

Epidemiology of schistosomiasis, soil-transmitted helminths, malaria, coinfections and anaemia among pregnant women in southern Busia County, Kenya: a cross-sectional study

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Abstract

Schistosomiasis, soil-transmitted helminth infections (STH), and malaria remain major public health problems in sub-Saharan Africa, yet data among pregnant women are scarce. This cross-sectional study assessed helminth and malaria infections, anaemia, coinfection patterns, and factors associated with helminth infections among pregnant women in southern Busia County, western Kenya. A total of 209 women presenting for delivery at two rural hospitals between May 2023 and November 2024 were enrolled. Helminth infections were diagnosed using duplicate Kato–Katz thick smears, malaria by light microscopy, and haemoglobin concentration using a portable haemoglobin analyser. *Schistosoma mansoni* infection was detected in 12.4% of participants, STH infections in 9.6% (hookworm, 7.7%), and malaria in 2.9%. Most helminth infections were of light intensity, coinfections were rare, and no malaria–helminth coinfections were identified. Anaemia affected 64.1% of women. No significant associations were observed between anaemia and parasitic infections, although the small number of infected individuals limited statistical power. Student status was the only factor independently associated with hookworm infection. Schistosomiasis and hookworm transmission persist, whereas malaria prevalence was low. The high prevalence of anaemia despite relatively infrequent parasitic infections suggests an important contribution from non-parasitic determinants. Integrated parasite control and further studies incorporating nutritional, genetic and inflammatory determinants are warranted.

Introduction

Helminth infections and malaria remain among the most important parasitic diseases worldwide, particularly in sub-Saharan Africa (SSA), where they continue to impose a substantial public health burden [1]. Helminthiases constitute a major group of neglected tropical diseases (NTDs), accounting for approximately 14.5 million disability-adjusted life years (DALYs) globally, with more than 584 million people in Africa at risk of infection [2]. Among these, schistosomiasis and soil-transmitted helminth infections (STH) are the most prevalent, particularly in communities with limited access to safe water, sanitation and hygiene (WASH) services [3–4]. Malaria also remains highly endemic across SSA, causing an estimated 610,000 deaths worldwide in 2024, more than 90% of which occurred in this region [5]. Because malaria and helminth infections overlap geographically, coinfections are common in many endemic settings and may contribute to greater morbidity through their combined pathological effects [6].

In Kenya, soil-transmitted helminth infections (STH) remain widespread, affecting more than five million people, particularly in rural communities where inadequate sanitation and poor hygiene facilitate transmission [7]. In western Kenya, STH infections have been reported in both children and adults [8, 9]. Intestinal schistosomiasis caused by *Schistosoma mansoni* is also endemic in this region, particularly in communities bordering Lake Victoria, where prevalences exceeding 60% have been documented among school-aged children [10, 11]. In contrast, epidemiological information on adult populations, and especially pregnant women, remains limited. This knowledge gap partly reflects the historical emphasis of control programmes on school-aged children, despite recognition of women of reproductive age,

including pregnant women, as an at-risk population for preventive chemotherapy [12, 13]. Consequently, the epidemiology of schistosomiasis and other helminth infections among pregnant women in endemic areas of western Kenya remains poorly characterised.

Malaria remains a major public health challenge in Kenya, where more than 70% of the population lives in areas at risk of transmission [14]. The burden is particularly high in western Kenya, including communities surrounding Lake Victoria, where transmission remains perennial despite sustained control efforts. Previous studies have reported malaria prevalences ranging from 9% to 28% among pregnant women in this region [15]. Pregnancy increases susceptibility to *Plasmodium falciparum* infection through physiological and immunological changes that reduce acquired immunity, increasing the risk of adverse maternal and fetal outcomes [16, 17]. However, epidemiological information from southern Busia County remains scarce, particularly regarding the concurrent distribution of malaria, helminth infections and anaemia among pregnant women.

