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# Biochemical, coagulation, and platelet count profiles among *Schistosoma mansoni* infected patients attending at selected Dembiya health institutions, Northwest Ethiopia

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## Abstract

**Background** Schistosomiasis is a parasitic disease that causes coagulation disorders and biochemical abnormalities. This is due to liver failure, platelet destruction, disruption of blood flow, and endothelial function by the schistosomes. However, there is no adequate data on biochemical and coagulation profiles and platelet count of patients infected with *Schistosoma mansoni* in Dembiya Selected Health Institutions. Hence, the aim of this study was to assess the effect of *Schistosoma mansoni* infection on selected biochemical and coagulation profiles and platelet count.

**Method** An institutional-based comparative cross-sectional study was conducted from March to August 2022 at Dembiya Primary Hospital, Chuahit Health Center, and Abrija Health Center, Northwest Ethiopia. A total of 70 individuals were enrolled in the study using convenient sampling techniques. A stool sample was collected for *Schistosoma mansoni* detection. Likewise, a blood sample was collected for biochemical and coagulation profiles and platelet count analysis. The data were analyzed using SPSS version 25. A p-value less than 0.05 was considered statistically significant.

**Results** Median values for alanine aminotransferase, aspartate aminotransferase, creatinine, total bilirubin, and direct bilirubin values were significantly higher, while total protein and glucose were significantly lower in *Schistosoma mansoni* infected than in the healthy control participants ($P < 0.05$). Prothrombin time, activated partial thromboplastin time, and international normalization ratio were significantly higher, while the platelet count was significantly lower in the *Schistosoma mansoni* infected than healthy control participants ($P < 0.05$). The values of alanine aminotransferase, aspartate aminotransferase, creatinine, total bilirubin, direct bilirubin, prothrombin time, activated partial thromboplastin time, and international normalization ratio were significantly higher, while total protein, glucose, and platelet count were significantly lower in those with moderate and heavy *Schistosoma mansoni* infection intensity compared to healthy control participants ($P < 0.05$). The number of *Schistosoma mansoni* eggs per

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gram of stool had a positive correlation with biochemical and coagulation profiles, except for total protein, glucose, and platelet count, which were correlated negatively in *Schistosoma mansoni* infected participants ($P < 0.05$).

**Conclusion** Biochemical and coagulation profiles, including alanine aminotransferase, aspartate aminotransferase, creatinine, total bilirubin, direct bilirubin, glucose, total protein, prothrombin time, activated partial thromboplastin time, international normalization ratio, and platelet count, were significantly altered in *S. mansoni* infected participants compared to controls ($p < 0.05$). These findings underscore the need for routine biochemical and coagulation monitoring in endemic areas.

**Keywords** Biochemical profile, Coagulation profile, *Schistosoma mansoni*, Dembiya, Ethiopia

## Introduction

Schistosomiasis is a parasitic disease caused by the genus *Schistosoma* of blood dwelling trematodes. *Schistosoma mansoni*, *Schistosoma haematobium*, and *Schistosoma japonicum* are the species that infect humans [1]. The species of *Schistosoma* and severity of *Schistosoma* infection influence the clinical presentation and pathology of schistosomiasis [2].The mesenteric plexus is a habitat for *S. mansoni*, which causes intestinal or hepatosplenic schistosomiasis that affects the gut, liver, and spleen [3]. Based on a global burden of disease study, schistosomes infect 252 million people, 90% of whom reside in sub-Saharan Africa, and are estimated to have cost the world 3.3 million disability-adjusted life years [4]. Moreover, according to the World Health Organization, 258 million people globally require schistosomiasis preventive treatment on a frequent and regular basis [5]. Schistosomiasis is a severe public health problem in sub-Saharan African countries, with 120 million people infected and more than 130,000 deaths annually due to nonfunctioning kidney hematemesis from *S. mansoni*, respectively [6, 7].

*Schistosoma mansoni* pathogenesis is mainly associated with the host's immune responses to *Schistosoma* egg antigens [8]. Also, *S. mansoni* infection involves adult male and female worms residing and mating in the veins of their mammal host, producing around 300 eggs daily. Some eggs stay permanently lodged in the host's liver tissue, causing granulomatous lesions, inflammation, immunological reactions, and liver fibrosis [3]. In addition, *Schistosoma* hepatopathy is the most well-known form of chronic disease and is usually caused by heavy *S. mansoni* infections [9].

Moreover, these egg induced granulomas causes liver failure, which leads to protein synthesis impairment and an increment of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) levels [10, 11]. In addition, several factors might influence both the clinical manifestations and severity of schistosomiasis disease in an exposed individual, among them the degree and length of exposure, the intensity of the infection, superimposed infections, nutritional status, parasite strain, and genetic predisposition [12, 13]. As a result, schistosomiasis causes stunted growth, cognitive impairment, anemia, impaired aerobic capacity, and death [3].

*Schistosoma mansoni* also has an impact on hematological profiles, either directly through the gut or indirectly by aggravating blood loss through feces by rupturing blood vessels with the help of the egg spine [14]. The existence of thrombocytopenia in schistosomiasis patients may be due to the association of *S. mansoni* infection with splenomegaly, which enhances platelet destruction and filtering by the spleen [15]. Moreover, schistosomiasis causes coagulation disorders due to decreased hepatic synthesis of coagulation proteins, as well as decreased clearance of activated forms associated with the consumption of coagulation factors [16]. The adult and egg stages of schistosomes disrupt blood flow and endothelial function, which results in hypercoagulability. Patients with schistosomiasis have elevated levels of coagulation activation markers, prolonged prothrombin time (PT), activated partial thromboplastin time (APTT), thrombin time, and extensive fibrin deposition over hepatic egg granulomas due to activation of the coagulation system and thrombin generation [17, 18]. Several factors contribute to the loss of coagulation proteins, such as the consumption of coagulation factors and impairment of liver function due to schistosomiasis [19].

Also, schistosomiasis causes chronic hepatitis, portal hypertension, bleeding esophageal varices, anemia, and liver failure due to egg granuloma formation [20, 21]. Gastro esophageal varices are a complication of portal hypertension, and bleeding from varices can lead to death and morbidity, which may occur due to schistosomiasis [22]. Schistosomiasis infection causes the incidence of different problems; however, studies on the impact of schistosomiasis infection on biochemical and coagulation profiles and platelet count are still limited. Several factors impact the assessment of *S. mansoni* infection's effects on biochemical and coagulation profiles, some of which may have been involved in previous studies. Other infections, comorbidities, and environmental factors can all interfere with *S. mansoni's* unique effects. Methodological variability, such as variations in laboratory procedures and diagnostic criteria, adds to inconsistency in results. The timing of blood sample collection is crucial

because changes between acute and chronic infection stages might produce different biochemical and coagulation profile outcomes. Finally, not all key biochemical and coagulation profiles were assessed in earlier research, resulting in inadequate profiles that hampered comprehensive evaluation. Many studies have focused primarily on symptomatic populations, often neglecting asymptomatic individuals who may also exhibit biochemical and coagulation profile alterations, thereby limiting the understanding of the full spectrum of infection effects. Furthermore, the majority of research tends to concentrate on specific geographic regions, potentially overlooking variations in disease manifestation related to genetic, environmental, or lifestyle factors in diverse populations. Some biochemical and coagulation profiles may have been overlooked in *S. mansoni* infected patients due to a focus on the infection's more visible clinical symptoms, such as gastrointestinal distress and liver dysfunction, rather than the underlying biochemical and coagulation profile changes. Furthermore, limited research resources and funding frequently shifted attention to more widespread health issues, whereas the complexities of biochemical and coagulation profile assessments necessitate specialized laboratory facilities that may not be available in endemic regions. Variability in patient demographics and coexisting health issues can also complicate data interpretation; therefore, researchers avoid doing these assessments without strong controls. Furthermore, previous shortcomings in understanding the systemic effects of schistosomiasis have led to this absence, despite new research trends addressing these crucial biochemical and coagulation profiles.

