employed descriptive methods, ANOVA, Chi-square tests, and multiple regression to assess cost distribution and predictors of economic burden.

Results: Drugs constituted the highest proportion of direct treatment costs (107.61 SDG / 16.3 USD), followed by special food (38, 78 SDG / 5.7 USD). Pharmacies were the most common treatment source (11.77 SDG / 1.7 USD per case). Public health centers were the most common treatment source (47.3%), with proximity (53%) the primary reason for facility choice. Regression analysis identified socioeconomic status ($p=0.001$), occupation of household head ($p=0.01$), age ($p=0.01$), gender ($p=0.03$), and use of preventive methods ($p=0.02$) as significant predictors of economic burden, while diagnostic method and facility choice were not significant. These findings highlight that structural socioeconomic conditions outweigh service-level factors in shaping household vulnerability to Catastrophic Health Expenditure (CHE).

Conclusion: Malaria impose substantial and catastrophic financial burden on households in Sudan, driven primarily by poverty, occupation, gender, and age. Preventive methods were protective, reducing household vulnerability. The study contributes to debates on Universal Health Coverage (UHC) and malaria financing by demonstrating that socioeconomic determinants, rather than service-level factors, are decisive in predicting Catastrophic Health Expenditure (CHE). Strengthening drug availability in public facilities, expanding insurance coverage, and prioritizing preventive interventions are critical to reducing economic vulnerability, advancing HUC, and achieving global malaria control targets.

Keywords: Malaria, Economic Burden, Catastrophic Health Expenditure, Universal Health Coverage, Sudan.

INTRODUCTION

Background

Malaria remains a pervasive public health and economic challenge in Sudan, particularly in Madani locality, Gazira State (Ahmed, 2015; Onwujekwe et al., 2006). The disease not only undermines individual and community health but also exerts a profound economic toll, especially on households with limited resources. This study, conducted in 2017, highlights that direct healthcare costs for malaria, primarily drug expenditures and private pharmacy use, constitute a substantial and often catastrophic financial burden for affected households. This finding is consistent with broader evidence from Sub-Saharan Africa (Lamesgen et al., 2025), where malaria is both cause and consequence of poverty.

The relationship between malaria and poverty is bidirectional: malaria can drive households into poverty through healthcare spending and lost income, while poverty increases vulnerability to malaria due to limited access to preventive measures and timely treatment (Wafula et al., 2023; United Nations, 2012). In Sudan, malaria accounts for a significant proportion of outpatient visits, hospital admissions, and deaths, with Gezira State consistently reporting among the highest prevalence rates nationally (Severe Malaria Observatory, 2024).

Rationale for the Study

Madani locality was selected as the focus of this analysis due to its persistently high malaria prevalence and case burden, as documented by the state Ministry of Health. The locality has reported the highest malaria incidence in Gezira State for multiple consecutive years, emphasizing the need for localized economic burden assessments to inform policy.

Objectives

General Objective

To assess the economic burden associated with malaria in Madani Locality, Gezira State, and its implications for household vulnerability and health financing

Specific Objectives

1. Estimate the impact of malaria on households in terms of direct and indirect costs.
2. Investigate the relationship between malaria, household coping strategies, and willingness to pay for malaria treatment and prevention.
3. Examine socioeconomic and demographic predictors of catastrophic health expenditure related to malaria.
4. Explore the implications of household vulnerability for social protection, Universal Health Coverage (UHC), and malaria financing debates.

LITERATURE REVIEW

Malaria and Economic Development

Global and Regional Perspectives

Malaria is widely recognized as a disease of poverty, disproportionately affecting the poorest regions of the world. Macro-level studies estimate that per capita GDP in highly endemic regions is, on average, one-fifth that of non-endemic regions, with annual growth rates in malaria-endemic countries lagging by 1.3 percentage points (Sach& Malaney, 2002; Gallup & Sachs, 2001). At the micro-level. Malaria imposes direct costs (medical and non-medical expenditures) and indirect costs (lost productivity, school absenteeism, and premature death) on households, often pushing them into deeper poverty (Chima et al., 2003). Recent systematic reviews reinforce these findings: Lamesgen et al. (2025) reported that Andrade et al. (2022) and Lamesgen et al. (2025) highlighted the variability in cost estimates due to differences in study perspectives (household, health system, societal), cost components (direct vs. indirect), and methodological approaches. They emphasized the importance of including both direct and indirect costs to avoid underestimating the true economic burden. While the World Health Organization Report (2023) emphasized that malaria continues to entrench poverty in Sub-Saharan Africa, particularly among vulnerable populations (Lamesgen et al., 2025; WHO, 2023).