Helminth infections and malaria remain important causes of morbidity among children and women of reproductive age because of increased exposure to contaminated environments and, in the case of pregnancy, physiological and immunological changes that increase susceptibility to infection [18]. During pregnancy, schistosomiasis has been associated with adverse maternal and fetal outcomes, including anaemia, placental inflammation, low birth weight, preterm delivery and ectopic pregnancy [19]. Several biological mechanisms may contribute to schistosomiasis-associated anaemia, including chronic intestinal blood loss caused by egg migration and inflammation-mediated disturbances of iron metabolism through increased hepcidin expression [20–22]. Likewise, malaria and STH infections have been associated with maternal anaemia, fetal growth restriction, preterm birth, low birth weight and increased infant mortality [23]. Although parasitic infections are recognised contributors to maternal anaemia in endemic settings, haemoglobin concentrations during pregnancy are influenced by a complex interplay of nutritional, genetic, infectious and inflammatory factors [24–27]. Consequently, the relative contribution of parasitic infections remains incompletely understood in many endemic populations.

Despite the endemicity of schistosomiasis, soil-transmitted helminth infections and malaria in western Kenya, their contemporary epidemiology among pregnant women in southern Busia County remains insufficiently characterised. Previous studies have largely focused on individual infections or paediatric populations, leaving limited information on the coexistence of multiple parasitic infections and anaemia in women presenting for delivery [11, 28]. This study therefore aimed to characterise the epidemiology of schistosomiasis, soil-transmitted helminth infections, malaria, coinfections and anaemia among pregnant women in southern Busia County, Kenya. Secondary objectives were to explore potential associations between parasitic infections and anaemia and to identify demographic and behavioural factors associated with helminth infections.

Methods

Ethical statement

Ethical approval for this study was obtained from the Kenya Medical Research Institute (KEMRI) Scientific and Ethics Review Unit (SERU; Ref. No. 4443) and the Egerton University Ethics Review Committee (EUERC; Ref. No. APP/180/2022). Written informed consent was obtained from all participants before enrolment. For participants who were minors, written informed consent was obtained from a parent or legal guardian, and assent was obtained from the participants before enrolment. Participant confidentiality was maintained using unique study identification numbers. Women diagnosed with any parasitic infection were referred to the nearest health facility for treatment according to Kenyan national guidelines. All methods were performed in accordance with the relevant KEMRI and Egerton University guidelines and regulations.

Study design and participants

This hospital-based cross-sectional study was conducted between May 2023 and November 2024 among pregnant women presenting for delivery at Port Victoria and Sio Port Sub-County Hospitals, two level 4 healthcare facilities located in Bunyala and Samia Sub-Counties, respectively, in southern Busia County, western Kenya. Both hospitals provide primary healthcare services, including maternity care and referral services, to predominantly rural communities bordering Lake Victoria.

The study area provides favourable conditions for the transmission of both schistosomiasis and malaria. Lake Victoria provides favourable ecological conditions for freshwater snails, the intermediate hosts of *Schistosoma mansoni*, as well as breeding habitats for *Anopheles* mosquitoes, the vectors of *Plasmodium falciparum*. Samia Sub-County (0°18'32"N, 34°9'27"E) has an estimated population of 107,176 inhabitants, whereas Bunyala Sub-County (0°5'53"N, 33°58'21"E) has approximately 66,723 inhabitants. Local livelihoods are primarily based on fishing, subsistence farming, livestock keeping and small-scale trading, with many households relying on Lake Victoria for domestic water use.

Pregnant women presenting for delivery constituted the study population. The required sample size was calculated using the Scalex SP calculator as previously described [29]. Assuming an expected prevalence of soil-transmitted helminth infection of 12.4% [9], a 95% confidence level, a 5% margin of error, and a 20% anticipated non-response rate, the minimum required sample size was estimated at 209 participants. This target sample size was achieved, and all enrolled women were included in the final analysis.

Eligible participants were women who had resided in the study area for at least six months before enrolment, had not received anthelmintic treatment within the previous three months, and attended one of the participating hospitals for delivery. Women with severe pre-existing medical conditions, immunosuppressive drug use, mental illness, conditions requiring emergency obstetric care, HIV infection, or those unwilling to participate were excluded from the study.

