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Household characteristics, water, sanitation and hygiene (WASH) and malaria prevalence among children aged 6-59 months in Ghana: An analysis of the 2022 Ghana Demographic and Health Survey

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Abstract

Background: Malaria remains a major public health challenge, particularly in sub-Saharan Africa, which accounted for approximately 95% of global malaria cases and 96% of malaria deaths in 2022. This study examined the prevalence of malaria among children aged 6–59 months in Ghana and assessed the influence of household characteristics and water, sanitation, and hygiene (WASH) factors on malaria prevalence.

Methods: We analyzed data from the 2022 Ghana Demographic and Health Survey (GDHS), using a weighted sample of 3,255 households with children aged 6–59 months. Malaria testing was performed with rapid diagnostic tests (RDTs). Descriptive statistics, chi-square tests, and multivariate logistic regression models were used to identify factors associated with malaria prevalence.

Results: The prevalence of malaria among children aged 6–59 months was 3.7%. Insecticide-treated net (ITN) ownership was high (78.9%), but only 51.5% of children slept under ITNs. Approximately 41.5% of children were anaemic. In multivariate analysis, children in households headed by persons aged 40-49 years (aOR=0.22; CI: 0.08-0.62) and 50-59 years (aOR=0.18; CI: 0.04-0.72) had lower odds of malaria compared to those in households headed by persons aged 70+. Children from wealthier households had significantly lower odds of malaria (aOR=0.15; CI: 0.03-0.71). Unexpectedly, children who did not sleep under ITNs had lower odds of malaria (aOR=0.52; CI: 0.30-0.92) compared to those who did. Anaemic children had more than twice the odds of malaria (aOR=2.03; CI: 1.36-3.04). Drinking untreated water (aOR=0.47; Cl:0.26-0.47) and improved sanitation (aOR=0.59; Cl:0.39-0.90) were associated with lower malaria risk, whereas having toilets located outside (aOR=16.64; CI:2.06-134.57) the dwelling was associated with higher odds of malaria.

Conclusion: These findings emphasise the need for targeted interventions in households with lower wealth and inadequate sanitation, alongside enhanced ITN distribution programs and sustainable WASH improvements to reduce malaria prevalence in children.

Keywords: Malaria, Children under five, Ghana, Household characteristics, WASH, Insecticide-treated nets, Anaemia

Introduction

Malaria remains a major global public health problem , with over 249 million cases and 608,000 deaths reported in 2022 [1]. Children under five years continue to bear a disproportionate burden, accounting for over three-quarters of malaria-related deaths worldwide [2,3]. In Ghana, malaria is

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endemic and remains a leading cause of childhood morbidity and mortality. In 2022 alone, more than 10 million malaria cases were reported, representing approximately 38% of all outpatient attendances [3]. Data from the 2022 Ghana Demographic and Health Survey (GDHS) reported that averagely 14.6 % of children aged 6–59 months nationwide tested positive for malaria by rapid diagnostic test (RDT) [4], highlighting the persistent burden of the disease despite national control efforts.

Malaria transmission in Ghana occurs year-round, particularly in rural areas where environmental and socio-economic conditions support mosquito breeding [5,6]. Over the past two decades, Ghana has implemented multiple malaria control interventions, including widespread distribution of insecticide-treated nets (ITNs), indoor residual spraying (IRS), improved case management, seasonal malaria chemoprevention in selected regions, and the pilot introduction of the RTS, S malaria vaccine [7–14]. These interventions have contributed to notable reductions in malaria prevalence in some settings. Household characteristics and water, sanitation, and hygiene (WASH) factors are increasingly recognised as important determinants of malaria risk. Children from poorer households, particularly those in rural and peri-urban areas, are at higher risk because of limited access to preventive interventions such as ITNs [15], substandard housing conditions, and inadequate access to clean water and improved sanitation [16,17]. Furthermore, mother-to-child malaria preventive interventions play a critical role in malaria prevalence among children under five. Studies have revealed that higher uptake of 3 or more doses of Sulfadoxine-Pyrimethamine (SP), is associated with reduced placental parasitaemia, which in turn is linked to lower risk of infant malaria exposure before and after birth [18,19].

Given that the evidence highlights the interrelationship between WASH and malaria has gained increasing attention. Evidence suggests that improved waste management, safe water storage, and access to proper sanitation facilities can significantly reduce malaria transmission [20-22]. Studies in Ghana, Nigeria, and Uganda have shown that households with piped water and improved toilets have a lower malaria incidence among children under five years [23–26]. Conversely, practices such as open defecation and uncovered water containers provide breeding grounds for mosquitoes, increasing the likelihood of malaria infections in young children [27]. Despite these strong associations and evidence, WASH interventions are often overlooked and underemphasized in malaria control programmes, which focus mainly on vector control and chemoprevention [28].

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According to the 2022 GDHS, only 62% of households had access to improved water sources and 25% to improved sanitation facilities [27]. Although 72% of children reportedly slept under an ITN the night before the survey [29], regional and socioeconomic disparities persist. Weak WASH infrastructure, combined with factors such as education and age of the household head, wealth index, and place of residence, further exacerbates children's vulnerability to malaria [17,19].