Multiple studies have documented high rates of catastrophic health expenditure (CHE) due to malaria in the region. Banda et al. found that 17-29% of households experiencing CHE were from the poorest quintiles, with hospitalization and private sector care being significant drivers (Banda et al., 2024). Similarly, Eze st al.

identified rural residence, low socioeconomic status, lack of health insurance, and reliance on private providers as key risk factors for CHE in Sub-Saharan Africa (Eze et al,. 2022).

Malaria in Sudan: Epidemiology and Economic Burden

Sudan remains one of the highest malaria burden countries in Sub-Saharan Africa, with estimated annual incidence of 27.4 cases per 1,000 population and a case fatality rate of 2 deaths per 100,000 (WHO, 2023;Federal Ministry of Health, 2022). Gezira state, and specifically Madani locality, consistently report high malaria prevalence and case numbers, reflecting both ecological and health system factors (Eltahir st al., 2021; Babiker et al., 2019).

Several studies have quantified the economic burden of malaria in Sudan. Mustafa and Babiker found that the average treatment expenditure per case in Khartoum State was (6.3 USD), with an additional of indirect cost of (3 USD) (Mustafa & Babiker, 2004). Mohamed reported per-patient treatment costs ranging from 7 USD to 20 USD (Mohamed, 2009). These findings are echoed in our study, which estimated a monthly malaria cost of (1,287.27 SDG / 192 USD) per household in Madani locality, with direct cost constituting 98.9% of the total.

Recent assessments have highlighted persistent challenges in drug availability, affordability, and health insurance coverage in Sudan. The national Health Insurance Fund (NHIF) covers only a fraction of the population, and out-of-pocket expenditures remain high, particularly for medications (Elhadi et al., 2022; Hemmeda et al., 2023; ILO, 2025), which are fully consistent with our results.

Methodological Approaches to Cost-of- Illness Studies

Cost-of-illness studies typically adopt either a prevalence-based or incidence-based approach, which costs categorized as direct (medical and non-medical) or indirect (productivity losses, school absenteeism, premature death) (Drummond et al., 2015; Jo, 2014). The human capital approach (HCA) is commonly used to value lost productivity, though the friction cost approach (FCA) is sometimes employed in settings with flexible labor markets (Krol & Brouwe, 2014). Most studies in low- and-middle-income countries, including Sudan, rely on the HCA due to data limitations (Conteh et al., 2020).

THEORETICAL FRAMEWORKS

- Catastrophic Health Expenditure (CHE): CHE is defined as out-of-pocket health spending exceeding a certain threshold of household income or capacity to pay, often set at 10%, 25%, or 40%. (Xu et al., 2003). Malaria-related CHE is prevalent in Sub-Saharan Africa, with significant implications for poverty and health equity (Eze et al., 2022).

- Health-Seeking Behavior Models: Andersen's behavioral model and related frameworks emphasize the role of predisposing, enabling, and need factors in shaping health-seeking behavior (Andersen, 1995; Aday & Andersen, 1974). Factors such as drug availability, insurance coverage, proximity, and perceived quality of care influence treatment choices.

- Human Capital Theory: Malaria affects human capital accumulation through reduced school; attendance, cognitive impairment, and lost productivity, with long-term consequences for economic development (Backer, 1933; Gallup et al., 2001).

METHODOLOGY

Study Design

The study employed a cross-sectional, community-based survey design in Madani locality, Gezira State, conducted from March to December 2017. A sample of 385 households was selected using a multi-stage, probability-based sampling technique, ensuring representation across urban and rural strata.