Data collection

Data were collected using two pre-tested semi-structured questionnaires administered by trained study personnel. The first questionnaire recorded socio-demographic characteristics, including age, ethnicity, occupation, marital status and educational level, together with obstetric information (gestational age at delivery and parity) and additional household characteristics, including height, weight, source of drinking water, history of malaria during pregnancy and livestock ownership. The second questionnaire collected behavioural and environmental exposure variables potentially associated with helminth infections. These included contact with Lake Victoria water, geophagy, disposal of children's faeces, drinking water treatment practices, fingernail hygiene and footwear use at home.

Stool collection and helminth examination

Approximately 4 g of fresh stool were collected from each participant using a clean, sterile, leak-proof stool container and processed immediately at the respective hospital laboratory. Two Kato-Katz thick smears were prepared from each sample and examined under light microscopy using a $\times 40$ objective to detect helminth eggs. Egg counts were multiplied by a standard factor of 24 to estimate eggs per gram (epg) of faeces. The mean egg count from the two Kato-Katz thick smears was used to calculate eggs per gram of faeces (epg).

Infection intensity was classified according to World Health Organization criteria as follows: *S. mansoni*: light (1–99 epg), moderate (100–399 epg) and heavy (≥ 400 epg); *A. lumbricoides*: light (1–4,999 epg), moderate (5,000–49,999 epg) and heavy ($\geq 50,000$ epg); *T. trichiura*: light (1–999 epg), moderate (1,000–9,999 epg) and heavy ($\geq 10,000$ epg); and hookworm: light (1–1,999 epg), moderate (2,000–3,999 epg) and heavy ($\geq 4,000$ epg).

For quality assurance, all slides were examined independently by two experienced certified microscopists blinded to each other's readings. Any discrepancies were resolved by a third experienced microscopist.

Blood collection and malaria parasite detection

Approximately 1 mL of capillary blood was collected by finger prick into EDTA tubes and processed at the respective hospital laboratory for the detection of *Plasmodium falciparum*. Thin and thick blood smears were prepared using 3 μL and 6 μL of blood, respectively. Thin smears were fixed with absolute methanol, air dried, and stained with freshly prepared 10% Giemsa solution for 20 minutes before microscopic examination. Slides were examined independently by experienced microscopists according to standard malaria microscopy procedures. *P. falciparum* parasites were identified microscopically, and parasite density was estimated from the thick blood smears. Parasite density (parasites/ μL) was

categorised for descriptive purposes as light (1–499 parasites/μL), moderate (500–1,999 parasites/μL) or heavy (≥2,000 parasites/μL).

Haemoglobin level determination

Haemoglobin (Hb) concentration was measured using the portable Mission Plus® HB analyser (ACON Laboratories Inc., San Diego, CA, USA) according to the manufacturer's instructions. Anaemia was defined according to WHO criteria as an Hb concentration <11.0 g/dL and classified as mild (10.0–10.9 g/dL), moderate (7.0–9.9 g/dL) or severe (<7.0 g/dL).

Data analysis

Data were entered into Microsoft Excel, checked for completeness and consistency, and analysed using R software version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria, 2025). Descriptive statistics, including frequencies, percentages, means and standard deviations, were used to summarise participant characteristics and infection profiles. Prevalence estimates for *Schistosoma mansoni*, soil-transmitted helminths (STH), malaria, coinfections and anaemia were calculated together with exact 95% confidence intervals. Mean haemoglobin concentrations and mean infection intensities were reported with standard deviations and 95% confidence intervals, where appropriate. Differences in mean haemoglobin concentrations between infected and uninfected participants were assessed using Student's t-test. Associations between anaemia status (anaemic versus non-anaemic) and parasitic infections were evaluated using Pearson's Chi-square test or Fisher's exact test, as appropriate according to expected cell frequencies. Individual and environmental factors associated with schistosomiasis and hookworm infection were investigated using multivariable binary logistic regression models. Because of the very small number of *Ascaris lumbricoides*, *Trichuris trichiura* and malaria infections detected, multivariable analyses were not performed for these infections. Statistical significance was defined as two-sided $P < 0.05$.

