



Research paper

Gestational intestinal parasitosis and anaemia: A double-hit for pregnancy outcomes

Heba M. Aboelela^a, Waleed M. Tawfik^b, Ghada M. Mahmoud^c, Ayman T. Morsy^d,
Ahmed F. Sherif^b, Asmaa M. Ammar^{e,*}

^a Medical Parasitology Department, Faculty of Medicine, Benha University, Qalyubiyya, Egypt

^b Obstetrics & Gynecology Department, Faculty of Medicine, Benha University, Qalyubiyya, Egypt

^c Clinical and Chemical Pathology Department, Faculty of Medicine, Benha University, Qalyubiyya, Egypt

^d Respiratory Care Technology Department, Faculty of Applied Health Science Technology, Misr University for Science and Technology, Giza, Egypt

^e Medical Parasitology Department, Faculty of Medicine, Ain Shams University, Cairo, Egypt

ARTICLE INFO

Keywords:

Gestational anaemia

Pregnant women

Intestinal parasitic infections

ABSTRACT

Gestational anaemia (GA) is a significant public health concern worldwide, affecting approximately 30 % of pregnant women. The causes of GA are multifactorial, and intestinal parasitic infections (IPIs) have been implicated as contributing factors. However, the prevalence of IPIs in pregnant women and its relationship with the incidence and severity of GA and pregnancy outcomes remain unclear. This study aimed to evaluate the prevalence of IPIs in pregnant women and its relation to the incidence and severity of GA and pregnancy outcomes.

A total of 238 pregnant women were clinically evaluated, stool specimens were collected for parasitological examinations, and blood samples were collected for ELISA detection of anti-*trichinella* and anti-*schistosoma* IgG. The haemoglobin concentration (HBC) was estimated during the 1st and 3rd trimesters, and the extent of change in HBC was calculated. The enrolled women were categorized according to the 1st trimester HBC into anaemic and non-anaemic groups, and the incidence of pregnancy outcomes was determined.

The 3rd trimester HBC was significantly lower than the 1st trimester HBC, and the incidence of GA increased from 30.25 % to 50.84 %. The frequency of IPIs was 45 %, with a coinfection rate of 43 % among infected women. Infection by *Ascaris* (*A.*) *lumbricoides* and *Ancylostoma* (*A.*) *duodenale* was detected in 33.6 % and 19.6 % of specimens, respectively. The frequency of infections by *A. duodenale* and *Schistosoma* species was significantly greater among anaemic women. Fifty-one women (21.4 %) developed pregnancy-related complications, with a significantly greater incidence among anaemic women. The incidence of miscarriage and small for gestational age (SGA) was significantly greater among anaemic women.

This study demonstrated that gestational IPIs induce and/or aggravate maternal anaemia and deleteriously affect pregnancy outcomes. Parasitic coinfection is a high-risk factor for the development of severe anaemia late in pregnancy, the occurrence of miscarriage, and SGA. The implementation of parasitological evaluation in routine pre-pregnancy counseling or at pregnancy diagnosis is mandatory to reduce the risk of adverse pregnancy outcomes.

Abbreviations: *A. duodenale*, *Ancylostoma duodenale*; *A. lumbricoides*, *Ascaris lumbricoides*; CDC, Centers for Disease Control and Prevention; *E. histolytica*, *Entamoeba histolytica*; *E. vermicularis*, *Enterobius vermicularis*; ELISA, Enzyme-linked immunosorbent assay; GA, Gestational anaemia; GDM, Gestational diabetes mellitus; GHTN, Gestational hypertension; GIDA, Gestational Iron deficiency anaemia; HBC, Haemoglobin concentration; IDA, Iron deficiency anaemia; IPIs, Intestinal parasitic infections; IUGR, Intrauterine growth retardation; PMROM, premature rupture of membranes; PPBG, postprandial blood glucose; ROC, Receiver operating characteristic; *S.*, *Schistosoma*; SGA, small for gestational age; STH, soil-transmitted helminth; *T. spiralis*, *Trichinella spiralis*; *T. trichiura*, *Trichuris trichiura*; WHO, World Health Organization.

* Corresponding author.

E-mail address: dr_asma_mostafa@med.asu.edu.eg (A.M. Ammar).

<https://doi.org/10.1016/j.parint.2025.103133>

Received 21 March 2025; Received in revised form 14 April 2025; Accepted 23 July 2025

Available online 26 July 2025

1383-5769/© 2025 Elsevier B.V. All rights reserved, including those for text and data mining, AI training, and similar technologies.

1. Introduction

Intestinal parasitic infections (IPIs) constitute a significant global health challenge and are particularly prevalent in tropical and sub-tropical regions. Pregnant women are undergoing physiological changes that heighten their vulnerability to infections and are considered the most at-risk population. Parasitic infections have been recognized as a pivotal factor influencing pregnancy outcomes [1]. The World Health Organization (WHO) estimates that up to a quarter of the global population, approximately 1.7 billion individuals, are afflicted by IPIs [2]. Among pregnant women in endemic areas, the prevalence of parasitic infections can range from 24 % to 70 %, with approximately 10 % of women experiencing multiple parasitic infections [3].

In Egypt, intestinal parasitic infections remain a significant public health concern despite national control efforts. Studies from various regions of Egypt have reported prevalence rates of intestinal parasites ranging from 27 % to 56 % among the general population, with higher rates observed in rural areas and among lower socioeconomic groups [4,5].

Gestational anaemia (GA) is categorized based on haemoglobin concentration (HBC), with severe anaemia characterized by HBC below 7 g/dl and moderate anaemia falling within the range of ≥ 7 - < 10 g/dl [6]. Iron deficiency is recognized as a primary contributor to anaemia, accounting for nearly half of the global burden. During pregnancy, the presence of IPIs can exacerbate anaemia, presenting a dual burden that poses substantial risks to both the mother and the developing embryo/foetus [7]. Intestinal parasites can contribute to or worsen anaemia through various mechanisms. For instance, parasites such as hookworms, schistosomes, and *Trichuris (T.) trichiura* can lead to intestinal blood loss, while others, such as *Giardia lamblia* and *Entamoeba (E.) histolytica*, may induce blood loss and hinder iron absorption. Additionally, parasitic infections can reduce appetite, impede nutrient intake, and trigger intestinal inflammation that limits nutrient absorption, further contributing to anaemia [1].

Geophagia, the deliberate consumption of soil or clay, is a common practice among pregnant women. It is another relevant factor contributing to iron deficiency and parasitic infections in developing countries. As highlighted by Ellwanger et al. [8] geophagia creates a "classic and neglected connection" between iron deficiency and soil-transmitted helminth infections through multiple pathways. Ingestion of soil directly increases exposure to infective helminth eggs and larvae. Many soil types consumed during geophagia bind iron in the gastrointestinal tract, reducing its bioavailability and worsening existing iron deficiency. Iron deficiency itself may lead to pica behaviors, including geophagia, creating a self-perpetuating cycle. Finally, both iron deficiency and helminth infections compromise immune function, further increasing susceptibility to infection.

The intricate relationship between intestinal parasitosis and anaemia during pregnancy not only heightens the risk of anaemia but also increases the likelihood of deficiencies in essential nutrients such as iron, energy, protein, folate, and zinc. These deficiencies can result in low pregnancy weight gain, intrauterine growth retardation (IUGR), elevated risks of infections, low birth weight, and increased rates of perinatal mortality [9].

Despite the established relationship between individual parasitic infections and anaemia, there remains a significant research gap regarding the impact of parasitic coinfections on pregnancy outcomes, particularly in Egypt. While most existing studies have examined the prevalence of specific parasites or general anaemia rates during pregnancy, few have comprehensively investigated how multiple concurrent parasitic infections, which are common in endemic regions, might synergistically affect maternal haemoglobin levels and subsequent pregnancy outcomes.

This study aimed to explore the combined impact of gestational intestinal parasitosis and anaemia on pregnancy outcomes, shedding light on this double hit. The relationships among parasitic infections,

anaemia, and pregnancy outcomes were investigated. This study investigated the frequency and multiplicity of parasitic infections and how this multiplicity may be related to changes in HBC during pregnancy. Additionally, the types of parasites responsible for parasitosis and their prevalence among pregnant women were examined, providing valuable insights into the impact of parasitic infections on anaemia and pregnancy. These findings will contribute to the existing knowledge in the field and may inform targeted interventions and public health strategies to improve maternal and fetal health outcomes.