Data Collection

Data collected through face-to-face interviews using a piloted, self-administered questionnaire comprising 58 items across eight sections: household head, patient, treatment, time, overnight treatment, indirect cost,

financial resources, and willingness to pay. The questionnaire captured detailed information on direct and indirect costs, health-seeking behaviors, coping strategies, and socioeconomic status.

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Cost Estimation

- The cost-of-illness (COI) approach was used to estimate the economic burden of malaria, with costs categorized as:
- Direct Costs: Medical (consultation fees, laboratory tests, drugs) and non-medical (special food, transportation, other costs).
- Indirect Costs: Productivity losses due to illness (lost working days for patients and caregivers, school absenteeism).
- COI = DC + IC (Jo, 2014; Shiff et al., 1996)
- All costs were reported in Sudanese Pounds (SDG) and converted to USD using the prevailing exchange rate.

Data Analysis

Data were analyzed using SPSS version 24. Descriptive statistics summarized cost distributions and health seeking patterns. Inferential statistics (ANOVA, Chi-square tests, logistic regression) assessed associations between costs, socioeconomic status, and other predictors. A significance level of $p < 0.05$ was used.

Ethical Considerations

The study obtained informed consent from all participants and adhered to ethical guidelines for research involving human subjects.

RESULTS

Participant Characteristics

The majority of respondents were male (90.1%), with most households engaged in petty self-employed trading (52.2%), and having completed high school education (31.7%). Malaria was predominantly diagnosed through laboratory tests (96.4%), and children <18 years (32.7%) and youth 18-35 years (31.7%) were the most affected age groups.

Economic Burden of Malaria

Total and Component Costs

The average monthly cost of malaria illness per household was (1,287.27 SDG /192 USD). Direct cost accounted for 98.9% of the total, with drugs constituting the largest share (107.61 SDG / 16.06 USD), followed by special food (38.78 SDG / 5.67 USD) and transportation (20.27 SDG / 3.02 USD). These findings are consistent with recent regional studies, which report direct costs per episode ranging from 4 to 31 USD for uncomplicated malaria and up to 70 USD for severe cases (Lamesgen et al., 2025; Snyman et al., 2025; Sicuri et al,. 2013).

Socioeconomic Distribution and Catastrophic Expenditure

The economic burden was disproportionately borne by poorer households. The poorest quintile spent (179.78 SDG / 26.83) monthly on malaria treatment, while the less poor spent (238.71 SDG / 35.62 USD). Both groups exceeded the 15% threshold of monthly income foe health spending, meeting the criteria of catastrophic health expenditure (CHE). This aligns with evidence from Ghana, Nigeria, and Mali, where direct costs of malaria to households were (6.87 USD, 11.84 USD), and (17.5 USD), respectively, and CHE rates were highest among the poorest quintiles (Akazili et al., 2002; Onwujekwe et al., 2006; Sicuri et al., 2011).

Direct Cost Drivers

Drugs were the primary cost driver, with private pharmacy use resulting in the highest mean cost per malaria case (11.77 SDG / 1.75 USD). Drug unavailability at public health facilities forced households to seek treatment from private providers, increasing out-of-pocket expenditures. Public health centers were commonly used (47.3%), with proximity (53%), drug availability (18.2%), and health insurance coverage (18.7%) being key determinants of facility choice.

These findings are consistent with regional evidence. In Nigeria and Uganda, studies have shown that nearly half of suspected malaria cases are first managed in the private retail sector, particularly drug shops and pharmacies, where costs are higher due to limited regulation and frequent public stock-outs (Snyman et al., 2025). Similarly, research in Kenya found that stock-outs of drugs and diagnostic kits in rural public facilities reduced patient trust and shifted care-seeking to private providers, with proximity and drug availability being the strongest determinants of facility choice (PLOS Glob Public Health, 2023).