Understanding the effects of *S. mansoni* infection on biochemical, coagulation, and platelet count profiles is essential for designing successful treatment methods and minimizing infection consequences. This information can be used to guide interventions aimed at preventing liver damage, bleeding, and other medical conditions.

In general, this comparative cross-sectional study makes it possible to compare groups directly in order to find differences or similarities. This can be extremely helpful in determining the extent and influence of the *S. mansoni* infection problem on the profiles of biochemical, coagulation, and platelet count. Therefore, the current study assessed the effect of *S. mansoni* infection on biochemical and coagulation profiles and platelet count.

## Method and material

### Study design, area, and period

An institution based comparative cross-sectional study was conducted from March 15 to July 27/2022 at Dembiya Primary Hospital, Chuahit Health Center, and Abrija Health Center, which are located within the Central Gondar Administrative Zone, Amhara Regional State. Dembiya Primary Hospital, Chuahit Health Center, and Abrija Health Center are found in Dembiya district. Dembiya district is located in Northwest Ethiopia, 35 km (Km) from Gondar, the town of Central Gondar Administrative Zone, 183 Km from Bahir Dar, the capital of Amhara Region State, and 762 Km from Addis Ababa, the capital city of Ethiopia, between 12° 39′ N and 37° 09′ E. The southern part of the district is bordered by Lake Tana. Dembiya district has 326,686 people, of whom 162,477 were men and 164,209 were women in 2017 [23]. It is located at an altitude of between 1500 and 2600 m above sea level. Its average annual rainfall and average temperature range from 995 to 1175 mm and 21.5 °C, respectively. There is one governmental primary hospital, ten health centers, nine private clinics, and 49 health posts providing health care services for Dembiya and its surrounding people. As reported by the District Health Bureau, *S. mansoni* is common in the study area.

### Eligibility criteria

#### *Inclusion criteria*

The study participants, who were microscopically positive for *S. mansoni*, voluntarily giving blood and stool samples and whose age is five years and above, were enrolled in the study as case participants. Also, participants who were microscopically negative for *S. mansoni*, voluntarily giving blood and stool samples and whose age is five years and above were enrolled in the study as healthy control participants. Potential confounding variables, including age, gender, and nutritional status, were controlled using a random matching method during participant selection. Additionally, strict inclusion and exclusion criteria were applied to minimize the influence of co-infections, chronic diseases, and medication use. Multivariate regression models were not employed due to sample size limitations, which are acknowledged as a limitation. Correspondingly, both case and control study participants were willing to give written consent for their participation.

#### *Exclusion criteria*

Individuals who were pregnant women, with multiple intestinal parasite infections, those who attended antiretroviral therapy, individuals having a history of chronic disease like hypertension, cardiac disease, and diabetes mellitus, chronic renal disease and inherited bleeding disorders, hepatitis B and hepatitis C virus positive individuals, those who were on anticoagulant therapy, and those who were smokers and alcohol abuse were excluded from the study.

Participants were also excluded if they were presented with splenectomy, use of hepatotoxic drugs, thrombocytopenic drugs, or drugs that change platelet function, and

lactating mothers. Patients with a history of malignancy were also excluded.

### Sample size determination and sampling technique

The sample size was determined using the rule of thumb suggested by Van Voorhis and Morgan [2007], which recommends a minimum of 30 participants per group to detect moderate effect sizes with 80% power [24]. This study enrolled 70 participants (35 infected, 35 healthy controls), which is sufficient for identifying clinically significant differences in biochemical and coagulation profiles, given prior evidence of marked alterations in similar populations [25]. While logistical and resource constraints limited the sample size, the selected sample size is adequate for the study's objectives. A convenient sampling technique was used to select study participants.

### Operational definition

Healthy individuals were microscopically negative for S. mansoni. Selected biochemical profiles were ALT, AST, creatinine, glucose, total bilirubin, direct bilirubin, and total protein. Similarly, selected coagulation profiles were PT, International Normalized Ratio (INR), and APTT. The abnormality of coagulation and platelet count is defined as: Prolonged PT, PT > 16 s (Sec), Prolonged INR, INR > 1.1, Prolonged APTT, APTT > 35 s, and low platelet count, platelet count < 150 × 103/ μL [26]. Also, the abnormality of biochemical profiles is defined as high ALT, ALT > 41 IU/L, high AST, AST > 40 IU/L, high total bilirubin, total bilirubin > 1.2 mg/dl, high direct bilirubin, direct bilirubin > 0.2 mg/dl, high creatinine, creatinine > 1.2 mg/dl, low protein, protein < 3.5 g/dl and low glucose, glucose < 74 mg/dl [27].

### Data collection procedures

#### *Questionnaire survey*

The sociodemographic characteristics of study participants were gathered using a standardized questionnaire prepared in English. Also, this questionnaire was translated into Amharic language. The principal investigator (PI) and trained data collectors used pretested questionnaires to obtain sociodemographic information from study participants. Trained physicians at Dembiya Selected Health Institution's Outpatient Department assessed clinical information and patient history.

#### *Sample collection and laboratory examination*

Blood samples were collected in the morning (7:00–9:00 AM) to minimize diurnal variations in biochemical markers. Participants were instructed to fast for 8 h before sample collection to control for postprandial effects on glucose and liver enzymes. Stool samples were collected on the same day, and all specimens were processed within 2 h of collection to maintain sample integrity.

**Microscopic detection of schistosome** A single stool specimen of about one gram was collected from each study participant. The sample was collected in a clean, dry, and leak-proof container with a unique identification number. *Schistosoma mansoni* was diagnosed by a direct wet mount microscopic examination of stool using normal saline. The Kato-Katz technique was used for determining the intensity of *S. mansoni* infection, which involved preparing Kato-Katz slides on a template containing 41.7 milligrams of stool. Eggs counted for *S. mansoni* were recorded and later converted into eggs per gram (EPG) of stool, multiplying by a factor of 24. Finally, infection intensity (light (1–99 epg), moderate (100–399 epg), and heavy (≥ 400)) was classified according to WHO criteria [28].

**Blood sample collection and examination** Seven milliliters (ml) of venous blood was collected by blood collectors and PI. The blood sample was transferred into three test tubes. The first 2.7 ml of blood obtained was placed in a test tube containing 3.2% sodium citrate anticoagulant. Platelet poor plasma was prepared for PT and APTT assays by centrifuging it for 15 min at 1500 revolutions per minute [25]. The plasma was then separated and stored at 20 °C in an Eppendorf tube until processing. The coagulation profiles (PT, APTT, and INR) were performed using a Semi-Auto Coagulation Analyzer (HumaClot Duo $^{Plus}$ Human) at Felege Hiwot Compressive Specialized Hospital Laboratory. The next 2 mL of blood was transferred into an EDTA test tube for platelet count. Platelet count was determined using the ADVIA 560 Fully Auto Hematology Analyzer. The remaining venous blood was put into an unanticoagulated tube and left to clot on the benchtop. After that, serum was isolated from the blood and stored in Eppendorf tubes at 20 °C until processing. The blood was centrifuged at 2,500 revolutions per minute for four minutes. Following that, serum was examined using a Fully Auto Chemistry Analyzer to determine the levels of ALT, AST, creatinine, glucose, total bilirubin, direct bilirubin, and total protein [29].