2. Methods

2.1. Ethical aspects

This study was approved by the Research Ethics Committee (REC) of Benha Faculty of Medicine under approval code RC-3-3-2024. Ethical clearance was obtained from the Ministry of Health under reference number MoHP No:0018122017 / Certificate No:1017. All participants provided written informed consent before enrollment.

2.2. Study population

2.2.1. Type of study and study population

This study adopted a prospective non-randomized comparative design. The study was conducted in the Departments of Obstetrics & Gynecology and Medical Parasitology at the Faculty of Medicine, Benha University, Al-Qalyubia, Egypt.

2.3. Participant evaluation and baseline assessment

A total of 257 pregnant women who presented at the antenatal care unit or were referred to the Obstetrics & Gynecology Department at Benha University Hospital were assessed for eligibility for the study. The preliminary evaluation consisted of collecting constitutional data, including age, weight, and height, to establish baseline characteristics.

Personal history data, such as residence area, level of education, type of work, and rough assessment of income status, were obtained. The obstetric history, including parity and past pregnancy complications such as miscarriage, gestational hypertension (GHTN), gestational diabetes mellitus (GDM), previous instances of delivering small for gestational age (SGA) or underweight newborns, and complications in previous deliveries, were documented.

Medical history was reviewed to identify essential hypertension; the presence of diabetes mellitus; liver, kidney, or cardiac lesions; autoimmune disorders; anaemia-inducing conditions (especially bleeding gastrointestinal disorders); and any ongoing drug therapies. Following the collection of history data, all participants underwent comprehensive general and obstetric examinations, including ultrasonographic imaging, to further assess their health status and confirm eligibility for participation in the study.

2.4. Patient grouping

Patients were categorized according to the HBC estimated at the time of enrollment into anaemic and non-anaemic groups.

2.4.1. Inclusion criteria for patients

The study included pregnant women aged 18–40 years in their first trimester of pregnancy, carrying a singleton foetus as confirmed by ultrasound, willing to provide written informed consent, not receiving anthelmintic treatment in the last 6 months, and from both urban and rural areas.

2.4.2. Exclusion criteria

Women were excluded if they had medical disorders known to cause anaemia (such as thalassemia, sickle cell anaemia, aplastic anaemia),

hemoglobinopathies, history of surgeries for gastric or small intestinal lesions. Additionally, patients taking medications that inhibit bone marrow function, those who had multiple foetal sacs identified via ultrasound imaging, pre-existing medical disorders known to impact pregnancy outcomes significantly (pre-existing hypertension, pre-existing diabetes mellitus, chronic kidney disease, autoimmune disorders), severe malnutrition, history of recurrent pregnancy loss, or declined to participate or were unable to attend follow-up visits were also excluded from the study. These exclusion criteria were applied to ensure that the study focused on gestational parasitic infections, anaemia, and their implications for pregnancy outcomes without the influence of confounding medical conditions or interventions.

2.5. Laboratory methods

2.5.1. Stool sample collection and processing

2.5.1.1. Stool specimen collection. Stool specimens were collected at the time of enrolment following the **guidelines of the Centers for Disease Control and Prevention (CDC)** [10]. Three stool samples were obtained, and samples were taken every three days and stored in dry, clean containers. The specimens were refrigerated at 3–5 °C until processing.

2.6. Mini-FLOTAC technique for stool sample processing

Stool specimens were processed using the Mini-FLOTAC technique to diagnose helminth infections in accordance with the manufacturer's instructions. The process involved filling the conical collector with approximately 2 g of feces using a spatula. Then, 38 ml of floatation solution was added to the Fill-FLOTAC stool container, which was then tightly closed. The sample was homogenized using a homogenizer in the cap of the Fill-FLOTAC. Subsequently, a tip was attached to the Fill-FLOTAC, and the suspension was mixed and transferred to the Mini-FLOTAC chambers through the filling holes. To prevent the formation of air bubbles, the Mini-FLOTAC apparatus was held at a 30° slope. After 10 min, the reading disc was applied and rotated to produce four films for examination.

2.7. Microscopic examination

The Fill-FLOTAC was placed under a microscope, using a microscope adaptor and examined at the maximum permissible magnification (x400). A multiplication factor of 10 was utilized to determine the number of eggs, larvae, oocysts, or cysts per gram of feces. The CDC Guide for Laboratory Procedures for the Diagnosis of Intestinal Parasites (1982) was used as an identification reference [10].

2.8. Blood sample collection and processing

2.8.1. Blood sample collection

Blood samples were obtained at the time of enrolment to establish baseline data and at the beginning of the 3rd trimester to reevaluate the HBC. Blood samples were collected under aseptic conditions and divided into three parts for different analyses in accordance with the **International Committee for Standardization in Haematology(1967)** [11].

2.9. Processing of blood samples

The first part of the blood sample was collected in an EDTA-containing tube for immediate estimation of HBC using the cyanomethemoglobin method. The second part was used for a peripheral blood smear by spreading a drop of blood as a thin film on a glass slide, which was then stained with Giemsa stain to assess the size, shape, and colour of red blood cells. The third part of the blood sample was collected in a plain, clean, dry tube, allowed to clot, and then centrifuged at 1500 rpm

for 10 min. The resulting serum was transferred to dry Eppendorf numbered tubes and frozen at –80 °C for subsequent analysis.

2.10. Assay procedures

The frozen serum samples were assayed for anti-*T. spiralis* IgG and anti-bilharzial IgG using enzyme-linked immunosorbent assay (ELISA) kits. The assays were performed in accordance with the manufacturer's instructions.

2.11. Enzyme-linked immunosorbent assay (ELISA)

ELISA was used for the qualitative measurement of specific antibodies. Anti-*T. spiralis* IgG levels were assessed using a human anti-*T. spiralis* IgG ELISA Kit (Cat. No. ab108780; Abcam Inc., San Francisco, USA). Similarly, the presence of anti-*Schistosoma mansoni* IgG was determined using a human anti-*Schistosoma* IgG Kit (Cat. No. ab108769; Abcam Inc., San Francisco, USA). Furthermore, the quantification of anti-*Schistosoma haematobium* IgG was performed using the designated kit (Cat. No. MBS9716177; bioMérieux SA, Marcy-l'Étoile, France).

2.12. Assessment of pregnancy-associated complications

- **GA:** Anaemia was classified based on the stained peripheral blood film into hypochromic microcytic, normochromic normocytic, and hyperchromic macrocytic anaemia [12]. Iron deficiency anaemia (IDA) was diagnosed as hypochromic microcytic anaemia without morphological changes, while gestational IDA (GIDA) was differentiated by trimester. In the 1st and 3rd trimesters, a haemoglobin concentration (HBC) <11 g/dl was considered diagnostic, while in the 2nd trimester, an HBC <10.5 g/dl indicated GIDA [13].
- **GHTN:** GHTN was defined as the development of elevated systolic and diastolic blood pressure measures (≥ 140 and ≥ 90 mmHg, respectively) on two separate measurements at least 4–6 h apart after the 20th week of gestation in a previously normotensive woman without proteinuria [14].
- **GDM:** GDM was defined according to the International Association of Diabetes and Pregnancy Study Group recommendations. Criteria included fasting blood glucose (FBG) ≥ 92 mg/dl, 1-h postprandial blood glucose (PPBG) ≥ 180 mg/dl, and 2-h PPBG ≥ 153 mg/dl on a 75-g oral glucose tolerance test consisting of fasting and postprandial blood samples taken after the ingestion of 75 g of glucose [15].

2.13. Statistical analyses

ANOVA was used for intragroup comparisons, paired *t*-tests were used for intergroup comparisons, and chi-square tests were used for categorical data. The extent of change in HBC was calculated by subtracting the HBC measured during the 3rd trimester from that estimated during the 1st trimester, dividing the result by the 1st-trimester concentration, and multiplying by 100. Pearson's correlation analysis was applied to assess the relationships between pregnancy outcomes, changes in HBC, and the incidences of parasitosis and coinfection. Receiver operating characteristic (ROC) curves were generated to evaluate the predictive ability of the studied variables for pregnancy outcomes, with significance indicated by the area under the curve (AUC) compared to the reference line. Regression analysis was performed to validate the results. All the statistical analyses were conducted using the IBM SPSS program (Version 22; 2017, IBM, USA), and the significance was reported as *P* values at a cut-off of 0.05.