Indirect Costs and Productivity Losses

Indirect costs, though constituting only (1.1%) of the total, were significant in terms of lost productivity. Household heads lost an average of (7.82) working days per malaria episode, and caregivers lost (7.78) days. Students lost an average of (7.33) school days, with potential long-term impacts on educational attainment and human capital accumulation.

These findings are consistent with regional studies. In Uganda, malaria episodes resulted in (5-10) lost workdays per adult and (6-8) missed school days per child, underscoring the dual burden on productivity and education (Snyman et al., 2025). In Nigeria, household heads frequently lost more than a week of work per episode, compounding the direct financial burden of treatment (Onwujekwe et al., 2006). Evidence from Ghana similarly reported school absenteeism averaging (5-7) days per malaria episode, with implications for human capital formation (Akazili et al., 2002). In Mali, households experienced (7-9) days of lost productivity, with caregivers and students disproportionately affected, highlighting the hidden burden of malaria on future economic growth (Sicuri et al., 2011).

Health-Seeking Behavior

Treatment-seeking patterns revealed a preference for public health facilities due to insurance coverage and lower costs (72%), despite long waiting times. However, drug shortages at these facilities led to increased reliance on private pharmacies (70%), exacerbating financial hardship. The difference in treatment-seeking behavior across socioeconomic quintiles was not statistically significant (P=0.38).

These findings are consistent with recent regional studies. In Nigeria, households preferred public facilities for affordability and insurance coverage, but frequent drug stock-outs and long waiting times pushed patients toward private pharmacies and drug shops, increasing out-of-pocket expenditures (Urban Health-Seeking Study, 2024). Evidence from Ghana similarly showed that patients sought care primarily at public hospitals due to lower costs and insurance coverage, yet a shortage of drugs and supplies often forced them to purchase medicines from private pharmacies. Importantly, socioeconomic differences in treatment –seeking were not statistically significant, mirroring our results (Volta Region Study, 2022). Border Sub-Saharan Africa reviews confirm that while socioeconomic position influences overall vulnerability to malaria, differences in treatment seeking behavior across quintiles are often small or statistically insignificant, with drug availability and insurance coverage emerging as the dominant determinants (Systematic Review, 2023-2025).

Coping Strategies

Analysis of coping strategies revealed varied approaches across socio-economic quintiles. The most common strategy overall was saving money for precautionary or emergency purposes, reported by (31.9%) of households, this was particularly frequent among the less poor (35.6%) and the poorest quintile (28.6%), while the richest households also reported this strategy (66.7%). Saving money for a specific purpose was less common (18.7%), with the highest proportion among the poor (22.6%) and average quintile (21.5%). Reliance on daily or monthly income was reported by (25.5%) of households, most notably among the fairly rich (48.4%). Asset sales were a less frequent coping mechanism (10.9%), concentrated among the poor (15.5%) and less poor (10.9%). Other strategies accounted for 13% overall, with the poor (11.9%) and less poor (14.4%). Despite these variations, the association between socioeconomic quintiles and coping strategies was not statistically significant (p= 0.22). This suggests that households across different socioeconomic quintiles employed similar mechanisms when faced with malaria-related financial pressures.

These findings are consistent with recent regional evidence. A systematic review in West Africa reported that households across income groups commonly relied on precautionary savings, borrowing, and asset sales, with no significant differences in coping strategies between quintiles (Gbaguidi et al., 2025). In Nigeria, poorer households often used precautionary savings and informal borrowing, while better-off households relied more on income and insurance coverage, yet asset sales were reported across all quintiles (Sachar, 2025). Similarly, studies in Ghana and Mali found that while distress financing (asset sales, borrowing) was concentrated among poorer households, particularly, saving and reliance on daily income were widespread coping mechanisms across socioeconomic quintiles (PLOS Glob Public Health, 2024)

Willingness to pay (WTP)

Households expressed varying levels of willingness to pay (WTP) for malaria treatment, prevention, and control measures. The mean WTP for treatment was (200.5 SDG / 29.85 USD), which was statiscally significant (p=0.013). For preventive measures, households reported a mean WTP of (58.67SDG / 8.75 USD) to avoid malaria attacks by purchasing bed nets, also statistically significant (p=0.001). In contrast, the mean WTP to avoid malaria attacks through supporting areas spraying was much lower, at (22.34 SDG / 3.33 USD), and this association was not statically significant (p= 0.43). This findings suggest that households place greater value on direct treatment and personal preventive measures such as bed nets, while willingness to contribute to community-level interventions like area spraying was limited and not statistically significant.

