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Original research article

Liver Function Alterations in Armed Forces Infected with Malaria and Intestinal Helminths in Cameroon's North West and South West Regions

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ABSTRACT

Cameroon is one of the sub-Saharan countries where malaria and intestinal helminths are endemic. The study evaluated the influence of malaria and intestinal helminths on liver parameters among armed forces in the North West and South West regions of Cameroon. This was a cross-sectional study conducted between May 2022 and April 2023. A total of 812 stool and venous blood samples were collected from males aged 18 to 52 years to identify malaria and intestinal parasites and to evaluate liver parameters. Giemsa staining and Kato-Katz microscopic methods were used for parasite identification, while the enzyme-linked immunosorbent assay (ELISA) was used for liver parameters evaluation. Statistical comparisons were performed using the Statistical Package for Social Sciences (SPSS). Results obtained showed that *Plasmodium falciparum* (11.9%) and *Plasmodium vivax* (1.7%) were identified. Five different species of intestinal helminths were identified out of which *Ascaris lumbricoides* was the most prevalent (4.7%), and the least prevalent species was *Schistosoma intercalatum* (1.2%). The overall co-infection rate was 3.2%. *Plasmodium* sp significantly affected the values of all the liver parameters (Aspartate transaminase: $p = 0.003$; Alanine transaminase: $p = 0.002$; Alkaline phosphatase: $p = 0.000$; Total Bilirubin: $p = 0.001$) while *Trichuris trichiura* and *Schistosoma mansoni* infection significantly influenced Alkaline phosphatase ($p = 0.000$) and ($p = 0.007$) respectively. *Schistosoma mansoni* equally significantly affected the value of Aspartate transaminase ($p = 0.018$). Malaria and intestinal helminths co-infection significantly influenced the values of all liver parameters at $p = 0.000$. *Plasmodium* parasite densities positively correlated with liver parameters and were statistically significant at $p = 0.0008$ with AST and at $p = 0.0004$ with Alanine transaminase. *Ascaris lumbricoide*, Hookworms, *S. mansoni*, and *S. intercalatum* negatively correlated with liver parameters, while *T. trichiura* positively correlated with these parameters. To improve management of liver-related complications, we recommend adding hepatic function assessments to routine evaluations of malaria and intestinal helminths in endemic areas.

Keywords: Malaria, Intestinal helminths, Liver parameters, Armed forces.

RÉSUMÉ

Le Cameroun est l'un des pays d'Afrique subsaharienne où le paludisme et les helminthes intestinaux sont endémiques. L'étude a évalué l'influence du paludisme et des helminthes intestinaux sur les paramètres hépatiques au sein des forces armées des régions du Nord-Ouest et du Sud-Ouest du Cameroun. Il s'agissait d'une étude transversale menée entre mai 2022 et avril 2023. Un total de 812 échantillons de selles et de sang veineux ont été prélevés chez des hommes âgés de 18 à 52 ans afin d'identifier le paludisme et les parasites intestinaux et d'évaluer les paramètres hépatiques. La coloration au Giemsa et les méthodes microscopiques de Kato-Katz ont été utilisées pour l'identification des parasites, tandis que

le test immuno-enzymatique (ELISA) a été utilisé pour l'évaluation des paramètres hépatiques. Les comparaisons statistiques ont été effectuées à l'aide du logiciel SPSS (Statistical Package for Social Sciences). Les résultats obtenus ont identifié Plasmodium falciparum (11,9 %) et Plasmodium vivax (1,7 %). Cinq espèces différentes d'helminthes intestinaux ont été identifiées, parmi lesquelles *Ascaris lumbricoides* était la plus répandue (4,7 %) et l'espèce la moins répandue était *Schistosoma intercalatum* (1,2 %). Le taux global de co-infection était de 3,2 %. Les parasites du paludisme ont affecté de manière significative les valeurs de tous les paramètres hépatiques (aspartate transaminase : p = 0,003 ; alanine transaminase : p = 0,002 ; phosphatase alcaline : p = 0,000 ; bilirubine totale : p = 0,001) ; tandis que l'infection par *Trichuris trichiura* et *Schistosoma mansoni* a influencé de manière significative la phosphatase alcaline (p = 0,000) et (p = 0,007) respectivement. *Schistosoma mansoni* a également affecté de manière significative la valeur de l'aspartate transaminase (p = 0,018). La co-infection par le paludisme et les helminthes intestinaux a eu une influence significative sur les valeurs de tous les paramètres hépatiques à p = 0,000. Les densités de parasites Plasmodium étaient positivement corrélées aux paramètres hépatiques et étaient statistiquement significatives à p = 0,0008 avec l'AST et à p = 0,0004 avec l'ALT. *Ascaris lumbricoide*, les ankylostomes, *S. mansoni* et *S. intercalatum* étaient négativement corrélés aux paramètres hépatiques tandis que *T. trichiura* était positivement corrélé à ces paramètres. Pour améliorer la prise en charge des complications hépatiques, nous recommandons d'ajouter des évaluations de la fonction hépatique aux évaluations de routine du paludisme et des helminthes intestinaux dans les zones d'endémie.