3. Results

3.1. Characteristics of the study

The baseline assessment of 257 women who were admitted to or

referred to the antenatal care unit resulted in the exclusion of 19 women for various reasons, including diabetes ($n = 4$), essential hypertension ($n = 4$), autoimmune diseases ($n = 3$), iron supplemental therapy ($n = 6$), and a history of early pregnancy loss ($n = 2$). Overall, 238 women were included in the study and were divided into two groups: 72 women were classified as anaemic, and 166 women were classified as non-anaemic based on their haemoglobin concentration estimated at the time of enrolment (Fig. 1).

3.2. Anaemia during pregnancy

The mean value of the estimated HBC in the samples of both groups obtained during the 3rd trimester (11.7 ± 0.88 g/dl) was significantly ($P < 0.001$) lower in comparison to that estimated during the 1st trimester (Fig. 2).

The estimated HBC during the 1st trimester indicated that 49 women had IDA, and this number increased progressively during pregnancy to 83 during the 3rd trimester. Macrocytic anaemia was detected in 23 women in the 1st trimester and increased to 38 women in the 3rd trimester. Overall, the incidence of GA was 72 women (30.25 %) in the 1st trimester (anaemic group) and increased to 112 women (50.84 %) in the 3rd trimester, with a subsequent decrease in the frequency of non-anaemic women from 166 (69.75 %) women (nonanaemic group) to 126 (49.16 %) women. The frequency of women with GIDA increased from 20.59 % to 34.87 %, and that of women with macrocytic anaemia risen from 9.66 % to 15.97 % (Fig. 3).

3.3. Sociodemographic characteristics

The enrolment data revealed no significant differences between anaemic and nonanaemic women in terms of age or type of work. However, several socioeconomic characteristics were found to be associated with anaemia. Anaemic women were more likely to come from rural areas ($p = 0.042^*$), have a lower educational level ($p = 0.032^*$), and have a lower monthly income ($p = 0.033^*$). Additionally, they had a larger family size than did nonanaemic women (Table 1).

3.4. Parasitological evaluation

Parasitological evaluation revealed 107 specimens (45 %) infected by various types of parasites. Among these 107 infected women, 65 specimens (39.2 %) from nonanaemic women and 42 specimens (58.3 %) from anaemic women had a significantly ($P = 0.0063$) higher incidence of infection among anaemic women. During the parasitological examination, 61 of the infected specimens (57 %) were infected by a single parasitic type, 33 specimens were infected by two parasitic types, and 13 specimens (12.2 %) were infected by more than two parasitic types, with a significantly ($P = 0.0016$) higher frequency of mixed parasitic infections among anaemic women (Table 2, Fig. 4).

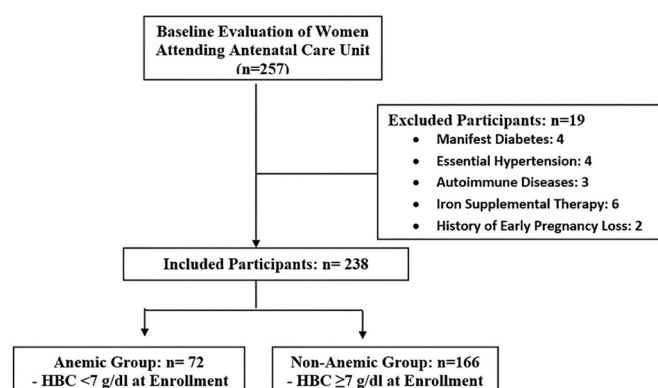


Fig. 1. Flow chart of patient selection.

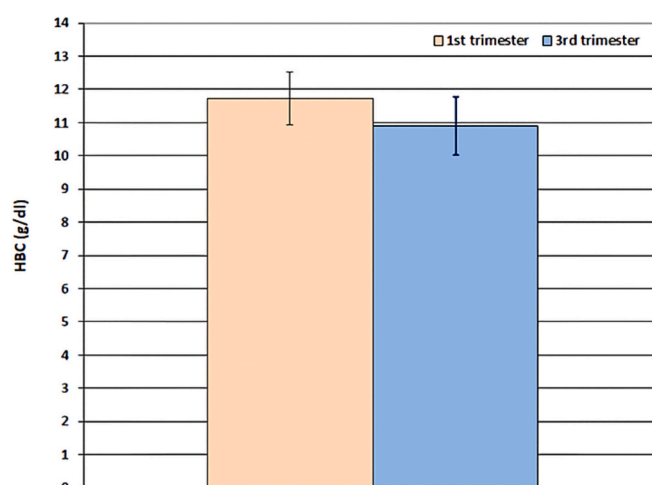


Fig. (2): Mean ($\pm$ SD) value of HBC of the study participants estimated at the 1st & 3rd trimesters

Fig. 2. HBC values of the study participants estimated at the 1st & 3rd trimesters.

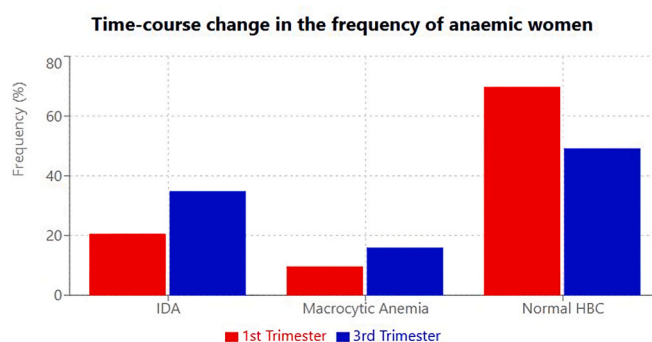


Fig. 3. Time-course change in the frequency of anaemic women.

The most common infecting parasite was *A. lumbricoides*, which was detected in 36 infected specimens (33.6 %); 27 specimens (25.2 %) were infected by *A. lumbricoides* as a single parasite. Infection by *A. duodenale* was diagnosed in 21 specimens (19.6 %), and 18 specimens (16.8 %) were infected by *A. duodenale* as a single parasite. Coinfection by *E. vermicularis* was detected in 17 specimens (15.9 %), and coinfection by *E. histolytica* was detected in 13 specimens (12.2 %). The frequency of infections by *A. duodenale* and *Schistosoma* species was significantly ($P = 0.035$ and 0.031 , respectively) higher among anaemic women than among nonanaemic women, while the frequency of infection by *A. lumbricoides* was not significantly ($P = 0.434$) higher among anaemic women than among nonanaemic women. In contrast, the frequency of infection by *E. vermicularis*, *E. histolytica*, *T. trichiura* and *T. spiralis* was lower among anaemic women, with a significant ($P = 0.011$) difference in the frequency of *E. vermicularis* and an insignificant ($P = 0.202$, 0.366 and 0.161) difference in the frequency of *E. histolytica*, *T. trichiura* and *T. spiralis*, respectively (Table 2).

During pregnancy, 51 women (21.4 %) developed pregnancy-related complications other than GA, with a significantly ($P = 0.0092$) higher incidence of complications among anaemic (31.9 %) than among non-anaemic (16.9 %) women. Thirteen women developed GDM, and 9 women (3.8 %) developed GHTN with insignificant difference between anaemic and non-anaemic women. Miscarriage was encountered in 10 women (4.2 %), 6 anaemic women (8.3 %) and 4 non-anaemic women (2.4 %), with a significantly ($P = 0.036$) higher incidence among anaemic women. Similarly, the incidence of SGA newborns was significantly ($P = 0.016$) greater among anaemic individuals (6.9 %) than

Table 1

Enrolment data of the study participants.