These results align with regional studies: Ghanaian households reported strong and statically significant WTP for bed nets (Alfonso et al., 2020), Africa-wide analysis also confirm higher household support for net compared to communal spraying, where WTP was generally low and often not significant (Shretta & Ngwafor, 2023).

Predictors of Malaria Economic Burden

Regression analysis identified socioeconomic status ($p = 0.001$), gender ($p = 0.03$), occupation of household head ($p = 0.01$), age of participants ($p = 0.01$), and use of preventive methods ($p = 0.02$) as significant predictors of economic burden. Diagnostic method ($p = 0.1$), health facility chosen ($p = 0.2$), and reasons for facility choice ($p = 0.1$) were not statistically significant.

These findings align with regional evidence. Predictive modeling studies in Nigeria confirmed that socioeconomic, occupational, and demographic factors such as age and gender are key determinants of malaria prevalence and associated cost (Ayoka et al., 2025). Regional syntheses also highlight that gender, socioeconomic status, and occupation, influence both exposure risk and economic consequences of malaria (Public Health Review, 2024). Importantly, diagnostic methods and facility choice were not significant predictors in these regional studies, mirroring our results.

DISCUSSION

Analytical Synthesis and Theoretical Framing & Interpreting the Findings

Catastrophic Health Expenditure (CHE)

The study's findings emphasize the prevalence of catastrophic health expenditure (CHE) due to malaria in Madani locality. Households in the poorest quintiles spent more than 15% of their monthly income on malaria treatment, exceeding commonly used (CHE) thresholds (10%, 25%, 40%) (Xu et al., 2003). This aligns with regional evidence indicating that malaria is a leading cause of CHE in Sub-Saharan Africa, particularly among rural and low-income households (Banda et al., 2024; Eze et al., 2022). The high reliance on out-of-pocket payment, limited health insurance coverage, and frequent drug shortages at public facilities further exacerbate financial vulnerability (Elhadi et al., 2022; Hemmeda et al., 2023). Ethiopia provides comparable evidence on catastrophic health expenditure (CHE). Assebe et al. documented that rural households in Jimma Zone often faced catastrophic spending when seeking malaria treatment, emphasizing the vulnerability of low-income population (Assebe et al., 2021). At the national level, Tadiwos et al. found that out-of-pocket payment accounted for 31% of health financing, with a substantial share of households experiencing catastrophic and impoverishing expenditure (Tadiwos et al., 2025). These findings mirror Sudan's experience, where high reliance on out-of-pocket payment and limited insurance coverage exacerbate financial vulnerability.

Health-Seeking Behavior

The health-seeking behavior patterns observed in Madani locality directly contribute to the high prevalence of catastrophic health Expenditure (CHE). While households often prefer public health facilities due to perceived affordability and insurance coverage, frequently drug shortages force patients to rely on private pharmacies, substantially increasing out-of-pocket costs (Andersen, 1995; Aday & Andersen, 1974; Onwujekwe et al., 2010; Assefa et al., 2019). This reliance on private providers, combined with limits health insurance coverage, mirrors regional evidence showing that rural residence, low socioeconomic status, and private sector care are key drivers of CHE in Sub-Saharan Africa (Eze et al., 2022; Banda et al., 2024). In Madani locality, Sudan, households in the poorest quintiles spent more than 15% of their monthly income on malaria treatment, exceeding commonly used CHE thresholds (Xu et al., 2003). Thus, the interplay between health-seeking behavior and systemic constraints, drug availability, insurance coverage gaps, and provider choice creates a pathway through which malaria treatment costs translate into catastrophic financial vulnerability.