This study is reported in accordance with the STROBE guidelines for cross-sectional studies.

Results

Characteristics of the study population

A total of 209 pregnant women presenting for delivery were enrolled in the study. Participants ranged in age from 15 to 40 years, with a mean (SD) age of 24.0 (±5.2) years and a mean gestational age of 38.0 (±1.3) weeks. Primigravidae accounted for 42.1% of the study population. Most participants were aged 20–24 years (41.1%), were farmers (27.8%), and had completed secondary education (48.8%) (Table 1).

		(N = 209)	Percentage (%)
General characteristics			
Age (years)	15 – 19	45	21.5
	20 – 24	86	41.1
	25 – 29	47	22.5
	≥ 30	31	14.8
	Mean age (years) (±SD)	24 (±5.2)	
Occupation	Business	48	23.0
	Farmer	58	27.8
	Informal employment	47	22.5
	Formal employment	4	1.9
	Unemployed	38	18.2
	Fishing	2	1.0
	Student	12	5.7
Education	None	1	0.5
	Adult education ^a	4	1.9
	Primary	87	41.6
	Secondary	102	48.8
	Tertiary	15	7.2
Obstetric characteristics			
Gravid status	Primi	88	42.1
	Secundi	46	22.0
	Multi	75	35.7
Gestation age at delivery (weeks)	<38	43	20.6
	≥38	166	79.4

Table 1. Demographic and obstetric characteristics of the study population at Port Victoria and Sio Port.
a: Formal education offered to adults who did not access formal primary or secondary education.

Information on behavioural and environmental exposure factors was available for 107 participants. Nearly half (47.7%) reported living near Lake Victoria, 55.1% reported regular contact with lake water, 72.0% practised geophagy, and 54.2% reported treating their drinking water. The distribution of all investigated exposure variables is presented in Supplementary Table S1.

Prevalence and intensity of parasitic infections

Overall, 26 women were infected with *Schistosoma mansoni*, corresponding to a prevalence of 12.4% (95% CI: 8.0–17.0%). The mean (SD) infection intensity was 109.8 (±138.5) eggs per gram (epg), with most infections classified as light intensity (76.9%), followed by moderate (19.2%) and heavy infections (3.8%).

Soil-transmitted helminths were detected in 20 participants (9.6%; 95% CI: 5.6–13.6%). Hookworm was the predominant species (7.7%), whereas *Ascaris lumbricoides* and *Trichuris trichiura* were identified in 1.4% and 0.5% of participants, respectively. All STH infections were of light intensity.

Plasmodium falciparum malaria was detected in six women (2.9%; 95% CI: 0.6–5.1%). Five infections (83.3%) were classified as light parasite density and one (16.7%) as moderate. Detailed prevalence estimates are presented in Table 2, whereas parasite-specific intensity classifications are provided in Supplementary Table S2.

Infection	Positive n (%)	95% CI	Mean intensity (SD), epg	Infection intensity distribution*
<i>Schistosoma mansoni</i>	26 (12.4)	8.0–17.0	109.8 ± 138.5 epg	20 light, 5 moderate, 1 heavy
Hookworms	16 (7.7)	4.1–11.3	121.5 ± 98.9 epg	16 light
<i>Ascaris lumbricoides</i>	3 (1.4)	–0.18–3.1	88.0 ± 27.7 epg	3 light
<i>Trichuris trichiura</i>	1 (0.5)	–0.5–1.4	NA†	1 light
Any STH	20 (9.6)	5.6–13.6	—	—
<i>Plasmodium falciparum</i>	6 (2.9)	0.6–5.1	10,640 ± 13,206.8 parasites/μL	5 light, 1 moderate

Table 2. Prevalence and summary intensity measures of parasitic infections among pregnant women in southern Busia County, Kenya. Epg – egg per gram; 95% CI – confidence interval; STH – soil-transmitted

helminthiasis; p – parasites. † Mean parasite density was not calculated because only one infection was detected. Light, moderate and heavy infection categories were defined according to World Health Organization criteria. Detailed World Health Organization infection intensity categories are presented in Supplementary Table S2.