Despite the availability of national survey data and sustained malaria control efforts in Ghana, there remains limited empirical evidence examining the associations between household characteristics, WASH factors, and malaria prevalence among children under five years. Existing studies have largely focused on descriptive patterns or examined household and environmental determinants in isolation [28–30], often without adjusting for key socio-demographic and health-related confounders. This limit understanding of the combined and independent effects of household and WASH conditions on childhood malaria risk. Addressing this gap is essential for informing targeted and integrated malaria prevention strategies. This study aims to examine the associations between household characteristics, WASH indicators, and malaria prevalence among children aged 6–59 months in Ghana, using data from the 2022 GDHS. By identifying key risk factors, this study provides evidence to inform targeted interventions for vulnerable populations, strengthen malaria prevention strategies, and contribute to the achievement of Sustainable Development Goal (SDG) 3, which seeks to ensure healthy lives and promote well-being for all. The findings aim to fill a critical knowledge gap and to provide practical guidance for policymakers, community health practitioners, and development partners working to improve equitable health outcomes in Ghana and similar settings.

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Methods

Study Design and Population

The study analysed household data from the 2022 Ghana Demographic and Health Survey (GDHS), a nationally representative cross-sectional survey [33]. The GDHS gathers detailed information on housing conditions, household demographics, fertility, child and maternal health, nutrition, malaria, HIV/AIDS knowledge and behaviours, adult health, and women's empowerment. The present study focused specifically on children aged 6-59 months, a sub-population highly vulnerable to malaria infection and were tested for malaria using Rapid Diagnostic Test (RDT) to generate evidence to inform policy and programmatic interventions. The

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2022 GDHS employed a stratified two-stage cluster sampling design. In the first stage, enumeration areas were selected across all regions of Ghana using probability proportional to size. In the second stage, households were systematically selected within each enumeration area. This approach ensured a nationally representative sample of households and children. Sampling weights were applied in all analyses to account for unequal probabilities of selection and to produce population-level estimates.

Sample Size

Data were obtained from the household dataset, adjusted to represent a weighted sample size of 3,255 households with children aged 6-59 months. DHS sampling weights (HV005) were applied after dividing the variable by 1,000,000 to correct for the DHS scaling factor and account for over- and under-sampling -sampling. Households with children under five within clusters or enumeration areas were identified.

Measurements

Outcome Variable

The outcome variable was malaria status among children under age five, determined by RDTs such as the Abbott Bioline kit. A 5µl of blood sample was collected via finger or heel prick, which was also used for anaemia testing. Results were available within 15 minutes and communicated to the child's parent or caregiver. Children who tested positive for malaria were either referred to a healthcare facility or provided with treatment if they met specific criteria: absence of severe anaemic, severe malaria symptoms, no recent malaria treatment, and parental or caregiver consent. Treatment adhered to Ghana's national malaria treatment guidelines. In addition, thick blood smears were prepared for microscopy at the National Public Health and Reference Laboratory (NPHRL) in Accra. For quality assurance, 10% of slides were randomly selected and sent to the Noguchi Memorial Institute for Medical Research (NMIMR) for re-examination. Field staff received comprehensive training on biomarker testing protocols, including lectures, videos and hands-on practice. Procedures covered respondent eligibility, informed consent, blood collection, malaria and anaemia testing, data recording and result reporting. Malaria test results were coded as "negative" (0) or "positive" (1) [33].

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Predictor Variables

Household Characteristics

We considered the following household-characteristics in the study: sex of household head (male or female), age of household head (20–29, 30–39, 40–49, 50–59, 60–69, 70+) and household wealth quintile (poorest, poorer, middle, richer, richest). Type of household cooking fuel was categorized into the following: Electric stove, Liquified Petroleum Gas (LPG), Charcoal, Fuel wood and other cooking fuel (straw/shrub/ grass, agricultural crops, and animal dung). Another factor that was considered was children under age five who, the night before the survey, slept under ITN (no ITN, did not sleep under ITN, Slept under ITN). Others were as follows: household undergone Indoor Residual Spraying (no, yes); household membership (2-5 members, 6-10 members, 11 or more members); household treated bed nets ownership (do not own, owned); number of bed nets household owned (zero bed net, 1-3 bed nets. 4-7 bed net); sex of child (boy, girl) and child anaemia status (anaemic, not anaemic).