		Non-anaemic (n = 166)	Anaemic (n = 72)	P
Age (years)	Average ($\pm$ SD)	28 ($\pm$ 2.9)	27.5 ($\pm$ 3.1)	0.231
	Age <25	23 (13.9 %)	11 (15.3 %)	0.674
	strata 25–29	99 (59.6 %)	47 (65.3 %)	
	30–34	39 (23.5 %)	13 (18 %)	
	≥ 35	5 (3 %)	1 (1.4 %)	
Body mass index (kg/ m ²)	Average ($\pm$ SD)			0.105
	BMI Average	4 (2.4 %)	5 (6.9 %)	0.071
	strata Overweight Obese	149 (89.8 %) 13 (7.8 %)	57 (79.2 %) 10 (13.9 %)	
Residence	Rustic	80 (48.2 %)	45 (62.5 %)	0.042
	Semi-urban	86 (51.8 %)	27 (37.5 %)	
Education	Illiterate & 1ry school	74 (44.6 %)	43 (59.7 %)	0.032
	2ry school & higher	92 (55.4 %)	29 (40.3 %)	
Work	Housewives	51 (30.7 %)	21 (29.2 %)	0.113
	Farmers	34 (20.5 %)	25 (34.7 %)	
	Workers	45 (27.1 %)	14 (19.4 %)	
	Officers	36 (21.7 %)	12 (16.7 %)	
Income	Low	71 (42.7 %)	44 (61.1 %)	0.033
	Medium	73 (44 %)	21 (29.2 %)	
	High	22 (13.3 %)	7 (9.7 %)	
Gravidity	Primigravida	59 (35.5 %)	15 (20.8 %)	0.024
	Multigravida	107 (64.5 %)	57 (79.2 %)	
Parity	Nullipara	59 (35.5 %)	15 (20.8 %)	0.031
	Primipara	37 (22.3 %)	14 (19.4 %)	
	Multipara	70 (42.2 %)	43 (59.8 %)	
Living offspring	No	59 (35.5 %)	15 (20.8 %)	0.014
	One	45 (27.2 %)	134 (19.4 %)	
	Two	34 (20.5 %)	22 (30.6 %)	
	>two	28 (16.9 %)	21 (29.2 %)	

* P value ≤ 0.05 indicates significance, and $P > 0.05$ indicates non-significance.

among non-anaemic individuals (1.2 %). The incidence of new-borns with IUGR and the incidence of PMROM were not significantly different between anaemic and non-anaemic women (Table 3).

The incidence of pregnancy-related complications was significantly ($P = 0.010$) higher among infected (29 %) than uninfected (15.3 %) women. The incidences of miscarriage and SGA were significantly ($P = 0.022$ and 0.027 , respectively) higher among anaemic women than among non-anaemic women. The incidences of IUGR and PMROM were insignificantly higher among anaemic than non-anaemic women. In contrast, the incidences of GDM and GHTN were insignificantly lower among anaemic than non-anaemic women (Table 3, Fig. 5).

The development of pregnancy-related complications was positively correlated with the extent of decrease in HBC ($r = 0.321$, $P < 0.001$), mixed parasitic infection ($r = 0.300$, $P < 0.001$), low HBC during the 1st trimester ($r = 0.169$, $P = 0.009$) and the presence of parasitic infection ($r = 0.166$, $P = 0.010$). The extent of the decrease in HBC during the 3rd trimester in relation to the HBC estimated during the 1st trimester was positively correlated with the presence of mixed parasitic infection ($r = 0.320$, $P < 0.001$), low HBC estimated during the 1st trimester ($r = 0.209$, $P = 0.001$) and the presence of parasitic infection ($r = 0.177$, $P = 0.006$) (Table 4).

The ROC curve analysis of maternal HBC and parasitic infection parameters revealed that a high percentage of HBC decreased during the 3rd trimester (AUC = 0.683, $P < 0.001$). A mixed parasitic infection (AUC = 0.656, $P = 0.001$), the presence of parasitic infection (AUC = 0.601, $P = 0.028$), and low HBC during the 1st trimester (AUC = 0.594, $P = 0.039$) were predictors of ongoing pregnancy complications (Fig. 6a). Regression analysis excluded low 1st trimester HBC as a predictor for oncoming pregnancy complications and confirmed the predictability of parasitic infection, mixed parasitic infection and a high percentage of HBC decrease during the 3rd trimester (Table 5).

ROC curve analysis revealed the predictive ability of mixed parasitic infection (AUC = 0.787, $P = 0.002$), low 1st trimester HBC (AUC = 0.719, $P = 0.019$) and parasitic infection (AUC = 0.683, $P = 0.048$) for

Table 2

Distribution of the study participants according to the results of parasitological evaluation.

		Total (n = 238)	Non- anaemic (n = 166)	Anaemic (n = 72)	P
Incidence of infection	Infected	107 (45 %)	65 (39.2 %)	42 (58.3 %)	0.0063
	Uninfected	131 (55 %)	101 (60.8 %)	30 (41.7 %)	
Number of parasitic type	Single	61 (57 %)	46 (70.8 %)	15 (35.7 %)	0.0016
	Mixed 2 types	33 (30.8 %)	14 (21.5 %)	19 (45.3 %)	
	>2 types	13 (12.2 %)	5 (7.7 %)	8 (19 %)	
	Type of parasite	Single	Two	>Two	Total
Distribution of the infected women according to type of parasite	<i>A. duodenale</i>	18 (16.8 %)	2 (1.9 %)	1 (0.9 %)	21 (19.6 %)
	<i>A. lumbricoides</i>	27 (25.2 %)	5 (4.7 %)	4 (3.7 %)	36 (33.6 %)
	<i>T. trichiura</i>	4 (3.7 %)	1 (0.9 %)	0	5 (4.7 %)
	<i>E. vermicularis</i>	0	12 (11.2 %)	5 (4.7 %)	17 (15.9 %)
	<i>T. spiralis</i>	5 (4.7 %)	2 (1.9 %)	0	7 (6.5 %)
	<i>E. histolytica</i>	0	10 (9.3 %)	3 (2.8 %)	13 (12.2 %)
Distribution of the infected women of both groups according to type of parasite	Schistosoma species	7 (6.5 %)	1 (0.9 %)	0	8 (7.5 %)
	Women Type of parasite	Total (n = 107)	Non- anaemic (n = 65)	Anaemic (n = 42)	P
	<i>A. duodenale</i>	21 (19.6 %)	8 (12.3 %)	13 (31 %)	0.035
	<i>A. lumbricoides</i>	36 (33.6 %)	20 (30.8 %)	16 (38.1 %)	0.434
	<i>T. trichiura</i>	5 (4.7 %)	4 (6.2 %)	1 (2.4 %)	0.366
	<i>E. vermicularis</i>	17 (15.9 %)	15 (23.1 %)	2 (4.8 %)	0.011
	<i>T. spiralis</i>	7 (6.5 %)	6 (9.2 %)	1 (2.4 %)	0.161
	<i>E. histolytica</i>	13 (12.2 %)	10 (15.4 %)	3 (7.1 %)	0.202
	Schistosoma species	8 (7.5 %)	2 (3.1 %)	6 (14.3 %)	0.031

oncoming pregnancy miscarriage (Fig. 6b). Regression analysis confirmed the ability of the presence of mixed parasitic infection and low 1st trimester HBC to predict oncoming miscarriage but excluded only the presence of parasitic infection.

ROC curve analysis revealed that the presence of mixed parasitic infection (AUC = 0.755, $P = 0.022$) and the extent of decrease in HBC (AUC = 0.719, $P = 0.019$) were predictors of the possibility of having SGA newborns, while other variables were excluded (Fig. 6c). Regression analysis excluded the extent of decrease in HBC and confirmed the ability of the presence of mixed parasitic infection to predict SGA newborns. In the evaluation of the impact of parasitosis on HBC, ROC curve analysis revealed that mixed -parasitosis was a significant predictor (AUC = 0.638, $P = 0.001$) of the extent of decrease in HBC during the 3rd trimester in relation to HBC measured during the 1st trimester

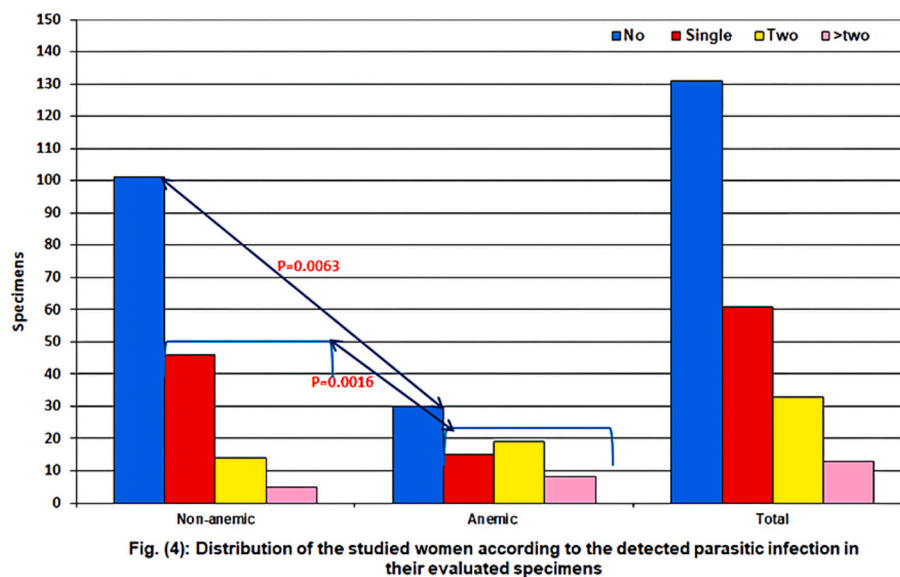


Fig. 4. Distribution of the studied women according to the detected parasitic infection.