Coinfection patterns

Coinfections were rare. One participant presented concurrent *S. mansoni*–hookworm infection and one concurrent *A. lumbricoides*–*T. trichiura* infection (0.5% each). No malaria–helminth coinfections were detected.

Anaemia and its association with parasitic infections

The mean (SD) haemoglobin concentration was 10.5 (±1.5) g/dL. Overall, 134 women (64.1%; 95% CI: 57.6–70.6%) were anaemic, of whom most presented moderate (55.2%) or mild anaemia (44.0%), while only one participant had severe anaemia.

Mean haemoglobin concentrations according to infection status are presented in Table 3. Women infected with hookworm had significantly lower haemoglobin concentrations than uninfected women ($P = 0.05$), whereas no significant differences were observed for *Schistosoma mansoni*, malaria or overall STH infection. When haemoglobin was analysed as a categorical outcome (anaemic versus non-anaemic), no statistically significant associations were identified for any parasitic infection (Supplementary Table S3).

Infection	Infected, n	Mean Hb ± SD (g/dL)	Uninfected, n	Mean Hb ± SD (g/dL)	Mean difference (95% CI)	P, value*
<i>Schistosoma mansoni</i>	26	10.92 ± 1.43	183	10.49 ± 1.53	0.43 (-0.18, 1.04)	0.17
Hookworms	16	9.99 ± 1.04	193	10.59 ± 1.54	-0.60 (-1.36, 1.04)	0.05
Any STH	20	9.94 ± 1.11	189	10.61 ± 1.54	-0.67 (-1.38, 0.04)	0.07
<i>Plasmodium falciparum</i>	6	10.73 ± 1.97	203	10.54 ± 1.51	0.19 (-1.04, 1.42)	0.76

Table 3. Association between parasitic infections and haemoglobin concentration among pregnant women in southern Busia County, Kenya. *Student's t-test. Abbreviations: Hb, haemoglobin; SD, standard deviation; STH, soil-transmitted helminths.

Factors associated with helminth infections

Multivariable logistic regression identified student status as the only variable independently associated with hookworm infection (log OR = 4.0, $P = 0.017$). No statistically significant associations were identified between the remaining demographic or behavioural variables included in the models and either hookworm or *Schistosoma mansoni* infection (Table 4).

Variable	Category	<i>Schistosoma mansoni</i> log(OR)	95% CI	P-value	Hookworm log(OR)	95% CI	P-value
Age (years)	Continuous	0.01	– 0.09 to 0.10	>0.9	0.09	– 0.03 to 0.22	0.14
Education	Adult education	Reference			Reference		
	None	53	–259 to 2539	>0.9	–14	–	>0.9
	Primary	33	–435 to –	>0.9	–0.84	–4.5 to 3.7	0.70
	Secondary	33	–435 to –	>0.9	–0.87	–4.6 to 3.7	0.70
	Tertiary	32	–169 to –	>0.9	0.02	–3.7 to 4.2	>0.9
Occupation	Business	Reference			Reference		
	Farmer	–0.91	–2.4 to 0.49	0.20	1.2	– 0.86 to 4.2	0.30
	Fishing	18	–499 to –	>0.9	–13	–	>0.9
	Formal employment	–15	–	>0.9	3.5	0.07 to 7.9	0.062
	Informal employment	0.40	– 0.82 to 1.7	0.50	1.2	–1.1 to 4.3	0.30
	Not employed	0.15	–1.6 to 1.8	0.90	1.1	–1.7 to 4.4	0.50
	Student	0.67	–1.9 to 3.1	0.60	4.0	0.94 to 7.7	0.017
Malaria history	Negative	Reference			Reference		