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Household Water, Sanitation and Hygiene (WASH)

The measurement and classification of the variable 'household source of drinking water' was guided by the WHO/United Nations International Children's Emergency Fund Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (WHO/UNICEF-JMP) classification of source of drinking water. For this study, the variable was dichotomised as improved and unimproved source of drinking water. In this study, improved source of drinking water comprised pipe-borne water inside dwelling, piped into dwelling, pipe to yard/plot, piped to neighbour's house/compound, tube well water, borehole, protected dug well, protected well, protected spring and rainwater collection, bottled water and sachet water. Unimproved source of drinking water in this study included unprotected well, surface from spring, unprotected spring, river/dam, tanker truck and cart with a small tank. Type of toilet facility was also classified as improved and unimproved. The classification of improved toilet facility was also guided by the WHO/UNICEF-JMP classification of sanitation technologies. Improved toilet facilities in this study comprised flushed to pipe sewer, flushed to septic tank, flushed to pit latrine, flushed to unknown place, flushed to bio-digester, ventilated improved pit latrine (VIP), pit latrine with slab, pit toilet latrine

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and composting toilets. The unimproved toilet facility included flush to somewhere else, pit without slab/open pit, no facility, bush/field and hanging toilet/ latrine. Other factors considered were location for hand washing (fixed place, mobile place, not observed), presence of water during hand washing (water not available, water available), treatment of water before drinking (no, yes) and location of toilet facility (In own dwelling, In own plot/yard, elsewhere).

Data analytical procedure

The data analysis was carried out using SPSS version 27, following a three-stage approach. The first step involved using descriptive statistics to summarize the outcome and predictor variables. In the second step, bivariate association between, household characteristics, WASH variables and malaria prevalence were using cross-tabulations and chi-square tests with statistical significance determined at a p-value of 0.05.

In the third step, three binary logistic regression models were fitted to examine the influence of household characteristics, along with household water, sanitation and hygiene factors on malaria prevalence among children under age five in Ghana. The first model assessed the relationship between household characteristics and malaria prevalence among children under five. The second model examined the relationship between household water, sanitation and hygiene and prevalence of malaria among children aged 6-59 months. The third model explored the combined effect of household characteristics, household water, sanitation and hygiene on malaria prevalence among children aged 6-59 months in Ghana. Adjusted odds ratios (aORs) with corresponding 95% confidence intervals (CIs) were reported to quantify the strength and significance of the associations. Sampling weights and the DHS complex survey design were applied throughout to obtain nationally representative estimates.

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Results

Malaria prevalence among children under five

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Fig 1 shows malaria prevalence in children under five years of age. Most children (96.3%) tested negative for malaria; 3.7% tested positive, indicating a relatively low burden of malaria in this age group.

Socio-demographic and environmental characteristics of households among children aged 6-59 months in Ghana

Table 1 presents key household characteristics from a weighted sample of 3,255 households. Most household heads were male (64.8%), and the largest age group was 30–39 years (35.2%). Cooking fuel was predominantly fuelwood (46.9%) and charcoal (30.2%), while 21.6% used liquefied petroleum gas (LPG), and less than 1% used electric stoves. Household wealth is relatively evenly distributed across quintiles, with 21.5% classified as poorest and 18.8% as richest. Most households (61.4%) have between 2-5 members. For malaria prevention, 78.9% of households owned at least one ITN, 61.7% owned 1-3 nets and 21.1% owned none. Among children, only 51.5% slept under an ITN the night before the survey, 26.7% did not, and 21.8% lived in households without ITNs. Only 9.4% of households was reported indoor residual spraying. Children in the sample were nearly evenly split by sex (51.3% boys and 48.7% girls), and 41.5% of children were anaemic. Most households (86.4%) use improved drinking water sources, but only 6.6% reported treating their water before consumption. A majority (72.5%) had mobile handwashing stations, yet just 57.0% reported having water available at the handwashing location. Improved toilet facilities were present in 59.7% of households, and 56.7% of toilets were located outside the dwelling or plot.

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Association (bivariate analysis) between household characteristics and malaria prevalence among children aged 6–59 months in Ghana

Table 2 presents the bivariate association between household, WASH characteristics and with malaria prevalence. significant associations were observed for: age of the household head, type of cooking fuel, household wealth index, household size, bed net ownership and number of bed nets, child ITN use, indoor residual spraying, childhood anaemia status, source of drinking water, handwashing practices, water treatment for drinking, type of toilet facility, and toilet location. Higher malaria prevalence was observed among children from poorer households, those using traditional cooking fuels, and those not sleeping under ITNs. Improved sanitation, access to clean water, and higher household wealth were associated with to lower malaria prevalence. Variables

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with significant bivariate associations were included in the multivariate logistic regression analysis.

Multivariable logistic regression of household determinants of malaria prevalence among children under five in Ghana

Table 3 presents the analysis of factors associated with malaria prevalence among children under age five in Ghana across three models. The results reveal significant associations with several household characteristics. In Model I, =children l in households headed by individuals aged 40-49 (aOR= 0.20; CI: 0.07-0.54) and 50-59 (aOR= 0.16; CI: 0.04-0.64) had lower odds of malaria prevalence compared to those in households headed by individuals aged 70 years and above. Household wealth index showed a strong inverse relationship with malaria prevalence. Compared with poorest households, children from poorer (aOR= 0.56; CI: 0.34-0.93), middle (aOR=0.33; CI: 0.17-0.63), richer (aOR=0.20; CI: 0.08-0.48) and richest (aOR=0.06; CI: 0.01-0.27) households had progressively lower odds of testing positive for malaria. ITN usage also demonstrated a significant association with malaria prevalence. Interestingly, children who did not sleep under ITNs (aOR= 0.52; CI: 0.30-0.92) were less likely to test positive for malaria than those who slept under ITNs. Additionally, childhood anaemia was strongly associated with malaria, where anaemic children (aOR= 2.10; CI:1.41-3.13) were having more than twice the odds of malaria compared to non-anaemic children.