**Serological tests** Immune-chromatographic assay was used to determine hepatitis B virus and hepatitis C virus to exclude individuals who were positive for these diseases.

**Urine collection and HCG examination** Urine was collected from all women whose age is 15–49 years in the study using a clean urine cup and a urine human chorionic gonadotropin (HCG) test was performed for both the cases and the controls using a rapid chromatographic immunoassay test strip for excluding pregnant women [30].

### Data quality control

Data collectors took appropriate training in order to maintain data quality. The blood sample was collected and processed in accordance with standard operating procedures to maintain its quality. Samples were inspected to ensure they met accepted standards, such as proper labeling, sample amount, collection time, and the lack of hemolysis and clotting. Strict adherence was maintained to safety and specimen handling protocols. Quality control was performed by re-reading all slides by an expert laboratory technologist to ensure the accuracy of the detection of *Schistosoma*, which was conducted by laboratory technologists. Standard operating procedures and manufacturer instructions were strictly followed throughout the procedures, and all reagents were stored and prepared according to the manufacturer's instruction.

**Table 1** Socio-demographic characteristics of study participants at selected Dembiya health institutions, 2022

| Socio-Demographic Characteristics | *S.mansoni* | | Healthy | |
|---|---|---|---|---|
| | Frequency | % | Frequency | % |
| Sex | | | | |
| Male | 18 | 51.4 | 16 | 45.7 |
| Female | 17 | 48.6 | 19 | 54.3 |
| Age | | | | |
| 5–14 | 14 | 40 | 7 | 20 |
| 15–24 | 7 | 20 | 11 | 31.4 |
| 25–34 | 8 | 22.9 | 10 | 28.6 |
| 35–44 | 3 | 8.6 | 4 | 11.4 |
| >44 | 3 | 8.6 | 3 | 8.6 |
| Residence | | | | |
| Urban | 14 | 40 | 20 | 57.1 |
| Rural | 21 | 60 | 15 | 42.9 |
| Occupation | | | | |
| Government employee | 3 | 8.6 | 8 | 22.9 |
| Nongovernment employee | 1 | 2.9 | 4 | 11.4 |
| House wife | 5 | 14.3 | 4 | 11.4 |
| Student | 14 | 40 | 11 | 31.2 |
| Daily laborer | 3 | 8.6 | 2 | 5.7 |
| Farmer | 7 | 20 | 4 | 11.4 |
| Merchant | 2 | 5.7 | 2 | 5.7 |
| Educational Status | | | | |
| Illiterate | 9 | 25.7 | 4 | 11.4 |
| Can read and write | 3 | 8.6 | 6 | 17.1 |
| Primary school | 15 | 42.9 | 4 | 11.4 |
| Secondary school | 5 | 14.3 | 2 | 5.7 |
| College/University | 1 | 2.9 | 13 | 37.1 |
| Diploma and above | 2 | 5.7 | 6 | 17.1 |
| Family size | | | | |
| 1–3 | 22 | 62.9 | 19 | 54.3 |
| 4–6 | 7 | 20 | 9 | 25.7 |
| 7–9 | 4 | 11.4 | 4 | 11.4 |
| >9 | 2 | 5.7 | 3 | 8.6 |
| Income | | | | |
| 500 Birr | 3 | 8.6 | 3 | 8.6 |
| 501–1000 | 2 | 5.7 | 2 | 5.7 |
| 1001–2500 | 8 | 22.9 | 8 | 22.9 |
| >2500 | 22 | 62.9 | 22 | 62.9 |

### Data management and analysis

The distribution of continuous variables was assessed using the Shapiro-Wilk test. For normally distributed data, parametric tests such as independent t-tests and one-way ANOVA were employed. Non-parametric tests (Mann-Whitney U test, Kruskal-Wallis test) were applied to skewed data. Correlations were assessed using Spearman's rank-order analysis for non-linear relationships. To account for multiple comparisons, Bonferroni corrections were applied where applicable. All analyses were performed using SPSS v25, and a p-value $< 0.05$ was considered statistically significant.

## Result

### Socio-demographic characteristics

A total of 70 study participants were included in the study. Of the 70 study participants, 34 [48.57%] and 36 [51.43%] were males and females, respectively. Participants from urban and rural were 34 [51.4%] and 36 [48.6%], respectively. Among these participants, 35 were *S. mansoni* infected, and 35 were healthy participants [Table 1].

### Intensity of *S. mansoni* infection

The overall mean of EPGs of stool was 146.1 in *S. mansoni* infected participants. Also, the mean of EPG in males and females was 129.3 and 163.8 in *S. mansoni* infected participants, respectively. In addition, from a total of 35 *S. mansoni* infected participants 18 [51.4%], 15 [42.9%], and 2 [5.7%] were due to light, moderate, and heavy *S. mansoni* infection intensity, respectively.

### Biochemical profiles among case and control groups

ALT, AST, total bilirubin, direct bilirubin, and creatinine were elevated in 13 [37.1%], 13 [37.1%], 13 [37.1%], 15 [42.9%], and 14 [40%] of *S. mansoni* infected participants, respectively. But 9 [25.7%] and 21[60%] of *S. mansoni* infected participants had decreased total protein and glucose, respectively. Conversely, among healthy control participants, 1 [2.9%], 1 [2.9%], 1 [2.9%], 9 [25.7%], and 1 [2.9%] had increased ALT, AST, total bilirubin, direct bilirubin, and creatinine, respectively, whereas 1 [2.9%] and 1 [2.9%] of healthy control participants had decreased total protein and glucose, respectively [Fig. 1].

Among *S. mansoni* infected participants, the median [interquartile range (IQR)] of ALT, AST, creatinine, total bilirubin, direct bilirubin, total protein, and glucose were 35.8 [14.20] IU/L, 37.8 [13.20] IU/L, 0.96 [0.84] mg/dL, 0.91 [1.55] mg/dL, 0.13 [0.69] mg/dL, 4.62 [3.22] g/dL,