	Positive	–1.1	–3.0 to 0.21	0.20	–0.33	–2.2 to 1.1	0.70
Marital status	Married	Reference			Reference		
	Single	0.00	–1.4 to 1.3	>0.9	1.0	– 0.67 to 2.7	0.20
Domestic animals	No	Reference			Reference		
	Yes	0.28	– 0.76 to 1.4	0.60	1.1	– 0.48 to 3.1	0.20
Drinking water source	Borehole	Reference			Reference		
	Lake	0.12	–1.5 to 1.9	0.90	–2.1	–4.9 to 0.03	0.083
	River	–17	– 1025 to 125	>0.9	–16	–	>0.9
	Tap	0.34	– 0.96 to 1.9	0.60	–1.3	–2.8 to 0.11	0.065

Table 4. Factors associated with *Schistosoma mansoni* and hookworm infection among pregnant women in southern Busia County, Kenya.

Discussion

This study provides contemporary epidemiological data on helminth infections, malaria and anaemia among pregnant women presenting for delivery in southern Busia County, western Kenya, a population for which recent evidence remains limited. *Schistosoma mansoni* infection remained moderately prevalent, whereas soil-transmitted helminths and malaria occurred at relatively low prevalence and intensity. In contrast, nearly two-thirds of participants were anaemic, indicating that maternal anaemia remains a major public health concern despite the relatively low burden of parasitic infections. Collectively, these findings suggest that although parasitic infections continue to circulate in this setting, other infectious and non-infectious determinants are also likely to contribute substantially to maternal health outcomes.

The prevalence of *Schistosoma mansoni* observed in this study is consistent with previous evidence indicating that intestinal schistosomiasis remains an important public health concern among pregnant women living in endemic areas. The prevalence was comparable to the global estimate reported in a

recent meta-analysis of pregnant women [30], although lower than that reported in Senegal, where the use of more sensitive molecular diagnostic methods probably increased the detection of low-intensity infections [31]. Despite longstanding schistosomiasis control programmes in Kenya, the persistence of infection among women of reproductive age suggests that transmission remains active in communities surrounding Lake Victoria. This finding is consistent with the current focus of national control strategies, which primarily target school-aged children through preventive chemotherapy, whereas adult populations—including pregnant women—receive considerably less attention despite continued occupational and domestic exposure to infested water bodies [12,32,33]. These observations reinforce the need to strengthen surveillance and preventive strategies for women of reproductive age in endemic communities and support consideration of complementary control approaches beyond school-based programmes.

The overall prevalence of STH infections was relatively low, and all infections were of light intensity, suggesting that ongoing deworming programmes and improvements in water, sanitation and hygiene may have contributed to reducing transmission in the study area. Nevertheless, the continued detection of STH infections indicates that transmission has not been interrupted. Hookworm remained the predominant STH species, consistent with previous reports from western Kenya [34]. This finding is clinically relevant because hookworm is the STH species most strongly associated with chronic intestinal blood loss and iron deficiency, both of which may contribute to maternal anaemia even in relatively light infections [35,36]. Differences in the predominant STH species reported across endemic regions probably reflect local ecological, environmental and socioeconomic factors influencing parasite transmission [37,38]. The persistence of exclusively low-intensity hookworm infections illustrates an important epidemiological challenge: reducing infection intensity does not necessarily imply interruption of transmission. Continued exposure to contaminated environments may contribute to maintaining low-level endemic transmission despite ongoing control programmes.