In Model II, significant associations were observed between household environmental factors and malaria prevalence. Children who drank untreated water (aOR=0.38; CI: 0.22-0.67) were less likely to test positive for malaria. Moreover, children from households with improved toilet facilities (aOR= 0.59; CI: 0.39-0.90) had lower likelihood of testing positive for malaria compared to those with unimproved toilet facilities. However, children whose toilets were located in the household own plot/yard (aOR=9.58; CI: 1.18-77.92) and elsewhere (aOR=16.64; CI: 2.06-134.57) had significantly higher odds of malaria compared to those with toilets located inside their dwelling. The larger odds ratios and confidence intervals may be due to the fact the outcome is rare and small differences in predictor values can heve disproportionately large effects on the odds.Model III, which included additional control variables, confirmed further significant associations. Children living in households headed by persons aged 40-49 (aOR=0.22; CI: 0.08-0.62) and 50-59 (aOR=0.18; CI:0.04-0.72) remain less likely to test positive for malaria compared to those headed by persons aged 70 years and above. Children from poorer (aOR=0.57; CI:0.33-

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0.96), middle (aOR=0.38; CI: 0.19-0.77), richer (aOR=0.28; CI: 0.11-0.71) and richest (aOR= 0.15; CI: 0.03-0.71) households continued to exhibit significantly lower odds of malaria relative to those from the poorest households. Children in households of six to ten members (aOR=0.08; CI: 0.04-1.19) are at lower risk of malaria infection compared to those from households with two to five members. Children who drank untreated water (aOR=0.47; CI: 0.26-0.87) were less likely to test positive for malaria. Finally, anaemic children (aOR=2.03; CI:1.36-3.04) were at a significantly higher risk of malaria infection compared to non-anaemic children.

Discussion

Summary of findings

This study found a malaria prevalence of 3.7% of children under five years in Ghana Key predictors of malaria included household head age, household wealth, child ITN use, child anaemia status, household water treatment practices, and toilet type and location. Children from wealthier households and those in household headed by individuals aged 40–59 years had significantly reduced odds of contracting malaria. Lower risk of malaria was also noted among children who consumed untreated water and those living in homes with improved toilet facilities, while anaemic children and those with toilets located outside the dwelling had a higher odd of malaria infection. Unexpectedly, children who did not sleep under ITNs were less likely to test positive for malaria than those who did.

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Malaria prevalence among children under five

The observed prevalence of malaria (3.7%), in this study is lower than the national average of 8.6% in 2022 [34]. This reduction may reflect the cumulative impact of malaria control interventions, including ITN distribution, seasonal malaria chemoprevention (SMC), indoor residual spraying, improved case management , health education and pilot rollout of the RTS, S/AS01 malaria vaccine [35]. Similar declining have been reported and documented in Malawi (10.5%) and Kenya (6.0%), where vaccine coverage and preventive strategies are robust [36,37]. Despite these gains, malaria remains a leading cause of child mortality in parts of sub-Saharan Africa. For instance, Burkina Faso reported a malaria prevalence of 21.2% among children under five, while Uganda recorded a national prevalence of 36.6% with some regions exceeding 30% [34,38]. These regional disparities are often associated gaps in intervention coverage, vector resistance and healthcare access. The relatively lower prevalence in Ghana may reflect

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urbanization, improved infrastructure, and targeted public health investments. Sustaining and expanding these gains will require continued investment in malaria surveillance, equitable distribution of preventive tools, and nationwide scaling of the RTS,S vaccine are essential, particularly in underserved and high-transmission areas [39].

Factors associated with malaria prevalence among children aged 6–59 months in Ghana

This study revealed that children in households headed by individuals aged 40 to 59 years were significantly less likely to test positive for malaria than those in households headed by individuals aged 70 years and above. This finding aligns with previous studies indicating that middle-aged household heads often possess greater health literacy, economic stability, and decision-making capacity , which support effective malaria prevention behaviours such as consistent use of ITNs and timely healthcare seeking [37,40]. They may also be more proactive in maintaining environmental hygiene and facilitating access to preventive tools. A strong inverse relationship was also observed between household wealth and malaria prevalence. Children from poorer, middle, richer, and richest households had progressively lower odds of malaria infection compared to those from the poorest households. This supports existing evidence that socioeconomic status strongly influences malaria risk through its impact on living conditions, housing quality, access to preventive interventions, and ability to seek care promptly [22,41,42]. Wealthier households are more likely to invest in structural protections such as window screens and improved building materials, which reduce mosquito entry and bite risk [22].