Table 3

Distribution of the study participants according to pregnancy-related complications.

		Total (n = 238)	Non-anaemic (n = 166)	Anaemic (n = 72)	P
Incidence of complications	Complicated	51 (21.4 %)	28 (16.9 %)	23 (31.9 %)	0.0092
	Uncomplicated	187 (78.6 %)	138 (83.1 %)	49 (68.1 %)	
Distribution of complication among anaemic and Non-anaemic women	GDM	13 (5.5 %)	10 (6 %)	3 (4.2 %)	0.562
	PE	9 (3.8 %)	5 (3 %)	4 (5.6 %)	0.345
	Miscarriage	10 (4.2 %)	4 (2.4 %)	6 (8.3 %)	0.036
	Small-for-GA	7 (2.9 %)	2 (1.2 %)	5 (6.9 %)	0.016
	IUGR	7 (2.9 %)	3 (1.8 %)	4 (5.6 %)	0.116
	PMROM	5 (2.1 %)	4 (2.4 %)	1 (1.4 %)	0.605
	Total (n = 238)		Uninfected (n = 131)	Infected (n = 107)	P
Incidence of complications	Complicated	51 (21.4 %)	20 (15.3 %)	31 (29 %)	0.010
Distribution of complication among infected and Uninfected women	Uncomplicated	187 (78.6 %)	111 (84.7 %)	76 (71 %)	
	GDM	13 (5.5 %)	9 (6.9 %)	4 (3.7 %)	0.290
	PE	9 (3.8 %)	5 (3.8 %)	4 (3.7 %)	0.975
	Miscarriage	10 (4.2 %)	2 (1.5 %)	8 (7.5 %)	0.022
	Small-for-GA	7 (2.9 %)	1 (0.8 %)	6 (5.6 %)	0.027
	IUGR	7 (2.9 %)	2 (1.5 %)	5 (3.8 %)	0.153
	PMROM	5 (2.1 %)	1 (0.8 %)	4 (3.7 %)	0.111

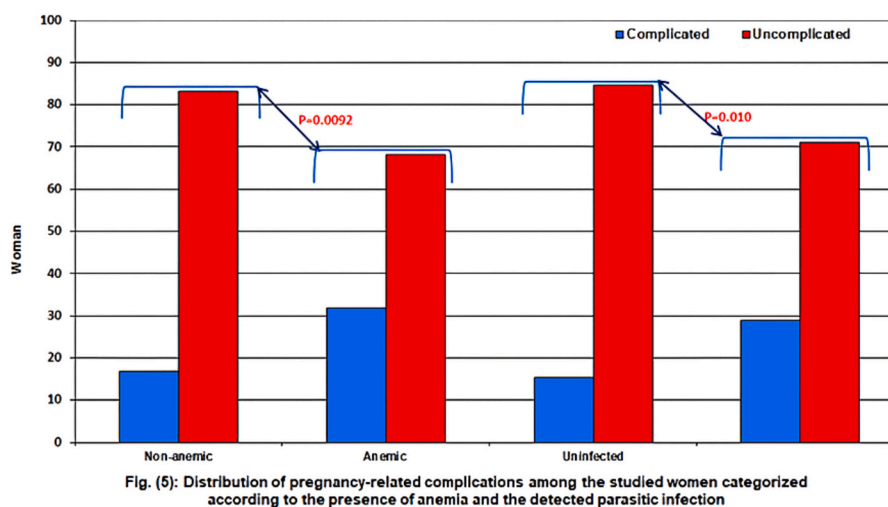


Fig. 5. Distribution of pregnancy-related complications among the studied women.

Table 4
Correlation analysis of HBC and parasitic infection data and pregnancy-related complication development.

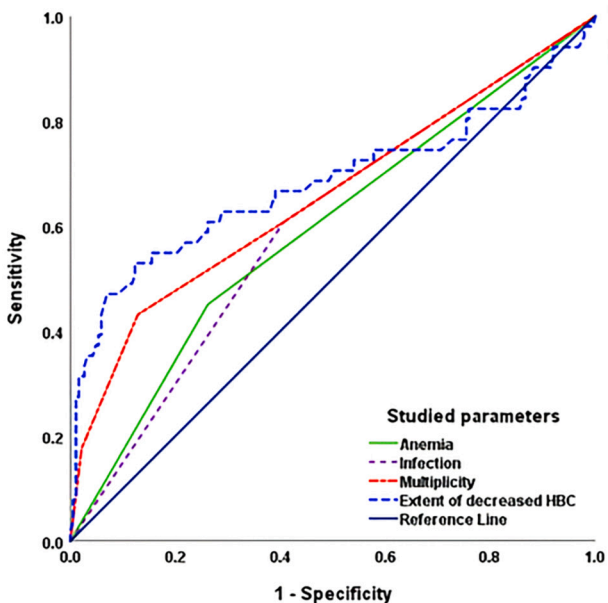
	Pregnancy complications		The extent of decreased HBC	
	Pearson's coefficient	P	Pearson's coefficient	P
Low HBC during 1st trimester	0.169	0.009	0.209	0.001
Parasitic infection	0.166	0.010	0.177	0.006
Mixed parasitic infection	0.300	<0.001	0.320	<0.001
Extent of decreased HBC	0.321	<0.001	–	–

(Table 5, Fig. 6d).

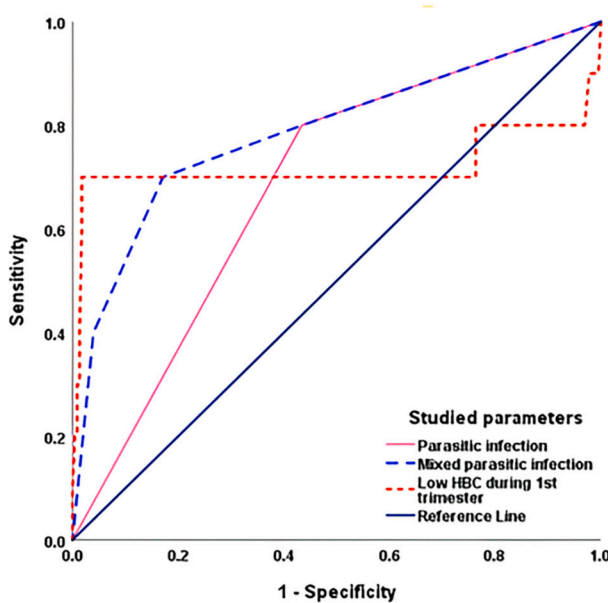
4. Discussion

The results of the current study illustrated the impacts of gestational IPIs on maternal and foetal outcomes, mainly through the induction of malnutrition and/or blood loss with the development of anaemia, IDA, and macrocytic anaemia due to a deficiency of folic acid and/or cyanocobalamine. In support of this assumption, the frequency of IPIs was significantly ($P = 0.0063$) higher among anaemic (58.3 %) than among non-anaemic (39.2 %) women, and the frequency of women who had parasitic mixed infections were significantly ($P = 0.0016$) greater among anaemic than non-anaemic women (64.3 % vs. 29.2 %).