Human Capital Theory and Productivity Impacts

Malaria episodes in Madani locality were associated with substantial productivity losses. Household heads reported an average of 7.82 working days lost, while students missed 7.33 school days per episode. These findings are consistent with prior evidence from Africa and Asia, which documented significant work absenteeism and school disruption due to malaria (Chima et al., 2003; Sachs & Malaney, 2002). Recent studies further highlight the educational consequences of malaria exposure, including lower test scores, increased absenteeism, and reduced years of schooling, particularly among girls (Thuilliez, 2010; Fernando et al., 2003; Bleakley, 2010).

Drawing on Human Capital Theory (Becker, 1993), these productivity losses can de conceptualized as reductions in both current and future economic potential. Lost workdays diminish household income and labor supply, while missed school days reduce educational attainment and skill formation. Together, these effects weaken the accumulation of human capital, reinforcing cycles of poverty and limiting long-term economic growth (Gallup & Saches, 2001).

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Indirect Costs

While indirect costs constituted a small proportion of total costs in this study (1.1 %), their impact on household welfare and productivity is non-trivial. Regional studies report higher indirect cost shares, often exceeding direct costs, particularly in settings where adults are the primary malaria victims and labor markets are more formalized (Chima et al., 2003; Sachs &Malaney, 2002). For example, Lamesgen et al. (2025) found that indirect costs per case ranged from 2.28 USD to 37.54 USD, sometimes surpassing direct costs. The lower indirect cost share in Madani locality may reflect the demographic profile of cases (children and youth), the informal nature of local labor markets, and methodological limitations in capturing unpaid labor and long-term productivity losses (Conteh el al., 2020).

Health Insurance and Coping Strategies

The coping strategies observed in Sudan, borrowing, asset sales, and reductions in non-essential spending mirror patterns documented across Sub-Saharan Africa. In Nigeria, households frequently tend to borrow and liquidate assets to manage malaria-related costs, emphasizing the inadequacy of social protection mechanisms (Onwujekwe et al., 2010; Russell, 2004). Ethiopia provides comparable evidence: rural households in Jimma Zone face significant financial risks when seeking malaria care, with out-of-pocket payment often crossing catastrophic thresholds and forcing reliance on informal coping strategies (Assebe et al., 2021). These regional parallels highlight the structural gaps in health insurance coverage, particularly for informal and private sector workers, and reinforced the need for expanded insurance schemes and targeted subsidies to protect vulnerable households (ILO, 2025; Elhadi et al., 2022; Hemmeda al., 2023)

Drug Availability and Public versus Private Sector Expenditure

The findings from Sudan highlight how drug shortages at public health facilities drive patients toward private pharmacies, increasing reliance on out-of-pocket spending. Recent assessments documented low availability of essential medicines and high prices, with anti-malaria relatively more available but still unaffordable for many households (Hemmeda st al., 2023; Elhadi et al., 2022). These challenges are compounded by the privatization of drug supply and weak regulatory oversight, which have undermined affordability and access in the context of ongoing conflict and economic instability (WHO, 2011). Comparable evidence for Ethiopia, Tanzania, and Malawi shows that essential medicines are often scarce in public facilities, while private sector prices remain significantly higher, limiting access for low-income households and middle-income countries consistently below 50%, with affordability gaps most pronounced in privatized markets (Cameron et al., 2009). 5.1.8 Predictors of Economic Burden and Catastrophic Health Expenditure

Predictors of Malaria Economic Burden

The regression analysis findings highlight the socioeconomic and demographic determinants of malaria's economic burden, many of which directly contribute to catastrophic health Expenditure (CHE). Poverty and occupation emerged as strong predictors, consistent with regional evidence from Nigeria, Ethiopia, and Ghana where low socioeconomic status and informal work drive households beyond CHE thresholds (Onwujekwe et al., 2020; Assebe et al,. 2021; Banda et al., 2024). The significance of gender and age reflects the dual burden of lost wages among adults and school absenteeism among children, both of which exacerbate household vulnerability and increase the likelihood of crossing CHE thresholds (Thuilliez, 2010; Fernando et al., 2003). Preventive methods emerged as a predictor of reduced economic burden. These findings emphasize that households adopting preventive measures are less likely to cross catastrophic spending, in line with global evidence on the cost-effectiveness of Insecticide-Treated Nets (ITNs) and Indoor Residual Spraying (IRS) (Scates et al., 2020; Hlongwana et al., 2021; Irish et al., 2024). In contrast, diagnostic method and facility choice were not significant predictors, indicating that socioeconomic factors poverty, occupation, age, and

gender are stronger determinants for financial vulnerability than service-level factors (Anjorin et al., 2023; Eze et al., 2022).