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Unexpectedly, children who did not sleep under ITNs were less likely to test positive for malaria compared with those who slept under them. Although ITNs are proven malaria prevention tool, several factors may explain this counterintuitive finding. Additionally, improper or inconsistent ITN use, damaged nets, and exposure to mosquito bites during evening outdoor activities before sleeping may reduce the protective effectiveness of ITNs [43]. These findings highlight the importance of addressing behavioural, environmental, and structural factors alongside ITN distribution to achieve sustained reductions in malaria transmission. Reverse causality is also possible, whereby households in high-transmission settings or with previous malaria episodes may be more likely to prioritise ITN use. In contrast, children living in households with better housing quality, improved sanitation, or lower environmental exposure to mosquitoes may have reduced malaria risk despite lower ITN use. Residual confounding related to socioeconomic status and

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housing conditions may therefore partly explain this association. Additionally, children in wealthier households who face lower malaria exposure due to improved housing may use ITNs less frequently, as reported in previous studies [37-39]. Exposure to mosquito bites during evening outdoor activities before bedtime may also undermine ITN effectiveness [40]. Anaemia emerged as a significant risk factor, with anaemic children more than twice as likely to have malaria. This finding is consistent with evidence of a bidirectional relationship between malaria and anaemia, malaria contributes to anaemia through haemolysis and bone-marrow suppression, while anaemia may increase susceptibility to malaria due to weakened immunity [41,42]. Environmental factors also emerged as significant predictors of malaria prevalence. Surprisingly, children who consumed untreated water had lower odds of malaria infection than those who drank treated water. This counterintuitive finding may reflect geographic and contextual differences; for example, untreated water sources in rural areas may be flowing and less stagnant, thus less conducive to mosquito breeding compared to treated water sources in urban or peri-urban settings where water storage and pipe leaks that create breeding sites [43-45]. The presence of improved toilet facilities was associated with a reduced likelihood of malaria risk , emphasizing the importance of sanitation in minimizing mosquito breeding site and improving environmental health [46]. Conversely, households with toilets located outside the dwelling (in the yard or elsewhere), had higher odds of malaria infection, likely due to increased exposure to mosquitoes during nighttime trips to outdoor. This is consistent with studies highlighting outdoor night-time exposure as a critical malaria risk factor [40,47]. Household size also showed a modest protective effect, with children from household of six to ten members having lower odds of malaria infection compared to those from smaller households. This may reflect shared vigilance, reduced individual exposure, or improved distribution of preventive tools. However, the evidence on household size and malaria risk remains mixed, with some studies linking overcrowding may increase risk [48,49]. Further research is needed to clarify this relationship.

The observed association between consumption of untreated water and lower malaria prevalence should be interpreted cautiously. This finding may reflect geographic and contextual variations in water sources across Ghana. In many rural settings, untreated water sources such as flowing rivers or boreholes may be less conducive to mosquito breeding than treated water in urban and peri-urban areas, where intermittent supply, household water storage, and leaking pipes can create stagnant water habitats favourable for mosquito proliferation. Similarly, the counterintuitive

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association between ITN non-use and lower malaria prevalence may reflect residual confounding and reverse causality, whereby households in higher transmission settings are more likely to prioritise ITN use. Children living in better-quality housing with improved sanitation and reduced vector exposure may therefore experience lower malaria risk despite lower ITN utilisation [50-53]. These findings highlight the importance of contextualising behavioural and environmental indicators when interpreting malaria risk.

Implications for public health policy and practice

The findings highlight the need for targeted malaria elimination strategies in Ghana. The Ghana Health Service, together with the Ministry of Health, National Malaria Elimination Programme, and the Ministry of Sanitation and Water Resources, should intensify efforts among vulnerable populations, particularly poor households with young children. Key actions include: Expanding equitable distribution and proper use of ITNs through mass health education. Deploying community health workers for household-based testing, treatment, and awareness campaigns will also reinforce prevention. Integrating WASH education into school and community programs to promote safe water, sanitation, and handwashing. Combining malaria screening with nutrition and anaemia interventions to address co-morbidities. Providing targeted support to households headed by the elderly, who may struggle with preventive practices. Investing in improved housing, sanitation, drainage and environmental management at district and municipal levels. In addition, strengthening routine surveillance, monitoring and community engagement through public awareness campaigns. governments must invest in units, enhancements, supplemented by mass and regular monitoring to ease the malaria burden among young children.

Limitations in this study

This study has several limitations that should be considered when interpreting the findings. Malaria prevalence was measured using rapid diagnostic tests conducted at the household level, which, although suitable for large-scale surveys, provide only a point-in-time assessment and may not detect recent or low-density infections, potentially leading to misclassification due to variations in test sensitivity and specificity. Furthermore, the study recognizes the malaria in pregnancy interventions and the critical role it plays malaria incidence and prevalence among children under five, considering the role of these interventions in future studies will help in understanding mother-

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to-child transmission of infectious diseases. The cross-sectional design further limits causal inference and precludes assessment of temporal relationships between household or environmental exposures and malaria infection. In addition, several key explanatory variables, including insecticide-treated net usage, water treatment, and sanitation practices, were self-reported by caregivers and household respondents and may therefore be influenced by recall bias or social desirability bias. Although such self-reported measures are standard in population-based surveys such as the Ghana Demographic and Health Survey, future studies could improve validity by incorporating objective assessments, such as direct observation of net condition and use or testing of household drinking water quality. Finally, while the survey is nationally representative, the analysis was restricted to children under five years who were tested for malaria, which may limit generalisability to older age groups or to regions with smaller analytic samples. In addition, the cross-sectional design of the study limits the ability to establish causal relationships between household characteristics, WASH factors, and malaria prevalence. The observed associations represent correlations at a single point in time and should be interpreted with caution. Longitudinal studies are needed to assess temporal relationships and to evaluate the long-term impact of household and environmental conditions on malaria incidence.