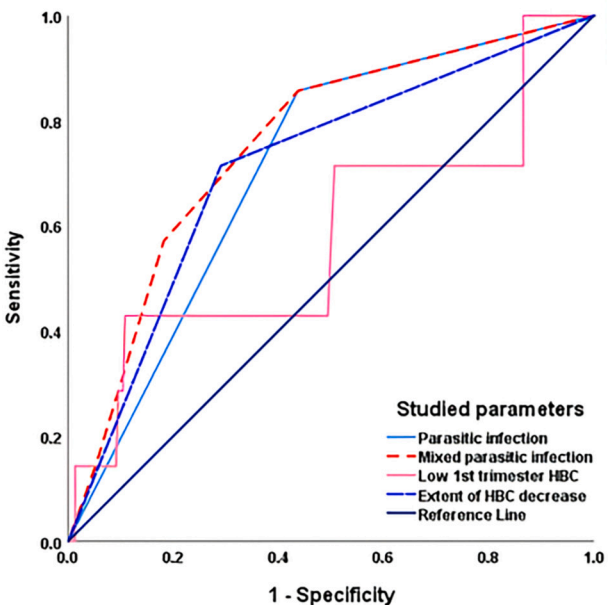
The most frequently detected parasites were *A. lumbricoides* and



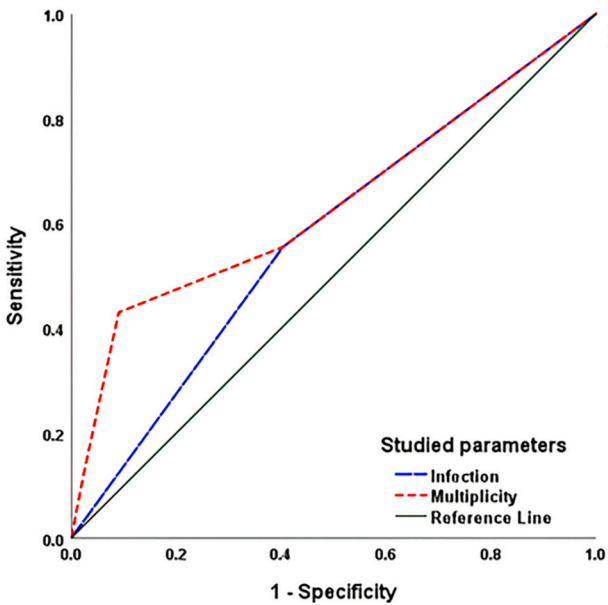
(a)



(b)



(c)



(d)

Fig. 6. ROC curve for analysis of maternal HBC and parasitic infection data.

Table 5
Statistical analyses of HBC, parasitic infection, and pregnancy-related complication data.

Point of evaluation	Analysis procedure	Receiver Operating curve (ROC)				Regression	
	Parameters	AUC	Std.	P	95 % CI	β	P
Development of pregnancy-related Complication	Parasitic infection	0.601	0.045	0.028	0.513–0.688	0.139	0.032
	Mixed parasitic infection	0.656	0.048	0.001	0.563–0.750	0.251	<0.001
	Low 1st trimester HBC	0.594	0.046	0.039	0.504–0.685	0.057	0.379
	Extent of HBC decrease	0.683	0.051	<0.001	0.583–0.784	0.219	0.001
Development of miscarriage	Parasitic infection	0.683	0.079	0.048	0.529–0.837	0.1.27	0.056
	Mixed parasitic infection	0.787	0.088	0.002	0.614–0.960	0.565	<0.001
	Low 1st trimester HBC	0.719	0.132	0.019	0.461–0.978	0.336	0.005
Development of small-for-age newborn	Parasitic infection	0.710	0.085	0.059	0.543–0.877	0.002	0.970
	Mixed parasitic infection	0.755	0.089	0.022	0.581–0.929	0.168	0.009
	Low 1st trimester HBC	0.579	0.127	0.474	0.330–0.829	0.012	0.851
	Extent of HBC decrease	0.722	0.100	0.042	0.516–0.909	0.112	0.085
Extent of decreased HBC	Parasitic infection	0.576	0.040	0.063	0.497–0.655	–	–
	Mixed parasitic infection	0.638	0.043	0.001	0.555–0.722	–	–

A. duodenale, which were detected in 33.6 % and 19.6 %, respectively, of the studied pregnant women and 38.1 % and 31 % of anaemic women with pregnancy complications. Moreover, the extent of the decrease in HBC during pregnancy was positively correlated with both parasitic infection per se and parasitic coinfection. Statistical analyses revealed that the presence of parasitic coinfection was the most significant predictor of the extent of the decrease in HBC, which is a highly significant predictor of ongoing pregnancy complications.

Similarly, Demeke et al. [16] reported that IPIs during pregnancy adversely impact the haematological profiles of pregnant women and are an independent predictor of anaemia. Additionally, Brummaier et al. [17] surveyed 12,742 pregnant women for IPIs and reported the following findings: 21.2 % of surveyed women had confirmed infection with *A. lumbricoides*, hookworm, and *T. trichiura* alone or in combination. *A. lumbricoides* and hookworm infection were associated with maternal anaemia at the first antenatal care visit, and maternal anaemia, especially in late pregnancy, was related to soil-transmitted helminth (STH) infection. Recently, Alvarado-Gonzalez et al. [18] out of a systematic review, reported an average prevalence of GA of 40 %, and they reported that hookworm and *A. lumbricoides* were the predominant species detected, with a prevalence of 50 % and 39.5 %, respectively, and that GA was positively associated with infection by *A. lumbricoides* and hookworms. Additionally, Assefa et al. [19] detected an overall prevalence of STHs of 36.5 % and reported that hookworm species and *A. lumbricoides* were the most common STHs, with double the percentage of infections.

Using an ELISA for *Schistosoma* (*S.*) *haematobium*, IgM infection was detected in eight samples (3.3 %) and was more prevalent among anaemic women. In line with this finding, a systematic review revealed a 13.2 % prevalence of schistosomiasis during pregnancy, with a significantly higher prevalence of *S. haematobium* than *S. mansoni*, and 6 studies reported that schistosomiasis was associated with GA [20]. Additionally, Murenjekwa et al. [21] detected urogenital schistosomiasis in 26.8 % of pregnant women, and Wachamo et al. [22] reported that approximately 50 % of pregnant women were infected with intestinal parasites; the most frequently identified parasites were *A. lumbricoides* (27.9 %) and *Schistosma* species (13.7 %), but *T. trichiura*, hookworms, and *Taenia* species were detected with lower prevalence, at 5.1 %, 4.8 %, and 1.4 %, respectively. Jeza et al. [23] detected 3.8 % and 5.6 % overall prevalence of *S. haematobium* and STHs, respectively, among women of reproductive age. Hookworms were the most prevalent STHs, and coinfection with *S. haematobium* and STHs was common, especially in pregnant women.

Pregnancy per se has deleterious impacts on maternal stores, leading to the deterioration of maternal HBC even in non-anaemic pregnant women, and this was illustrated in the current study by the increased frequency of anaemia from 30.25 % to 50.84 % from the 1st to the 3rd trimester, with significantly ($P < 0.001$) lower HBC in samples obtained

during the 3rd trimester (10.9 vs. 11.7 g/dl) and an extent of decrease of 7.07 %. In line with the high prevalence of GA, Turawa et al. [24] detected an increased prevalence of GA among pregnant women in South Africa, ranging between 29 % and 42.7 %. In Nepal, Paudyal et al. [25] reported that the prevalence of GA was 46 %, despite a 12-fold increase in the proportion of women who consumed iron and folic acid supplements for 3 months during pregnancy. Additionally, Abbas et al. [26] and Copaja-Corzo et al. [27] reported a GA prevalence of 37 % in Sudan and 33 % in Peuro, respectively. The reported progressive increase in the incidence of IDA and vitamin B12 deficiency anaemia between the 1st and 3rd trimesters is consistent with the findings of Amarasinghe et al. [28], who detected a prevalence of iron and B12 deficiency in 41.9 % and 23.8 % of anaemic pregnant women.

The studied anaemic women were found to be from rural areas, of low educational grade and monthly income, and had large families, with significant differences compared with non-anaemic women. This may reflect the impact of living conditions, behavioural eating habits, type of water supply, and level of sanitation on the risk of malnutrition leading to anaemia. Additionally, parasitic infections, which showed a higher prevalence among anaemic women, increase the incidence and severity of malnutrition and anaemia. Women diagnosed with anaemia or intestinal parasitic infections during the study were referred to local healthcare services and received appropriate medical treatment and nutritional guidance in accordance with ethical protocols. Similarly, Wachamo et al. [22] reported that intestinal parasitosis was more prevalent among women with low educational levels, a low monthly income, who used lake water for washing clothes, and who had poor dietary habits, especially when eating raw vegetables. Additionally, Murenjekwa et al. [21], reported that the risk factors significantly associated with schistosomiasis were maternal age, education, marital status, household drinking water sources, and the presence of latrine. Furthermore, Nyarko et al. [29], performed an analysis of the most recent demographic and health surveys of 26 countries in Sub-Saharan Africa and reported that anaemia is prevalent among ~50 % of pregnant women in both urban and rural areas, but rural women are more likely to have anaemia and mostly receive antiparasitic therapy for intestinal parasitosis during pregnancy. In support of the relationship between living conditions and the development of GA, Inal & Inal [30], detected a significantly higher rate of GA among Syrian refugees than among Turkish women, and Assefa et al. [19], reported that a large family size and lack of latrine facilities were significantly associated with STH infections.