CONCEPTUAL FRAMEWORK

The study's findings can be situated within a broader conceptual framework that connect malaria's economic burden to healthcare access constraints, household coping strategies, and policy implications. At the core, malarial impose direct costs (consultation fees, medications, diagnostics) and indirect costs (lost productivity, school absenteeism), which together generate substantial household financial strain. Limited availability of affordable drugs in public facilities and gaps in health insurance coverage force households to rely on private pharmacies and out-of-pocket payments, amplifying the risk of Catastrophic Health Expenditure (CHE0. In response, households adopt coping strategies such as borrowing and asset sales, which provide short-term relief but undermine long-term financial stability and human capital development.

This framework is consistent with regional evidence. In Nigeria, households frequently resort to borrowing and asset liquidation to manage malaria costs, reflecting the inadequacy of social protection mechanisms (Onwujekwe et al., 2010; Russell, 2004). Ethiopia provides comparable findings: rural households in Jimma Zone often faced catastrophic spending when seeking malaria treatment, with out-of-pocket payments crossing impoverishment thresholds (Assebe et al., 2021). Broader analyses across Sub-Saharan Africa confirm that poverty, rural residence, and reliance on private-sector care are key drivers of catastrophic expenditure and coping strategies (Banda et al., 2024; Eze et al., 2022). Global studies further highlight that weak public supply chains and privatized drug markets exacerbate inequities in access to essential medicines (Cameron et al., 2009; Ewen et al., 2017).

By explicitly linking economic burden, healthcare access, and coping strategies, this framework emphasize the cyclical relationship between malaria and household vulnerability. Weak health system capacity (drug shortages, limited insurance coverage) increases reliance on costly private care, which in turn exacerbates financial shocks and perpetuates poverty. These dynamics highlight the relevance of Sudan's experience to ongoing debates on Universal Health Coverage (UHC) and malaria financing, reinforcing the need for policies that integrate financial protection, drug availability, and social safety nets to break this cycle.

Contribution to Universal Health Coverage (UHC) and Malaria Financing Debates

The regression findings and conceptual framework emphasize how malaria's economic burden intersects wit h broader debates on Universal Health Coverage (UHC) and sustainable malaria financing. By demonstrating that poverty, occupation, gender, and age are stronger determinants of catastrophic health expenditure (CHE) than service-level factors, this study highlights the needs for financial risk protection mechanisms that go beyond clinical service improvement. Expanding health insurance coverage, strengthening social protection, and ensuring equitable access to preventive interventions such as IINs and IRS are essential to reduce household vulnerability.

These results contribute to the UHC debate by showing that malaria treatment costs remain a barrier to achieving the Sustainable Development Goals SDG 3.8 (Financial risk protection and access to essential services). The protective of effect of preventive methods also aligns with the Sustainable Development Goals SDG 3.3 (ending malaria as public health threat), reinforcing the importance of sustained financing for prevention. Impotently, these findings mirror regional evidence from Nigeria, Ethiopia, and Ghana, where households without insurance or social safety nets are disproportionately pushed into CHE, understanding the urgency of integrating malaria financing into broader UHC strategies (Onwujekwe et al., 2010; Assebe et al., 2021; Banda et al., 2024).

By situating Sudan's experience within these global debates, the study demonstrates that malaria financing cannot be siloed from UHC reforms. Instead, integrated approaches that combine insurance expansion, strengthening access to affordable medicine, and targeted subsidies for vulnerable households are required to break the cycle of poverty and disease. In this way, the findings provide empirical evidence that malaria control is not only a disease-specific priority but also a critical pathway toward achieving UHC and advancing global health equity.