Recommendations for future studies

Future research should adopt longitudinal designs to strengthen causal inference between household characteristics, Water, Sanitation and Hygiene conditions, and malaria infection. Integrating environmental and entomological evidence, including climatic variables, mosquito density, vector species composition, breeding site characteristics, and vector behaviour, would provide a more comprehensive understanding of malaria transmission dynamics. Greater emphasis is required on insecticide-treated net use, particularly net condition, correct hanging, consistency of use, and behavioural patterns that influence exposure during evening and outdoor activities, considering the unexpected inverse association observed in this study. The use of more sensitive diagnostic methods, such as Polymerase Chain Reaction alongside rapid diagnostic tests and microscopy, could improve detection of subclinical and low-density infections. In addition, regionally disaggregated and urban–rural analyses would support identification of localised transmission hotspots and inform targeted interventions. Finally, mixed-methods approaches combining quantitative and qualitative data would enhance understanding of community

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perceptions, health system barriers, and contextual factors shaping malaria prevention and health-seeking behaviour.

Conclusion

Based on the study findings, malaria control efforts in Ghana should prioritise integrated household-level interventions. Targeted investments in WASH infrastructure, particularly improved sanitation facilities and safer toilet locations, are needed in low-income and high-risk households to minimise environmental exposure to malaria vectors. Malaria prevention programmes should also strengthen equitable access to insecticide-treated nets, with greater emphasis on consistent and correct use supported by sustained community-based health education. Routine child health services should integrate malaria screening with anaemia prevention and management, given the strong association between anaemia and malaria infection. In addition, targeted support for socioeconomically disadvantaged households and those headed by older adults is essential to address persistent inequalities in malaria risk. Collectively, these prioritised actions can enhance the effectiveness and context-specificity of malaria reduction strategies among children under five in Ghana.

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Declarations

Ethical approval and consent to participate

The 2022 GDHS protocol received approval from the Institutional Review Board and the Ethics Review Committee of the Ghana Health Service. Permission to use the dataset was obtained and conditions of use were strictly observed. Informed consent was obtained from parents or caregivers prior to malaria and anaemia testing. All study procedures adhered to relevant ethical guidelines and protocols.

Consent for Publication

Not applicable

Availability of data and materials

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Datasets used for this study are openly available and can be accessed through https://dhsprogram.com/

Competing interests

The authors declare no competing interests.

Funding
None

Authors' contributions

DK as the main author contributed to the study's conceptualization, data analysis and data interpretation. AA drafted the entire manuscript, ESV contributed to the study design, and methodology. AA, MAA and ESV critically reviewed the manuscript. All authors approved the final version of the manuscript.

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Abbreviations

Abbreviation	Full Meaning
aOR	Adjusted Odds Ratio
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
GDHS	Ghana Demographic and Health Survey
IRS	Indoor Residual Spraying
ITN	Insecticide-Treated Net
LPG	Liquefied Petroleum Gas
RDT	Rapid Diagnostic Test
SDG	Sustainable Development Goal
UNICEF	United Nations International Children's Emergency Fund
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization

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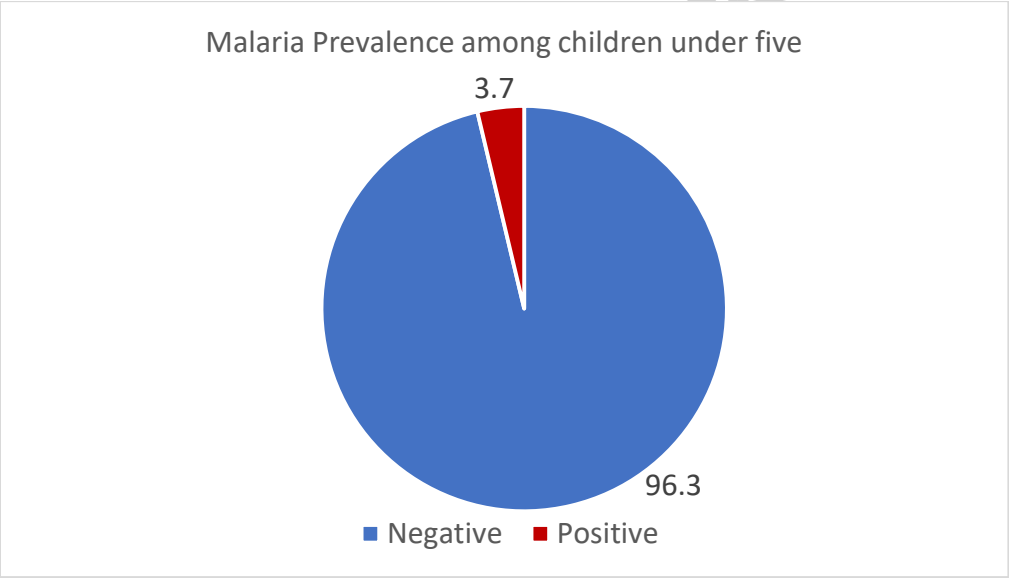