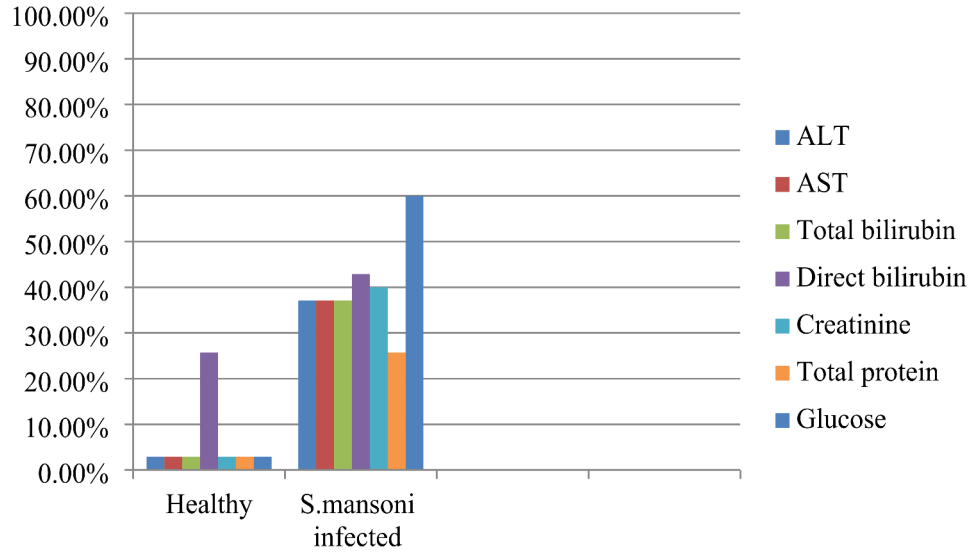


**Fig. 1** Prevalence of abnormal biochemical profiles, showing significantly elevated ALT and AST in *S. mansoni* infected participants compared to controls ($P < 0.05$) at selected Dembiya Health Institutions, 2022

**Table 2** Comparison of biochemical profiles between *S. mansoni* infected and healthy participants at selected Dembiya health institutions, 2022

| Profiles | S. mansoni infected participants Median (IQR) | Healthy control participants Median (IQR) | *P* value |
|---|---|---|---|
| ALT (IU/L) | 35.8 [14.20], | 15.6 [11.10] | **< 0.001** |
| AST (IU/L) | 37.8 [13.20], | 19.3 [9.90] | **< 0.001** |
| Creatinine (mg/dL) | 0.96 [0.84], | 0.85 [0.17] | **< 0.001** |
| Totalbilirubin (mg/dL) | 0.91 [1.55], | 0.42 [0.36], | **< 0.001** |
| Direct bilirubin (mg/dL) | 0.13 [0.69] | 0.12 [0.13], | **< 0.001** |
| Total protein (g/dl | 4.62 [3.22] | 7.64 [1.61] | **< 0.001** |
| Glucose (mg/dL) | 71.9 [10], | 89.1 [25.20] | **< 0.001** |

and 71.9 [10] mg/dL, respectively. Likewise, the median [IQR] values of ALT, AST, creatinine, total bilirubin, direct bilirubin, total protein, and glucose were 15.6 [11.10] IU/L, 19.3 [9.90] IU/L, 0.85 [0.17] mg/dL, 0.42 [0.36] mg/dL, 0.12 [0.13] mg/dL, 7.64 [1.61] g/dL, and 89.1 [25.20] mg/dL in the healthy control participants, respectively.

The biochemical profile values like ALT, AST, creatinine, total bilirubin, direct bilirubin, total protein, and glucose were abnormally distributed. Therefore, the Mann-Whitney U test showed significantly higher median values for ALT, AST, creatinine, total bilirubin, and direct bilirubin in *S. mansoni* infected participants compared to the healthy control participants ($P < 0.05$). However, the total protein and glucose median values were significantly lower in *S. mansoni* infected participants than in healthy control participants ($P < 0.05$) [Table 2].

### Biochemical profiles across different levels of *Schistosoma mansoni* infection intensity among study participants

The mean [standard deviation (SD)] values of ALT, AST, creatinine, total bilirubin, direct bilirubin, glucose, and total protein were 17.4 [8.6] IU/L, 22.0 [0.93] IU/L, 0.84 [0.13] mg/dL, 0.48 [0.27] mg/dL, 0.17 [0.12] mg/dL, 91.9 [12.76] mg/dL, and 7.51[1.18] g/dL, respectively, in healthy control participants. Similarly, 29 [6.16] IU/L, 31.8 [4.9] IU/L, 0.75 [0.16] mg/dL, 0.64 [ 0.65] mg/dL, 0.150 [0.24] mg/dL,78.5 [9.88] mg/dL, and 5.7 [1.47] g/dL were the mean values of ALT, AST, creatinine, total bilirubin, direct bilirubin, glucose, and total protein, respectively, in light *S. mansoni* infected participants. The mean values of ALT, AST, creatinine, total bilirubin, direct bilirubin, glucose, and total protein were 42.8 [5.31] IU/L, 44 [4.2] IU/L,1.44 [0.37] mg/dL,1.78 [0.94] mg/dL,0.64 [0.53] mg/dL, 70.8 [5.99] mg/dL, and 4.2 [1.48] g/dL in moderately infected participants and 47.6 [2.69] IU/L, 50.6 [1.27] IU/L, 1.96 [0.00] mg/dL, 3.02 [0.5] mg/dL, 1.79 [0.01] mg/dL, 64.9 [3.25] mg/dL, and 3.19 [0.25] g/dL in heavy *S. mansoni* infected participants, respectively.

One-way ANOVA revealed that the mean [SD] values of ALT, AST, creatinine, total bilirubin, direct bilirubin, glucose, and total protein showed a significant difference among healthy controls, light, moderate, and heavy *S. mansoni* infected participants ($P < 0.05$).The mean values of ALT, AST, creatinine, total bilirubin, and direct bilirubin were significantly lowered, but total protein and glucose were significantly higher in healthy control participants compared to those with light, moderate, and heavy *S. mansoni* infection intensity ($P < 0.05$). The mean values of ALT, AST, creatinine, total bilirubin, and direct bilirubin were significantly lowered, but glucose was significantly higher in light infection intensity compared

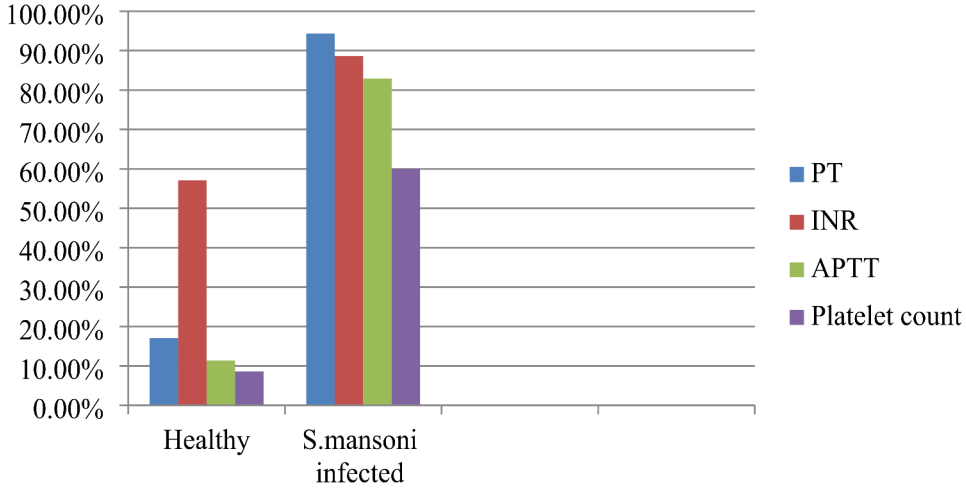


**Fig. 2** Prevalence of abnormal coagulation profiles, showing significantly elevated PT, INR, and APTT in *S. mansoni* infected participants compared to controls ($P < 0.05$) at selected Dembiya Health Institutions, 2022

to those with moderate and heavy *S. mansoni* infection intensity in *S. mansoni* infection ($P < 0.05$).