Malaria prevalence was low (2.9%) among pregnant women at delivery in southern Busia County, contrasting with the substantially higher prevalences reported in neighbouring Siaya County [15], Uganda [39], and coastal Kenya [40]. Several factors may account for these differences. First, malaria transmission in western Kenya is highly heterogeneous despite geographical proximity, reflecting local variation in ecological conditions, vector abundance, rainfall patterns, and the implementation and effectiveness of control interventions [41-43]. Thus, communities surrounding Lake Victoria should not be considered epidemiologically homogeneous. Second, differences in study design may have contributed to the observed discrepancies. Our study enrolled women at the time of delivery, whereas many previous investigations recruited participants during antenatal care, when infections may be more common before completion of intermittent preventive treatment in pregnancy (IPTp) and before repeated contact with antenatal services [44,45]. Consequently, our findings probably reflect malaria prevalence at the end of pregnancy rather than cumulative exposure throughout gestation. Finally, the relatively low prevalence observed may also indicate the positive impact of sustained malaria control strategies in the study area, including widespread use of long-lasting insecticidal nets, indoor residual spraying, and routine administration of sulphadoxine–pyrimethamine for IPTp [46]. Although our study was not

designed to evaluate the effectiveness of these interventions, the findings are consistent with the progressive reduction in malaria burden reported in several parts of western Kenya over recent years [41-43].

Coinfections were uncommon in this cohort. Only one participant presented concurrent *S. mansoni*–hookworm infection and one presented concurrent *A. lumbricoides*–*T. trichiura* infection, while no malaria–helminth coinfections were identified. These findings contrast with reports from other endemic areas of Kenya [40], where higher levels of polyparasitism have been described, but are consistent with studies reporting infrequent coinfections among pregnant women in Nigeria [18]. The low frequency of coinfections observed in the present study is likely explained by the relatively low prevalence of both malaria and STH infections, which substantially reduces the probability of concurrent infections occurring within the same individual. In addition, differences in transmission intensity, environmental exposure, WASH conditions, study populations, and the coverage of parasite control programmes probably contribute to the marked heterogeneity in coinfection patterns reported across endemic settings. Because participants were recruited at delivery, these findings represent coinfection status at the end of pregnancy and may underestimate transient coinfections occurring earlier during gestation. As only two coinfecting individuals were identified, the present study was not powered to evaluate the clinical significance of coinfection or its potential relationship with anaemia. Nevertheless, the findings suggest that, in this setting, the current epidemiological burden is characterised by the persistence of individual parasitic infections rather than by frequent polyparasitism.

Anaemia affected nearly two-thirds of the women included in the study despite the relatively low prevalence of parasitic infections, making it the most common adverse health condition identified in this cohort. The observed prevalence was comparable to that reported in some studies from India [47] but exceeded pooled estimates for sub-Saharan Africa [48], underscoring the considerable burden of maternal anaemia in this setting. Conversely, the prevalence was lower than that reported among pregnant women attending antenatal clinics in Mkuranga District, Tanzania, where anaemia affected more than 80% of participants [49]. Differences in nutritional status, dietary diversity, access to antenatal care, and the timing of recruitment may partly explain the variation between settings. Although parasitic infections remain important contributors to poor maternal health, these findings suggest that anaemia in southern Busia County is likely driven by multiple interacting determinants [46,50,51]. The rural context of the study area and the potential contribution of nutritional and socioeconomic factors may partly explain this high background prevalence.

Although helminth infections and malaria are well-recognised causes of maternal anaemia through mechanisms including chronic blood loss, inflammation and impaired iron metabolism, no statistically significant associations were identified in the present study. This finding should be interpreted cautiously. The relatively small number of infected participants considerably reduced the statistical power to detect modest associations, increasing the likelihood of type II error. Therefore, the absence of statistical significance should not be interpreted as evidence that parasitic infections do not contribute to maternal anaemia in this population. Rather, our findings suggest that parasitic infections represent

only one component of a multifactorial condition in which nutritional deficiencies, iron and folate status, inherited haemoglobin disorders, chronic inflammation and other maternal health conditions may collectively explain the substantial burden of anaemia observed. Future studies integrating parasitological, nutritional and clinical assessments will be necessary to clarify the relative contribution of these determinants.

Interestingly, hookworm infection was associated with lower mean haemoglobin concentrations when haemoglobin was analysed as a continuous variable, whereas no association was observed after dichotomising participants according to WHO anaemia criteria. This apparent discrepancy most likely reflects the loss of statistical information associated with converting a continuous variable into a binary outcome and suggesting that analyses based solely on anaemia categories may be less sensitive to subtle differences in maternal haemoglobin concentration associated with low-intensity hookworm infection.