Figure 1: Malaria Prevalence among children under five

Source: Computed from the 2022 GDHS

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Table 1: Socio-demographic and environmental characteristics of households among children aged 6-59 months in Ghana

Household Characteristics	Weighted Sample n= 3255	%
Sex of Household Head		
Male	2109	64.8
Female	1146	35.2
Age of Household Head		
20-29	527	16.2
30-39	1145	35.2
40-49	812	25.0
50-59	343	10.5
60-69	294	9.0
70+	134	4.1
Cooking Fuel type		
Electric stove	24	0.7
Liquified Petroleum Gas (LPG)	704	21.6
Charcoal	983	30.2
Fuel wood	1528	46.9
Other cooking fuel	17	0.5
Household wealth Index		
Poorest	700	21.5
Poorer	651	20.0
Middle	628	19.3
Richer	666	20.4
Richest	612	18.8

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Household Membership		
2-5	2000	61.4
6-10	1158	35.6
11+	97	3.0
Household bednet ownership	2979	59.5
Do not own	686	21.1
Own	2569	78.9
Number of bednet owned by household		
Zero bednet	686	21.1
1-3 bednets	2007	61.7
4-7 bednets	562	17.3
Children use of Insecticides Treated Net (ITN)		
No ITN in the household	709	21.8
Did not slept under ITN	869	26.7
Slept under ITN	1677	51.5
Household undergone Indoor Residual Spraying		
No	2950	90.6
Yes	305	9.4
Sex of children under five in household		
Boy	1671	51.3
Girl	1585	48.7
Childhood anaemia status		
Anaemic	1350	41.5
Not anaemia	1905	58.5
Household Water and Sanitation activities		
Source of drinking water		
Improved source	2813	86.4
Unimproved source	442	13.6
Place household members wash their hand		
Fixed Place	517	15.9
Mobile Place	2359	72.5
Not observed	379	11.6
Presence of water at hand washing place		
Water not available	1400	43.0
Water available	1855	57.0
Water treatment for safe drinking		
No	3040	93.4
Yes	215	6.6
Household type of toilet facility		
Improved	1943	59.7
Unimproved	1312	40.3
Household location of toilet		
In own dwelling	453	13.9
In own plot/yard	956	29.4
Elsewhere	1846	56.7

%=Percent

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Source: Computed from 2022 Ghana Demographic and Health Survey (GDHS)

Table 2: Association (bivariate analysis) between household characteristics and malaria prevalence among children aged 6–59 months in Ghana

Factors	**Malaria prevalence among children aged 6-59 months in Ghana**		
Household Characteristics	Negative	Positive	P values
Sex of Household Head			
Male	96.5	3.5	0.295
Female	95.8	4.2	
Age of Household Head			
20-29	92.0	8.0	
30-39	95.7	4.3	0.000***
40-49	99.0	1.0	
50-59	99.1	0.9	
60-69	96.6	3.4	
70+	93.3	6.7	
Cooking Fuel type			
Electric stove	100.0	0.0	
Liquified Petroleum Gas (LPG)	98.7	1.3	
Charcoal	96.6	3.4	0.000***
Fuel wood	94.8	5.2	
Other cooking fuel	94.1	5.9	
Household wealth Index			
Poorest	92.4	7.6	
Poorer	95.4	4.6	0.000***
Middle	96.3	3.7	
Richer	98.0	2.0	
Richest	99.5	0.5	
Household Membership			

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2-5	94.3	5.7	
6-10	99.4	0.6	0.000***
11+	100.0	0.0	
Household bednet ownership			
Do not own	98.3	1.7	0.002**
Own	95.8	4.2	
Number of bednet owned by household			
Zero bednet	98.3	1.7	
1-3 bednets	95.2	4.8	0.000***
4-7 bednets	97.9	2.1	
Children use of Insecticides Treated Net (ITN)			
No ITN in the household	98.3	1.7	0.000***
Did not slept under ITN	98.2	1.8	
Slept under ITN	94.5	5.5	
Household undergone Indoor Residual Spraying			
No	96.5	3.5	0.034*
Yes	94.1	5.9	
Sex of children under five in household			
Boy	96.2	3.8	0.865
Girl	96.3	3.7	
Childhood anaemia status			
Anaemic	94.2	5.8	0.000***
Not anaemia	97.7	2.3	
Household Water and Sanitation activities			
Source of drinking water			
Improved source	96.7	3.3	
Unimproved source	93.9	6.1	0.004**
Place household members wash their hand			
Fixed Place	98.9	1.4	0.007**
Mobile Place	95.8	4.2	
Not observed	96.3	3.7	
Presence of water at hand washing place			
Water not available	95.8	4.2	0.193
Water available	96.7	3.3	
Water treatment for safe drinking			
No	96.5	3.5	0.003**
Yes	92.5	7.5	
Household type of toilet facility			
Improved	97.7	2.3	
Unimproved	94.1	5.9	0.000***
Household location of toilet			
In own dwelling	99.8	0.2	
In own plot/yard	97.5	2.5	0.000***
Elsewhere	94.7	5.3	