### Correlation of intensity of *Schistosoma mansoni* infection with biochemical profiles

In *S. mansoni* infected participants, Spearman's rank-order correlation analysis showed that the number of *S. mansoni* eggs per gram of stool had been significantly and positively correlated with biochemical profiles [ALT, AST, creatinine, total bilirubin, and direct bilirubin) (Spearman's rank-order correlation coefficients $r = 0.873$, 0.851, 0.708, 0.738, and 0.789, respectively; $p < 0.05$]. However, total protein and glucose were significantly and negatively correlated with the number of *S. mansoni* eggs per gram of stool in *S. mansoni* infected participants [Spearman's rank-order $r$ = -0.579 and −0.793, respectively; $p < 0.05$].

### Coagulation profiles and platelet count among study participants

The percentages of prolonged PT, INR, APTT, and low platelet count were higher in *S. mansoni* infected participants than in healthy control participants. In *S. mansoni* infected participants, 33 [94.3%], 31 [88.6%], and 29 [82.9%] had prolonged PT, INR, and APTT, respectively. On the other hand, 0 [0%], 2 [5.7%], 6 [17.1%, and 14 [40%] of the *S. mansoni* infected participants had normal values of PT, INR, APTT, and platelet count, respectively. However, 21 [60%] of the *S. mansoni* infected participants had a low platelet count. In healthy controls, 6 [17.1%], 20 [57.1%], and 4 [11.4%] had prolonged PT, INR, and APTT, respectively. Likewise, 6 [17.1%], 13 [37.1%], 25 [65.7%], and 29 [82.9%] of the healthy control participants had normal values of PT, INR, APTT, and platelet count, respectively. In addition, only 3 [8.6%] of the healthy control participants had a low platelet count [Fig. 2].

**Table 3** Comparison of coagulation profiles and platelet count between *S. mansoni* infected and healthy participants at selected Dembiya health institutions, 2022

| Profiles | S. mansoni infected participants Mean [SD] | healthy control participants Mean [SD] | *P* value |
|---|---|---|---|
| PT(sec) | 20.9 [6.23] | 14.5 [2.88] | **< 0.001** |
| INR | 1.97 [0.69], | 1.23 [0.28] | **< 0.001** |
| APTT (sec) | 40.49 [7.59] | 28.72 [5.27] | **< 0.001** |
| Platelet count ($10^3$/µl) | 153.4 [37.6] | 266.9 [53.43] | **< 0.001** |

### Comparison of coagulation profiles and platelet count among study participants

In the *S. mansoni* infected participants, the mean [SD] values of PT, INR, APTT, and platelet count were 20.9 [6.23] sec, 1.97 [0.69], 40.49 [7.59] sec, and 153.4 [37.6] x $10^3$/µl, respectively. In addition, the mean [SD] values of PT, INR, APTT, and platelet count were 14.5 [2.88] sec, 1.23 [0.28], 28.72 [5.27] sec, and 266.9 [53.43] x $10^3$/µl, respectively, in the healthy control participants. Since the data were normally distributed, a parametric test (independent t test) was used to compare the mean difference in coagulation profiles and platelet count between cases and controls. For this reason, an independent t-test showed significantly higher mean values for PT, INR, and APTT in *S. mansoni* infected participants compared to the healthy participants ($P < 0.05$). However, the platelet count mean value was significantly lower in *S. mansoni* infected participants than in healthy participants ($P < 0.05$) [Table 3].

The median [IQR] values of PT, INR, APTT, and platelet count were 14.5 [2.88] sec, 1.23 [0.28], 28.72 [5.27] sec,

and 266.9 [53.4] x $10^3$/μl, respectively, in healthy control participants. Similarly, 16.5 [3.96] sec, 1.5 [0.47], 37 [5.45] sec, and 167.9 [36.39] x $10^3$/μl were the median [IQR] values of PT, INR, APTT, and platelet count, respectively, in light *S. mansoni* infected participants. The median [IQR] values of PT, INR, APTT, and platelet count were 24.74 [4.48] sec, 2.4 [0.5], 43 [7.5] sec, and 143.2 [31.8] x $10^3$/μl in moderate and 31.1 [0.85] sec, 3.0 [0], 53.0 [6.1] sec, and 99.0 [4.2] x $10^3$/μl in heavy *S. mansoni*-infected participants, respectively.

Kruskal–Wallis H-test revealed that the median [IQR] value of PT, INR, APTT, and platelet count showed significant differences among healthy controls, light, moderate, and heavy infected *S. mansoni* egg density-infected participants in *S. mansoni* infected participants ($P < 0.05$). The median [IQR] values of PT, INR, and APTT were significantly lowered, and values of platelet count were significantly higher in healthy participants compared to those with moderate and heavy *S. mansoni* infection intensity in *S. mansoni* infected participants ($P < 0.05$). The median values of PT, INR, and APTT were significantly lowered in light *S. mansoni* egg density compared to those with moderate and heavy *S. mansoni* egg density in *S. mansoni* infected participants ($P < 0.05$).

### Correlation of infection intensity with coagulation profiles and platelet count

Spearman's rank-order correlation analysis showed that the number of *S. mansoni* eggs per gram of stool had been significantly and positively correlated with coagulation profiles [PT, INR, and APTT] [Spearman's rho correlation coefficient $r = 0.803$, 0.767, and 0.609, respectively; $p < 0.05$] in *S. mansoni* infected participants. But the platelet count of *S. mansoni* infected participants was significantly and negatively correlated with the number of S. *mansoni* eggs per gram of stool [Spearman's rho correlation coefficient r = -0.554; $p < 0.05$].

## Discussion

The present study aimed to investigate the effect of *S. mansoni* infection on the biochemical and coagulation profiles and platelet count at Dembiya Primary Hospital, Chuahit Health Center, and Abrija Health Center, Northwest Ethiopia.

Infection with *S. mansoni* was associated with changes in biochemical and coagulation profiles and platelet count. In the present study, median values of ALT, AST, creatinine, total bilirubin, and direct bilirubin in the *S. mansoni* infected participants were significantly higher than in healthy control group ($P < 0.05$). This finding is concordant with studies set in Brazil [31], Nigeria [32], Egypt [33], and northwest Ethiopia [34] that found statistically significant elevated ALT, AST, total bilirubin, and direct bilirubin in *S. mansoni* infected individuals compared to healthy controls ($P < 0.05$). However, the level of total protein and glucose in *S. mansoni* infected individuals was lower than in healthy controls. This finding is consistent with studies set in Northwest Ethiopia [34] that found statistically significant lowered total protein and glucose in *S. mansoni* infected individuals compared to healthy controls ($P < 0.05$).

This abnormality in biochemical profiles might be caused by a variety of factors, including renal function, immunological response, liver involvement, and bilirubin metabolism. The parasite can induce inflammation and damage to liver tissues, resulting in high levels of liver enzymes, including ALT and AST. The illness can alter normal bilirubin metabolism, leading to higher levels of total and direct bilirubin. This can develop as a result of liver malfunction or hemolysis, in which red blood cells are destroyed at greater rates. Elevated creatinine levels indicate damaged kidney function, which can be caused by systemic infection-related consequences such as inflammation and possible renal tissue damage. The immunological response to the illness might further disrupt biochemical profiles since cytokines and other mediators may change normal physiological processes. Changes in biochemical profiles due to *S. mansoni*, including those of protein and glucose, can affect general health and immunological function. This can worsen the disease and make recovery more challenging [35, 36].