These socioeconomic and environmental factors demonstrate significant regional variations that influence our findings. For instance, Silver et al. [31] documented significant geographical differences in helminth infections based on community settings in South Asia and Southeast Asia, with tribal communities showing higher prevalence of *Ascaris* (32 %) and *Trichuris* (38 %) compared to rural communities (14

% and 13 % respectively), while urban communities had much lower rates of hookworm (3 % versus 19 % in rural areas). Our observed prevalence of *A. lumbricoides* (33.6 %) and hookworm infection (19.6 %) aligns closely with the patterns seen in rural and tribal communities in the Silver et al. study, suggesting similar environmental risk factors in our study population. Brooker et al. [32] demonstrated a strong correlation between access to clean water and the prevalence of *A. lumbricoides*, with infection rates decreasing by approximately 30 % in communities with improved water infrastructure.

During pregnancy, 51 (21.4 %) women developed gestational complications other than anaemia, with a significantly higher incidence among anaemic and infected women ($P = 0.0092$ and 0.010 , respectively). In line with the impact of anaemia on pregnancy outcomes, Johnson et al. [33], detected a higher incidence of preeclampsia, maternal complications, preterm labour, low birth-weight babies, and a higher number of new-borns admitted to the Neonatal Intensive Care Unit among hypertensive anaemic pregnant women than among hypertensive non-anaemic pregnant women. Additionally, Ma et al. [34], reported a significantly greater frequency of neonatal complications among women with aplastic anaemia than among non-anaemic pregnant women.

In line with the detected impact of intestinal parasitosis on pregnancy outcomes, Abioye et al. [35], documented that hookworms induce pregnancy complications through the induction of a deregulated intrauterine immune milieu where hookworm infection was found to be associated with elevated placental interleukin (IL)-1, CXCL8 and interferon- γ , with a positive correlation between the risk of small-for-gestational age and cord blood levels of IL-6, IL-10, and CXCL8, while the risk of prematurity parallels cord blood levels of the soluble form of tumor necrosis factor receptor-I and placental levels of IL-5. Also, Boltena et al. [9], reported that coinfection of pregnant women with malaria and intestinal helminths decreased HBC, leading to maternal anaemia, preterm delivery, and still-birth, and that hookworm, *A. lumbricoides*, and *T. trichiura* were the most commonly detected intestinal helminthic parasites.

5. Conclusion

This study highlights the significant relationship between gestational intestinal parasitic infection (IPI) and anaemia, as well as its adverse effects on pregnancy outcomes. The results suggest that IPI is a major risk factor for the development of severe anaemia in the third trimester, which increases the risk of miscarriage and small-for-gestational-age newborns. Moreover, this study demonstrated that parasitic coinfection is a strong predictor of the extent of the decrease in haemoglobin and the likelihood of pregnancy complications.

The findings of this study have important implications for healthcare providers. Gestational IPI is a common and often underdiagnosed condition that can have significant consequences for maternal and foetal health. Early detection and treatment of IPIs can help prevent or reduce the severity of anaemia, miscarriage, and other pregnancy complications.

Public health efforts to reduce intestinal parasitic infections in pregnant women should focus on key actions. First, routine parasite screening during prenatal check-ups, particularly in rural areas, can help detect infections early. Second, community education programs should teach proper hygiene, safe food handling, and the dangers of eating soil. Ensuring access to clean drinking water and better sanitation systems is crucial to prevent transmission. Including deworming treatments and nutritional support in maternal care programs can help prevent anaemia and related complications. These combined measures could effectively reduce the burden of intestinal parasites among pregnant women in Egypt.

Financial interests

The authors have no relevant financial or non-financial interests to disclose.

CRediT authorship contribution statement

Heba M. Aboelela: Project administration, Conceptualization, Methodology. **Waleed M. Tawfik:** Methodology, Resources, Investigation. **Ghada M. Mahmoud:** Validation, Formal analysis, Investigation. **Ayman T. Morsy:** Resources, Visualization, Investigation. **Ahmed F. Sherif:** Resources, Formal analysis, Methodology. **Asmaa M. Ammar:** Writing – review & editing, Conceptualization, Methodology, Writing – original draft.

Consent for publication

Not applicable.

Ethics approval and consent to participate

The study was performed following the recommendations of the Ethics Committee of Benha University (Approval Code: RC-3-3-2024). Written informed consent was obtained from all participants after the purpose of the research was explained orally by the researcher. Participants who were found to have anaemia and/or intestinal parasites were linked with clinicians at the health centers and received treatment under the supervision of a local nurse. The participants were informed about their right to withdraw from the study.

Funding

The authors declare that there was no funding source for this research.

Declaration of competing interest

The authors declare no competing interests.

Acknowledgments

Not applicable.

Data availability

All the data obtained are presented and attached to the manuscript.

References

- [1] A. Vasconcelos, S. Sousa, N. Bandeira, M. Alves, A.L. Papoila, F. Pereira, M. C. Machado, Intestinal parasitic infections, treatment and associated factors among pregnant women in Sao Tome and Principe: a cross-sectional study, *J. Trop. Med.* 2022 (1) (2022) 7492020.
- [2] WHO, Soil-transmitted helminth infections, 2022 [cited 2023 Dec 15]. Available from: <https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections>.
- [3] S. Mohan, G. Halle-Ekane, J.C. Konje, Intestinal parasitic infections in pregnancy—a review, *Eur. J. Obstet. Gynecol. Reprod. Biol.* 254 (2020) 59–63.
- [4] E.S. El-Wakil, R.S. Zalat, A.A. El-Badry, Mapping gut parasitism patterns in a cohort of Egyptians, *Sci. Rep.* 13 (1) (2023) 9961.
- [5] I.M. Bakr, N.A. Arafa, M.A. Ahmed, M.K. Mohamed, Prevalence of intestinal parasitosis in a rural population in Egypt, and its relation to socio-demographic characteristics, *J. Egypt. Soc. Parasitol.* 39 (1) (2009) 371–381.
- [6] P.K. Edelson, D. Cao, K. James, J. Ngongzi, D. Roberts, L. Bebell, A. Boatin, Maternal anemia is associated with adverse maternal and neonatal outcomes in Mbarara, Uganda, *J. Matern. Fetal Neonatal Med.* 36 (1) (2023) 2190834, <https://doi.org/10.1080/14767058.2023.2190834>.
- [7] S. Nadhiroh, F. Micheala, S. Tung, C. Kustiawan, Association between maternal anemia and stunting in infants and children aged 0-60 months: a systematic literature review, *Nutrition* 115 (2023) 112094, <https://doi.org/10.1016/j.nut.2023.112094>.