*** p=0.000 ** p=0.001 * p<0.05

Source: Computed from 2022 Ghana Demographic and Health Survey (GDHS)

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Table 3: Multivariable logistic regression of household determinants of malaria prevalence among children under five years

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Household characteristics	Malaria Prevalence among children under age five in Ghana		
	Model I aOR [95% CI]	Model II aOR[95% CI]	Model III aOR[95% CI]
Sex of Household Head			
Male	Ref		Ref
Female	0.97[0.65-1.46]		0.99[0.65-1.50]
Age of Household Head			
20-29	0.77[0.34-1.76]		0.87[0.38-2.03]
30-39	0.62[0.27-1.40]		0.73[0.31-1.68]
40-49	**0.20**[0.07-0.54]**		**0.22**[0.08-0.62]**
50-59	**0.16*[0.04-0.64]**		**0.18*[0.04-0.74]**
60-69	0.54[0.20-1.47]		0.63[0.23-1.74]
70+	Ref		Ref
Cooking Fuel type			
Electric stove	1.23[0.05- 24.45]		1.34[0.06-26.03]
Liquified Petroleum Gas (LPG)	1.54[0.09-29.73]		1.56[0.08-30.07]
Charcoal	2.01[0.12-34.61]		2.00[0.12-34.51]
Fuel wood	1.38[0.08-22.99]		1.51[0.09-25.16]
Other cooking fuel	Ref		Ref
Household wealth Index			
Poorest	Ref		Ref
Poorer	**0.56*[0.34-0.93]**		**0.57*[0.33-0.96]**
Middle	**0.33**[0.17-0.63]**		**0.38**[0.19-0.77]**
Richer	**0.20***[0.08-0.48]**		**0.28**[0.11-0.71]**
Richest	**0.06***[0.01-0.27]**		**0.15*[0.03-0.71]**
Household Membership			
2-5	Ref		Ref
6-10	**0.08***[0.04-1.19]**		**0.08***[0.04-1.19]**
11+	0.81[0.38-1.87]		0.85[0.42-2.02]
Household bednet ownership			
Do not own	2.89[0.48-37.82]		2.94[0.55-39.24]
Own	Ref		Ref
Number of bednet owned by household			
Zero bednet	1.52[0.87-24.69]		1.45[0.73-21.36]
1-3 bednets	0.89[0.47-1.71]		0.89[0.46-1.71]
4-7 bednets	Ref		Ref
Children use of Insecticides Treated Net (ITN)			
No ITN in the household	0.07[0.24-0.16]		0.05[0.21-0.19]
Did not slept under ITN	**0.52*[0.30-0.92]**		**0.52*[0.29-0.91]**
Slept under ITN	Ref		Ref

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Household undergone Indoor Residual Spraying			
No	Ref		Ref
Yes	1.51[0.86-2.65]		1.46[0.80-2.68]
Sex of children under five in household			
Boy	0.98[0.67-1.44]		0.96[0.65-1.41]
Girl	Ref		Ref
Childhood anaemia status			
Anaemic	**2.10***[1.41-3.13]**		**2.03****[1.36-3.04]**
Not anaemic	Ref		Ref
Household Water and Sanitation activities			
Source of drinking water			
Improved source		0.95[0.59-1.52]	1.27[1.36-3.04]
Unimproved source		Ref	Ref
Place household members wash their hand			
Fixed Place		0.86[0.32-2.31]	1.06[0.37-0.31]
Mobile Place		1.32 [0.71-2.47]	1.17[0.61-2.27]
Not observed (		Ref	Ref
Presence of water at hand washing place			
Water not available		Ref	Ref
Water available		0.99[0.66-1.47]	1.00[0.64-1.56]
Water treatment for safe drinking			
No		**0.38**[0.22-0.67]**	**0.47*[0.26-0.87]**
Yes		Ref	Ref
Household type of toilet facility			
Improved		**0.59* [0.39-0.90]**	0.84[0.52-1.36]
Unimproved		Ref	Ref
Household location of toilet			
In own dwelling		Ref	Ref
In own plot/yard		**9.58*[1.18-77.92]**	4.96[0.54-45.43]
Elsewhere		**16.64**[2.06-134.57]**	6.84[0.75-62.76]

*** p=0.000 ** p=0.001 * p<0.05

Ref: Reference Category

Source: Computed from 2022 Ghana Demographic and Health Survey (GDHS)