Student status was the only variable independently associated with hookworm infection in the multivariable analysis. This finding should be interpreted cautiously because of the relatively small number of hookworm infections detected, which may have resulted in unstable effect estimates. Although the underlying mechanisms remain uncertain, student status may act as a proxy for unmeasured behavioural, socioeconomic or environmental factors influencing exposure to hookworm transmission. Comparable associations have rarely been reported in the literature, limiting direct comparisons with previous studies. Consequently, this observation should be considered hypothesis-generating rather than conclusive and warrants confirmation in larger prospective studies incorporating more detailed exposure assessments.

Several limitations should be considered when interpreting these findings. First, although the sample size was adequate for estimating the prevalence of the investigated infections, the relatively small number of malaria and certain STH infections limited the statistical power to detect associations with anaemia and other outcomes. Consequently, the absence of statistically significant associations should not be interpreted as evidence of the absence of biological effects. Second, important determinants of maternal anaemia, including iron and folate status, dietary intake, inherited haemoglobin disorders (such as sickle cell disease or thalassaemia), and other chronic inflammatory or infectious conditions, were not assessed. These unmeasured factors may explain a substantial proportion of the high anaemia prevalence observed. Third, diagnosis relied on conventional microscopy and the Kato–Katz technique, which may underestimate low-intensity malaria and helminth infections despite rigorous quality assurance procedures. Furthermore, only a single stool specimen was analysed from each participant, potentially reducing the sensitivity of helminth detection because of day-to-day variation in egg excretion. Finally, because this was a hospital-based cross-sectional study including women presenting for delivery, the findings may not be fully generalisable to pregnant women in the wider community or to earlier stages of pregnancy. Despite these limitations, the study provides contemporary epidemiological data from a population for which updated information remains scarce.

Conclusion

This study provides updated epidemiological evidence on helminth infections, malaria and anaemia among pregnant women in southern Busia County, a population for which contemporary data remain limited. Although the prevalence of malaria and soil-transmitted helminth infections was relatively low, the persistence of *Schistosoma mansoni* and hookworm infections indicates that exposure to these parasites remains ongoing in communities surrounding Lake Victoria. In contrast, the high prevalence of maternal anaemia despite the relatively low burden of parasitic infections suggests that nutritional and other non-parasitic determinants play a major role in this setting. These findings support the need for integrated maternal health strategies combining sustained parasite control, improvements in water, sanitation and hygiene, nutritional interventions, and routine antenatal screening. Future studies incorporating parasitological, nutritional and inflammatory assessments will be essential to clarify the multifactorial causes of maternal anaemia and to guide evidence-based public health interventions in endemic regions.

Declarations

Data availability. All data supporting the findings of this study are available within the paper and its Supplementary Information.

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Author's contribution. GI: Conceptualisation of the study, study design, data collection, laboratory examination, data analysis, visualisation, and wrote the original draft of the manuscript. DMW: Study design, reviewing and editing the manuscript. DK: Data collection. DK, MA, EC, SC, SK: Reviewing and editing the manuscript. RPC: Data interpretation, reviewing and editing the manuscript. BNO: conceptualisation of the study, study design, acquisition of resources, reviewing and editing the manuscript, and overall supervision. All authors read and approved the final manuscript.

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Ethical statements. The study received ethical approval from the Kenya Medical Research Institute (KEMRI) Scientific and Ethics Review Unit (SERU; Ref. No. 4443) and the Egerton University Ethics Review Committee (EUERC; Ref. No. APP/180/2022). Prior to enrolment, participants were informed

about the study and written informed consent was obtained. For participants who were minors, consent was provided by a parent or legal guardian, and assent was obtained from the participants before their participation. All study procedures were conducted in accordance with the relevant guidelines and regulations.

Additional information

Supplementary Information. The online version contains supplementary material available at...

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