Similarly, in this study, mean values of ALT, AST, creatinine, total bilirubin, and direct bilirubin were significantly dropped, but total protein and glucose were significantly higher in the healthy controls compared with those with low, moderate, and heavy *S. mansoni* egg density ($P < 0.05$). This elevation of biochemical profiles might indicate the impairment of organs like the liver and kidney. Organ-specific morbidity, brought on by the accumulation of parasite eggs and fibrosis development, can emerge during established acute and late chronic stages. The severity of hepatosplenomegaly usually correlates with the intensity of the infection [37–39].

Moreover, in this study the number of *S. mansoni* EPGs in the stool showed a positive correlation with biochemical profiles [ALT, AST, creatinine, total bilirubin, and direct bilirubin] and a negative correlation with the total protein and glucose of the *S. mansoni* infected group [$P < 0.05$]. The possible reason for this correlation was due to severe morbidity in *S. mansoni* infections, which is caused by high intensity of infections as revealed by excreted egg counts [3].

Our finding showed that PT, INR, and APTT were significantly higher in *S. mansoni* infected than in healthy control participants ($P < 0.05$). This finding is similar with studies set in China [40], North Ethiopia [41] that found statistically significant elevated PT, INR, and APTT in *S. mansoni* infected participants compared to healthy

controls ($P < 0.05$). However, platelet count in *S. mansoni* infected participants was lower than in healthy control participants. This finding is comparable with studies set in Ethiopia [41, 42] that found statistically significant lowered platelet count in *S. mansoni* infected participants compared to healthy control participants ($P < 0.05$). This might also be due to coagulation cascade disturbance, hepatic dysfunction, an inflammatory response, consumption coagulopathy, or dietary inadequacies. *Schistosoma mansoni* infection can cause modifications in the coagulation cascade, changing the balance of pro- and anti-coagulant factors. Also, *S. mansoni* frequently causes liver injury, which impairs the synthesis of coagulation components generated by the liver, resulting in extended PT and APTT. The immunological reaction to the infection might cause inflammation, which can compromise vascular integrity and the coagulation system. In certain situations, the presence of the parasite might cause disseminated intravascular coagulation, which occurs when coagulation components are eaten faster than created. Chronic infection can cause malnutrition, which can reduce the availability of vitamin K and other nutrients, which are essential for proper coagulation [1, 43].

Furthermore, our findings showed that median values of PT, INR, and APTT were significantly lowered in healthy participants compared to those with moderate and heavy *S. mansoni* infection intensity in *S. mansoni* infected participants ($P < 0.05$). The heavy egg density infected group recorded a higher median score of PT, INR, and APTT than the light and moderate egg density infected group in *S. mansoni* infected individuals ($P < 0.05$). The pathogenesis in schistosomiasis is caused by eggs, which results in tissue fibrosis and chronic schistosomiasis morbidity through chronic inflammation. Furthermore, there are structural and biochemical alterations in the liver as a consequence of the disease caused by schistosomes eggs [44, 45]. Hepatomegaly, which results in an imbalanced liver function, develops in heavy infections as a result of ongoing granuloma formation and fibrosis, high portal pressure, and persistent granuloma formation. Heavy intensity infections are typically linked to the more severe disease [46, 47]. According to many studies, the range of clinical manifestations, disease progression, organ-specific clinical symptoms, and complications in schistosomiasis often positively correlate and depend mostly on the intensity of infection [3, 44, 45, 47]. This could be the possible reason for the higher mean score and prolonged value of PT, INR, and APTT in heavily infected individuals in the infected group.

In this study, we found that platelet count was significantly different among the healthy controls, light, moderate, and heavy intensity of *S. mansoni* infection in the *S. mansoni* infected groups ( $P < 0.05$). The healthy controls group recorded a higher mean score of platelet count than the light, moderate and heavy infection of *S. mansoni* in *S. mansoni* infected participants. Lower platelet count occurs when the severity of *S. mansoni* infection is high in advanced hepatosplenic schistosomiasis, which is characterized by thrombocytopenia and coagulation problems [31, 48].

Also, in this study, the values of PT, INR, and APTT showed a positive correlation with the number of *S. mansoni* EPG of stool, while the platelet count of *S. mansoni* infected individuals showed a negative correlation ($P < 0.05$). The probable scientific clarification for this correlation was due to the schistosomiasis disease's progression and complications, which usually show positive correlations with the severity of the disease as revealed by excreted egg counts and exacerbated due to the incidence of infection [49, 50]. In general, abnormal coagulation profiles may demand specialized treatment techniques, such as the use of anticoagulants or certain supportive medicines to alleviate problems such as portal hypertension or bleeding. Health officials may prioritize resource allocation for diagnostic instruments and treatments in locations with a high incidence of coagulation profile abnormalities and severe schistosomiasis infections, guaranteeing appropriate healthcare access. Policies may encourage integrated treatments that combine schistosomiasis therapy with the care of related illnesses such as liver disease. Policymakers may also stimulate research into the association between aberrant coagulation profiles and illness outcomes, which might lead to the development of novel diagnostic tools and treatment strategies [51, 52]. The main strength of the current study is that it provided a picture of the biochemical and coagulation profiles, as well as platelet count, in *S. mansoni* infected subjects. However, this study has several limitations. The cross-sectional design limits the ability to establish causality between *S. mansoni* infection and changes in biochemical and coagulation profiles. Convenience sampling may introduce selection bias, reducing the generalizability of findings. Residual confounding from unmeasured variables, such as socio-economic status, may also affect results. Additionally, the exclusion of children under five years and pregnant women limits the scope of the application. Future studies should consider larger, more diverse samples and longitudinal designs to explore causal relationships. Moreover, future research should include larger and more diverse samples, incorporating children under five years, pregnant women, and individuals with co-morbidities. Longitudinal studies are recommended to evaluate the causal relationship between *S. mansoni* infection and biochemical or coagulation changes. Further exploration of specific markers, such as inflammatory cytokines or advanced liver fibrosis indicators, could provide deeper insights into disease pathogenesis. Intervention studies assessing the impact

of treatment regimens on these profiles over time would also be valuable.

## Conclusions and recommendations

In the present study, biochemical and coagulation profiles, as well as platelet count, in *S. mansoni* infected participants were significantly altered compared to healthy control participants. Since ALT, AST, total bilirubin, direct bilirubin, creatinine, PT, INR, and APTT were significantly elevated, while total protein, glucose, and platelet count were reduced in *S. mansoni* infected participants compared to healthy controls. Also, these biochemical and coagulation profiles were significantly worse with increasing *S. mansoni* infection intensity and correlated positively with EPG except glucose, total protein, and platelet count.

Furthermore, evaluating biochemical and coagulation profiles, as well as platelet count alterations in *S. mansoni* infection patients is important for various reasons: early diagnosis, monitoring disease progression, and identifying complications to measure therapy success, enabling quick treatment and avoiding complications such as liver damage or blood coagulation disorders, allowing for appropriate intervention.

Likewise, the findings of biochemical, coagulation, and platelet count profiles in *S. mansoni* infected patients can considerably improve clinical practice by allowing for early diagnosis, monitoring disease progression, guiding treatment decisions, and holistic patient management. Recognizing aberrant profiles can lead to earlier detection and treatment of schistosomiasis and lower morbidity. Knowing about coagulation abnormalities might help you make judgments about surgical treatments or anticoagulant medication, lowering your risk during procedures. Healthcare professionals may improve patient care, modify treatment regimens, and improve the prognosis for *S. mansoni* patients by adopting these findings into clinical practice.