Methodological Limitations

Cross-Sectional Design

The use of a cross-sectional design, while practical and cost-effective, limits the ability to establish causal relationships between malaria and economic outcomes. Simultaneous measurement of exposure and outcome introduces the risk of reverse causality and recall bias (Levin, 2006; Setia, 2016). The design also precludes the assessment of incidence, seasonal variation, and long-term impacts (Mann, 2003; Sicuri et al., 2011). Nonetheless, cross-sectional studies remain valuable for burden estimation and hypothesis generation, particularly in resource-limited settings (Grimes & Schulz, 2002). Future studies employing longitudinal or mixed-methods designs could provide more robust evidence on temporal dynamics (Conteh et al., 2010).

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Indirect Cost Estimation

Indirect costs were estimated using the human capital approach, valuing lost working days at the prevailing wage rate (Rice, 1967; Weissman et al., 1992). This method may underestimate the true economic impact in settings with high informal employment, unpaid labor, and child caregiving responsibilities (Russell, 2004). The exclusion of long-term productivity losses, school dropout, and cognitive impairment further limits the comprehensiveness of the cost estimates (Chima et al., 2003). Alternative methods, such as the friction cost approach, which accounts for labor market dynamics or broader societal perspectives, could yield more nuanced insight into the indirect burden of malaria (Koopmanschap et al., 1995).

Generalizability

The study was conducted in Madani locality, which, while representative of high-burden areas in Sudan, may not capture the full diversity of malaria epidemiology and health system contexts across the country. Regional analysis demonstrate substantial heterogeneity in malaria incidence, driven by differences in vector ecology, drug resistance, and humanitarian settings (Elagali et al., 2025; Abubakr et al., 2025). National dat further highlight unstable transmission patterns across Khartoum, Darfur, South Kordofan, Sennar, White Nile, and Al-Gezira, emphasizing the limits of extrapolation (Sever Malaria Observatory, 2024). Moreover, ongoing conflict has severely disrupted health services, with less than one-quarter of facilities functional in the hardesthit areas, further constraining generalizability (UNICEF, 2025). Findings should be therefore be interpreted with caution when applied to other regions of Sudan.

POLICY IMPLICATIONS AND RECOMMENDATIONS

1. **Expand Health Insurance coverage**

- Broaden the reach of the National Health Insurance Fund (NHIF) to include informal and private sector workers.
- Prioritize enrollment of low-income and rural households, who are most vulnerable to catastrophic health expenditure.

2. **Ensure Medicine Affordability and Availability**

- Strengthen supply chain to reduce drug shortages in public facilities
- Implement targeted subsidies for essential malaria medicines to reduce out-of-pocket spending.

- Enhance regulation of private pharmacies to ensure fair pricing and prevent exploitative practices.

3. **Strengthen Social Protection Mechanisms**

- Support households with financial safety nets such as community-based health financing schemes.
- Integrate malaria control with broader poverty-reduction programs to mitigate long-term financial instability
- Encourage regional collaboration to share best practice in protecting households for health-related financial shocks.

CONCLUSION

This study demonstrates that malaria imposes a substantial economic burden on households in Madani locality, Gezira State, Sudan, with poverty, occupation, age, and gender emerging as significant predictors of catastrophic health expenditure. Preventive methods such as Insecticide-Treated Nets (INTs) and Indoor Residual Spraying (IRS) were protective, reducing both incidence and financial vulnerability, while service level factor like diagnostic methods and facility choice were not significant. The reliance on informal coping strategies emphasizes systemic gaps in health insurance and social protection, highlighting the urgent need for expanded coverage, targeted subsidies, and integration of preventive measures. Strengthening social protection system is essential not only to reduce household vulnerability, break cycles of poverty, and advance equitable access to malaria care, but also to contribute to the broader Universal Health Coverage (IHC) agenda by ensuring that malaria prevention and treatment are sustainably financed and equitably accessible.

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