- [8] J.H. Ellwanger, M. Ziliotto, B. Kulmann-Leal, J.A. Chies, Iron deficiency and soil-transmitted helminth infection: classic and neglected connections, *Parasitol. Res.* 121 (12) (2022) 3381–3392.
- [9] M. Boltena, Z. El-Khatib, A. Kebede, B. Asamoah, A. Boltena, M. Yesambaw, M. Biru, Comorbidity of geo-Helminthes among malaria outpatients of the health facilities in Ethiopia: systematic review and meta-analysis, *Int. J. Environ. Res. Public Health* 18 (3) (2021) 862, <https://doi.org/10.3390/ijerph18030862>.
- [10] D.M. Melvin, Laboratory procedures for the diagnosis of intestinal parasites, US Department of Health and Human Services, Public Health Service, Centers for Disease Control (CDC), Laboratory Improvement Program Office, Laboratory Training and Consultation Division, 1982.
- [11] International committee for standardization in Hematology, Recommendations for hemoglobinometry in human blood, *Br. J. Hematol.* 13 (Suppl.1) (1967) 71.
- [12] J. Ford, Red blood cell morphology, *Int. J. Lab. Hematol.* 35 (3) (2013) 351–357.
- [13] O. Api, C. Breyman, M. Çetiner, C. Demir, T. Eder, Diagnosis and treatment of iron deficiency anemia during pregnancy and the postpartum period: Iron deficiency anemia working group consensus report, *Turk. J. Obstet. Gynecol.* 12 (3) (2015) 173–181.
- [14] M.D. Lindheimer, S.J. Taler, F.G. Cunningham, American Society of Hypertension: ASH position paper: hypertension in pregnancy, *J. Clin. Hypertens. (Greenwich)* 11 (4) (2009) 214–225.
- [15] B.E. Metzger, S.G. Gabbe, B. Persson, L.P. Lowe, A.R. Dyer, J.J. Oats, T. A. Buchanan, International association of diabetes and pregnancy study groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy: response to Weinert, *Diabetes Care* 33 (7) (2010) e98.
- [16] G. Demeke, G. Mengistu, A. Abebaw, M. Toru, M. Yigzaw, A. Shiferaw, H. Mengist, T. Dilnessa, Effects of intestinal parasite infection on hematological profiles of pregnant women attending antenatal care at Debre Markos referral hospital, Northwest Ethiopia: institution based prospective cohort study, *PLoS One* 16 (5) (2021) e0250990, <https://doi.org/10.1371/journal.pone.0250990>.
- [17] T. Brummaier, N. Tun, A. Min, M. Gilder, L. Archasuksan, S. Proux, D. Kiestra, P. Charunwatthana, J. Utzinger, D. Paris, M. Nacher, J. Simpson, F. Nosten, R. McGready, Burden of soil-transmitted helminth infection in pregnant refugees and migrants on the Thailand-Myanmar border: results from a retrospective cohort, *PLoS Negl. Trop. Dis.* 15 (3) (2021) e0009219, <https://doi.org/10.1371/journal.pntd.0009219>.
- [18] J.C. Alvarado-Gonzalez, N. Alvis-Zakzuk, D. Castillo-Saavedra, I. Lozada-Martinez, A. Picón-Jaimes, A. Narvaez-Rojas, J. Zakzuk, Impact of helminthiasis on gestational anemia in low- and middle-income countries: a systematic review and meta-analysis of more than 19,000 women, *Infez. Med.* 31 (1) (2023) 36–48, <https://doi.org/10.53854/liim-3101-6>.
- [19] G. Assefa, M. Alemu, A. Ayehu, High prevalence of hookworm species and associated factors among soil-transmitted helminth-infected household contacts in Burie Zuria District, Northwest Ethiopia: a community-based cross-sectional study, *Biomed. Res. Int.* 2023 (1) (2023) 6553913.
- [20] I. Adam, ALhabardi N, Al-Wutayd O, Khamis a: prevalence of schistosomiasis and its association with anemia among pregnant women: a systematic review and meta-analysis, *Parasit. Vectors* 14 (1) (2021) 133, <https://doi.org/10.1186/s13071-021-04642-4>.
- [21] W. Murenjekwa, R. Makasi, R. Ntozini, B. Chasekwa, K. Mutasa, L. Moulton, J. Tielsch, J. Humphrey, L. Smith, A. Prendergast, C. Bourke, Determinants of urogenital schistosomiasis among pregnant women and its association with pregnancy outcomes, neonatal deaths, and child growth, *J. Infect. Dis.* 223 (8) (2021) 1433–1444, <https://doi.org/10.1093/infdis/jiz664>.
- [22] D. Wachamo, F. Bonja, B. Tadege, S. Hussien, Magnitude of parasitic infections and associated factors among pregnant women at health facilities in Hawassa, southern Ethiopia, *F1000Res* 10 (2021) 122, <https://doi.org/10.12688/f1000research.27584.1>.
- [23] V. Jeza, F. Mutuku, L. Kaduka, C. Mwandawiro, J. Masaku, C. Okoyo, H. Kanyi, J. Kamau, Z. Ng'ang'a, J. Kihara, Schistosomiasis, soil transmitted helminthiasis, and malaria co-infections among women of reproductive age in rural communities of Kwale County, coastal Kenya, *BMC Public Health* 22 (1) (2022) 136, <https://doi.org/10.1186/s12889-022-12526-0>.
- [24] E. Turawa, O. Awotiwo, M. Dhansay, A. Cois, D. Labadarios, D. Bradshaw, V. Wyk, Prevalence of anaemia, Iron deficiency, and Iron deficiency anaemia in women of reproductive age and children under 5 years of age in South Africa (1997–2021): a systematic review, *Int. J. Environ. Res. Public Health* 18 (23) (2021) 12799, <https://doi.org/10.3390/ijerph182312799>.
- [25] N. Paudyal, K. Parajuli, V. Larsen, R. Adhikari, M. Devkota, S. Rijal, S. Chitekwe, Torlesse H: a review of the maternal iron and folic acid supplementation programme in Nepal: achievements and challenges, *Matern. Child Nutr.* 18 (Suppl. 1) (2022) e13173, <https://doi.org/10.1111/mcn.13173>.
- [26] W. Abbas, A. Elmugabil, H. Hamdan, D. Rayis, I. Adam, Iron deficiency and thyroid dysfunction among sudanese women in first trimester of pregnancy: a cross-sectional study, *BMC Endocr. Disord.* 23 (1) (2023) 223, <https://doi.org/10.1186/s12902-023-01487-z>.
- [27] C. Copaja-Corzo, S. Gomez-Colque, J. Vilchez-Cornejo, M. Hueda-Zavaleta, A. Taype-Rondan, Fetal death and its association with indicators of social inequality: 20-year analysis in Tacna, Peru, *PLoS One* 18 (10) (2023) e0292183, <https://doi.org/10.1371/journal.pone.0292183>.
- [28] G.S. Amarasinghe, T. Agampodi, V. Mendis, K. Malawanage, C. Kappagoda, S. Agampodi, Prevalence and aetiologies of anaemia among first trimester pregnant women in Sri Lanka; the need for revisiting the current control strategies, *BMC Pregnancy Childbirth* 22 (1) (2022) 16, <https://doi.org/10.1186/s12884-021-04341-z>.
- [29] S.H. Nyarko, E. Boateng, K. Dickson, D. Adzrago, I. Addo, E. Acquah, C. Ayebeng, Geospatial disparities and predictors of anaemia among pregnant women in sub-Saharan Africa, *BMC Pregnancy Childbirth* 23 (1) (2023) 743, <https://doi.org/10.1186/s12884-023-06008-3>.
- [30] H. Inal, Z. Inal, Comparison of perinatal outcomes between Syrian refugees and Turkish women in the middle Anatolia region of Turkey, *Matern. Child Health J.* 27 (12) (2023) 2139–2146, <https://doi.org/10.1007/s10995-023-03748-8>.
- [31] Z.A. Silver, S.P. Kaliappan, P. Samuel, S. Venugopal, G. Kang, R. Sarkar, S.S. R. Ajampur, Geographical distribution of soil transmitted helminths and the effects of community type in South Asia and South East Asia – a systematic review, *PLoS Negl. Trop. Dis.* 12 (1) (2018).
- [32] S.J. Brooker, B. Nikolay, D. Balabanova, R.L. Pullan, Global feasibility assessment of interrupting the transmission of soil-transmitted helminths: a statistical modelling study, *Lancet Infect. Dis.* 15 (8) (2015) 941–950.
- [33] A. Johnson, S. Vaithilingan, S. Avudaiappan, The interplay of hypertension and Anemia on pregnancy outcomes, *Cureus* 15 (10) (2023) e46390, <https://doi.org/10.7759/cureus.46390>.
- [34] J. Ma, F. Luo, L. Yan, Neonatal outcomes and related risk factors of 30 cases with aplastic anemia in pregnancy: a retrospective study, *Early Hum. Dev.* 185 (2023) 105855, <https://doi.org/10.1016/j.earlhumdev.2023.105855>.
- [35] A.I. Abioye, E. McDonald, S. Park, A. Joshi, J. Kurtis, H. Wu, S. Pond-Tor, S. Sharma, J. Ernerudh, P. Baltazar, L. Acosta, R. Olveda, V. Tallo, J. Friedman, Maternal, placental and cord blood cytokines and the risk of adverse birth outcomes among pregnant women infected with *Schistosoma japonicum* in the Philippines, *PLoS Negl. Trop. Dis.* 13 (6) (2019) e0007371, <https://doi.org/10.1371/journal.pntd.0007371>.