Further studies need to be conducted to reveal the possible alteration of biochemical and coagulation profiles and platelet count consequences of *S. mansoni* infection in different epidemiological settings, which include children under the age of 5 years and pregnant women, by using an appropriate sample size and removing all confounding factors. Finally, we would like to recommend that patients be screened and treated for *S. mansoni* infection associated biochemical and coagulation profiles and platelet count abnormalities to prevent biochemical and coagulation disorders.

#### Abbreviations

| | |
|---|---|
| ALT | Alanine Aminotransferase |
| APTT | Activated Partial Thromboplastin Time |
| AST | Aspartate Aminotransferase |
| EPG | Eggs Per Gram |
| INR | International Normalized Ration |
| IQR | Interquartile Range |
| KM | Kilometer |
| ML | Milliliters |
| PI | Principal Investigator |
| PT | Prothrombin Time |
| SD | Standard Deviation |

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#### Author contributions

W. A was conceived, designed the study, interpretation of the data, and wrote original draft of the manuscript. W.L was critically reviewed the manuscript. Y.T participated in the laboratory assay. A.S participated in the data collection. T.M and M.N.D participated in the data collection and entering data into the software. S.A performed statistical analysis of the data. A.B.Z and D.K involved in the analysis and interpretation of the data. T.E and A.D performed statistical analysis and interpretation of the data. All the authors were read and approved the final manuscript.

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#### Data availability

We confirmed that all the data for this manuscript are available, if someone wants to request the data can contact Wagaw Abebe.

### Declarations

#### Ethics approval and consent to participate

This study followed the ethical standards of the Declaration of Helsinki. Also, this study was conducted after ethical approval was obtained from the research and ethics committee of the School of Biomedical and Laboratory Sciences, College of Medicine and Health Sciences, University of Gondar (reference number: SBMLS/253). Moreover, a letter of support was submitted to the Dembiya Primary Hospital, Chuahit Health Center, and Abrija Health Center. Before starting the actual data collection, permission was obtained from the Hospital and Health Centers Chief Executive Officer or Administrator. Additionally, after explaining the purpose, benefits, and possible risks of the study, written informed consent from the age of 16 and above and/or assent from those less than 16 years old study participants, along with written informed consent from their respective parents/ caregivers/guardians, was obtained. Likewise, written informed consent from illiterate study participants was obtained from their respective parents/guardians. Participants were informed that they could withdraw from the study at any time with no negative consequences. All laboratory results were kept confidential. Since those were stored in a file using codes without study participants names. Apparently, those positive for parasites and with biochemical and coagulation profiles, and platelet count abnormality were linked to the hospital and health centers for appropriate treatment and management.

#### Consent for publication

Not applicable.

#### Competing interests

The authors declare no competing interests.

#### Patients or the public involvement

Patients or the public were not involved in the design, conduct, reporting, or dissemination plans of our research.

#### Clinical trial

In this manuscript **'Clinical trial number: not applicable'.**
We declare that this manuscript is original and has not been submitted or published in other journal. Also, all methods were achieved based on appropriate guidelines and regulations.

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**References**

1. Gryseels B, Polman K, Clerinx J, Kestens L. Human schistosomiasis. Lancet. 2006;368(9541):1106–18.
2. Aagaard-Hansen BBJ. The social context of schistosomiasis and its control. World Health Organization; 2008.
3. Colley DG, Bustinduy AL, Secor WE, King CH. Human schistosomiasis. Lancet. 2014;383(9936):2253–64.
4. Hotez PJ, Alvarado M, Basáñez M-G, Bolliger I, Bourne R, Boussinesq M, et al. The global burden of disease study 2010: interpretation and implications for the neglected tropical diseases. PLoS Negl Trop Dis. 2014;8(7):e2865.
5. WHO. Schistosomiasis– PCT database. 2015.
6. Van der Werf MJ, De Vlas SJ, Brooker S, Looman CW, Nagelkerke NJ, Habbema JDF, et al. Quantification of clinical morbidity associated with schistosome infection in sub-Saharan Africa. Acta Trop. 2003;86(2–3):125–39.
7. Adenowo AF, Oyinloye BE, Ogunyinka BI, Kappo AP. Impact of human schistosomiasis in sub-Saharan Africa. Brazilian J Infect Dis. 2015;19:196–205.
8. Bindseil E, Iburg T, Hurst MH, Johansen MV. Distinguishing periportal fibrosis from portal fibrosis in hepatic schistosomiasis. Trends Parasitol. 2004;8(20):361–2.
9. Lambertucci JR, Cota GF, Pinto-Silva RA, Serufo JC, Gerspacher-Lara R, Drummond SC, et al. Hepatosplenic schistosomiasis in field-based studies: a combined clinical and sonographic definition. Memórias Do Instituto Oswaldo Cruz. 2001;96:147–50.
10. Montresor A, Gyorkos TW, Crompton DW, Bundy D, Savioli L, Organization WH. Monitoring helminth control programmes: guidelines for monitoring the impact of control programmes aimed at reducing morbidity caused by soil-transmitted helminths and schistosomes, with particular reference to school-age children. World Health Organization; 1999.
11. Kardorff R, Gabone R, Mugashe C, Obiga D, Ramarokoto C, Mahlert C, et al. Schistosoma mansoni-related morbidity on Ukerewe Island, Tanzania: clinical, ultrasonographical and biochemical parameters. Tropical Med Int Health. 1997;2(3):230–9.
12. Organization WH. Progress in assessment of morbidity due to Schistosoma mansoni infection: a review of recent literature. 1988.
13. Abath FG, Morais CN, Montenegro CEL, Wynn TA, Montenegro SM. Immunopathogenic mechanisms in schistosomiasis: what can be learnt from human studies? Trends Parasitol. 2006;22(2):85–91.
14. Lawrence JD. The ingestion of red blood cells by Schistosoma mansoni. J Parasitol. 1973:60–3.
15. Da'dara AA, Skelly PJ. Schistosomes versus platelets. Thromb Res. 2014;134(6):1176–81.
16. Tanabe M. Haemostatic abnormalities in hepatosplenic schistosomiasis mansoni. Parasitol Int. 2003;52(4):351–9.
17. El-Bassiouni N, El Bassiouny A, Hussein N, El-Sayed H, Ibrahim I, Lotfy M, et al. The coagulation profile in hepatosplenic schistosomiasis. Blood Coagulation Fibrinolysis: Int J Haemostasis Thromb. 1998;9(2):189–94.
18. Leite LAC, Domingues ALC, Lopes EP, Ferreira RCS, Pimenta Filho AdA, Fonseca CSM, et al. Relationship between splenomegaly and hematologic findings in patients with hepatosplenic schistosomiasis. Revista Brasileira De Hematologia E Hemoterapia. 2013;35:332–6.
19. Silva FLd, Del-Rei RP, Fraga DBM, Leony LM, Souza AMGCd, Santos FLN. Alterations in the lipid profiles and Circulating liver enzymes in individuals infected by Schistosoma mansoni. Rev Soc Bras Med Trop. 2018;51:795–801.
20. Hesse M, Piccirillo CA, Belkaid Y, Prufer J, Mentink-Kane M, Leusink M, et al. The pathogenesis of schistosomiasis is controlled by cooperating IL-10-producing innate effector and regulatory T cells. J Immunol. 2004;172(5):3157–66.
21. Hotez PJ, Kamath A. Neglected tropical diseases in sub-Saharan Africa: review of their prevalence, distribution, and disease burden. PLoS Negl Trop Dis. 2009;3(8):e412.
22. Agha A, Abdulhadi MM, Marenco S, Bella A, AlSaudi D, El-Haddad A, et al. Use of the platelet count/spleen diameter ratio for the noninvasive diagnosis of esophageal varices in patients with schistosomiasis. Saudi J Gastroenterology: Official J Saudi Gastroenterol Association. 2011;17(5):307.
23. others. ZFa. Dembiya district finance and economic development office annual report 2017,Koladiba: officer of finance and economic development, Amhara Region, Ethiopia.
24. VanVoorhis CW, Morgan BL. Understanding power and rules of thumb for determining sample sizes. Tutorials Quant Methods Psychol. 2007;3(2):43–50.
25. Eyayu T, Zeleke AJ, Seyoum M, Worku L. Basic coagulation profiles and platelet count among Schistosoma mansoni-infected adults attending Sanja primary hospital, Northwest Ethiopia. Res Rep Trop Med. 2020:27–36.
26. Patel IJ, Davidson JC, Nikolic B, Salazar GM, Schwartzberg MS, Walker TG, et al. Consensus guidelines for periprocedural management of coagulation status and hemostasis risk in percutaneous image-guided interventions. J Vascular Interventional Radiology: JVIR. 2012;23(6):727–36.
27. Organization WH. Guidelines on standard operating procedures for clinical chemistry. WHO Regional Office for South-East Asia; 2000.
28. Schistosomiasis WECotCo, Organization WH. Prevention and control of schistosomiasis and soil-transmitted helminthiasis: report of a WHO expert committee. World Health Organization; 2002.
29. Reitman S, Frankel S. A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. Am J Clin Pathol. 1957;28(1):56–63.
30. Organization WH. Reproductive health indicators: guidelines for their generation. interpretation and analysis for global monitoring: World Health Organization; 2006.
31. Leite LAC, Pimenta Filho AA, Fonseca CSMd S, BSd F, RdCdS, Montenegro SML, et al. Hemostatic dysfunction is increased in patients with hepatosplenic schistosomiasis mansoni and advanced periportal fibrosis. PLoS Negl Trop Dis. 2013;7(7):e2314.
32. Egoro ET, Ilegbedion GI, Loveday ZU, Shonibare MS. Blood biochemical and haematological alterations in Schistosoma mansoni infected patients in Ijora–Badia Nigeria. Eur J Biomedical Pharm Sci. 2017;4(11):148–52.
33. A MAHMOUD E. A ELBESSOUMY A. Hematological and biochemical effects of Curcumin in Schistosoma mansoni infested mice. Assiut Veterinary Med J. 2014;60(142):184–95.
34. Dessie N, Lema W, Aemero M. Hematological and biochemical profile of patients infected with Schistosoma mansoni in comparison with apparently healthy individuals at Sanja Town, Northwest Ethiopia: a cross-sectional study. Journal of Tropical Medicine. 2020;2020.
35. Marques DVB, Felizardo AA, Souza RLM, Pereira AAC, Goncalves RV, Novaes RD. Could diet composition modulate pathological outcomes in schistosomiasis mansoni? A systematic review of in vivo preclinical evidence. Parasitology. 2018;145(9):1127–36.
36. You H, Stephenson RJ, Gobert GN, McManus DP. Revisiting glucose uptake and metabolism in schistosomes: new molecular insights for improved schistosomiasis therapies. Front Genet. 2014;5:176.
37. Ross AG, Vickers D, Olds GR, Shah SM, McManus DP. Katayama syndrome. Lancet Infect Dis. 2007;7(3):218–24.
38. Wilson S, Vennervald BJ, Kadzo H, Ireri E, Amaganga C, Booth M, et al. Health implications of chronic hepatosplenomegaly in Kenyan school-aged children chronically exposed to malarial infections and Schistosoma mansoni. Trans R Soc Trop Med Hyg. 2010;104(2):110–6.
39. Wilson S, Vennervald BJ, Dunne DW. Chronic hepatosplenomegaly in African school children: a common but neglected morbidity associated with schistosomiasis and malaria. PLoS Negl Trop Dis. 2011;5(8):e1149.
40. Shun L, Meng Q, Shao-Qian T. Analysis of coagulation related parameters between patients with advanced schistosomiasis cirrhosis and hepatitis B cirrhosis. Zhongguo Xue Xi Chong Bing Fang Zhi Za Zhi = Chinese. J Schistosomiasis Control. 2016;29(1):68–71.

41. Eyayu T, Zeleke AJ, Seyoum M, Worku L. Basic coagulation profiles and platelet count among Schistosoma mansoni-infected adults attending Sanja primary hospital, Northwest Ethiopia. Res Rep Trop Med. 2020;11:27.
42. Bisetegn H, Feleke DG, Ebrahim H, Tesfaye M, Gedefie A, Erkihun Y. A Comparative Cross-Sectional Study of Coagulation Profiles and Platelet Parameters of Schistosoma mansoni-Infected Adults at Haik Primary Hospital, Northeast Ethiopia. Interdisciplinary Perspectives on Infectious Diseases. 2022;2022.
43. El-Bassiouni N, El Bassiouny A, Hussein N, El-Sayed H, Ibrahim I, Lotfy M, et al. The coagulation profile in hepatosplenic schistosomiasis. Blood Coagul Fibrinolysis. 1998;9(2):189–94.
44. Burke M, Jones M, Gobert G, Li Y, Ellis M, McManus D. Immunopathogenesis of human schistosomiasis. Parasite Immunol. 2009;31(4):163–76.
45. Weerakoon KG, Gobert GN, Cai P, McManus DP. Advances in the diagnosis of human schistosomiasis. Clin Microbiol Rev. 2015;28(4):939–67.
46. Bica I, Hamer DH, Stadecker MJ. Hepatic schistosomiasis. Infect Dis Clin N Am. 2000;14(3):583–604.
47. McManus JF, Costa K, Ng HC, Zhou Y, Hoffmann SS, Major CO, et al. editors. Time-series transects of deglacial circulation changes in the deep North Atlantic ocean. AGU Fall Meeting Abstracts; 2018.
48. Le A, Zhang L, Liu W, Li X, Ren J, Ning A. A case control study on the structural equation model of the mechanism of coagulation and fibrinolysis imbalance in chronic schistosomiasis. Medicine. 2017;96(7).
49. McManus DP, Dunne DW, Sacko M, Utzinger J, Vennervald BJ, Zhou X-N, Schistosomiasis. Nat Reviews Disease Primers. 2018;4(1):13.
50. Wilson S, Jones F, Mwatha J, Kimani G, Booth M, Kariuki H, et al. Hepatosplenomegaly associated with chronic malaria exposure: evidence for a pro-inflammatory mechanism exacerbated by schistosomiasis. Parasite Immunol. 2009;31(2):64–71.
51. King CH. a12 schistosomiasis: challenges and opportunities.
52. Shaker Y, Samy N, Ashour E. Hepatobiliary schistosomiasis. J Clin Translational Hepatol. 2014;2(3):212.

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