Mots-clés: Paludisme, Helminthes intestinaux, Paramètres hépatiques, Forces armées.

1. INTRODUCTION

Health is a condition of complete physical, mental, and social well-being (WHO 2006). Common illnesses like malaria, soil-transmitted helminthiasis, bacterial infections, viruses, and others can compromise one's health (WHO, 2018). These parasitic infections are a major cause of morbidity and mortality in Africa, especially in resource-limited tropical and sub-tropical regions in sub-Saharan Africa (Degarege *et al*. 2019). This is due to socio-economic problems such as poverty, behavioural attributes, and environmental factors such as stagnant water and poor sanitation, which may favor the transmission of parasites (Abdullahi & Abubakar 2019). Intestinal helminthic and *Plasmodium* infestation are exceedingly common now, and the liver is usually the primary organ involved. These disease manifestations vary from the extremes of asymptomatic carriage to cirrhosis and decompensated liver disease (Kamgain *et al*. 2016). Therefore, having a high probability of suspicion is a critical step in the diagnosis and management of patients with hepatic helminthiasis or hepatic malaria.

The latest World Malaria Report shows that in 2023, there were an estimated 263 million malaria cases and 597,000 malaria deaths in 83 countries (WHO 2024). Also, the WHO African Region carries a disproportionately high share of the global malaria burden with 94% of malaria cases (246 million) and 95% (569 000) of malaria deaths (WHO 2024). In Cameroon, malaria is the primary cause of consultations and hospitalizations, accounting for 29.1% of consultations and 40% of hospitalizations (CS4ME 2021). Malaria can induce liver damage if not properly treated, due to the obligatory hepatic stage of its pathogenic agents (Kouam *et al*. 2023).

Worldwide, human helminthic infestation is quite prevalent, affecting somewhere from 1.5 to 2 billion people (WHO 2020). In Cameroon, in the Littoral region, the overall prevalence of intestinal helminths was 24.6% of which hookworm (16%), *Schistosoma mansoni* (10.8%), *Ascaris lumbricoides* (1.9%), and *Trichuris trichiura* (0.6%) were identified (Tofel *et al*. 2024). In the North West region of Cameroon, Soil-transmitted helminthic infections had an overall prevalence of 33.76% with males being more infected (35%) than females (30.86%) (Ntonifor *et al*. 2021). In South West Cameroon at the Tiko Health District Hospital, the overall prevalence of Schistosomiasis and Soil-transmitted helminth infection rate was 16.16% and14.44% respectively (Egbe *et al*. 2018). Nematodes, commonly referred to as roundworms, include soil-transmitted helminths as well as filarial worms responsible for *lymphatic filariasis* (LF) and *onchocerciasis* (Al Amin & Wadhwa 2023). The liver plays a vital role in various parasitic infections. For parasites transmitted orally, such as *Echinococcus* spp., liver flukes, *Ascaris lumbricoides*, and *Entamoeba histolytica*, it is the first solid organ encountered following mucosal penetration, either directly or through portal-venous blood circulation (Peters *et al*. 2021; Shahid *et al*. 2025). Other parasites, such as those causing schistosomiasis, reach the liver after their larvae penetrate the skin (Nation *et al*. 2020). Recent discussions have suggested that the liver provides a conductive immunological environment for parasites, as the immune response tends to favor tolerance over immunity towards external microorganisms (Deslyper *et al*. 2019; Peters *et al*. 2021; Shahid *et al*. 2025).

The Armed Forces, due to frequent movements in and out of endemic areas to these parasites, poor hygiene, poor sanitation, lack of mosquito repellents, lack of net beds, lack of clean water, and limited food during their deployment, may contribute to their transmission. The Armed Forces represent a unique and high-risk group of travelers. They are deployed for peacekeeping operations for 3 to 15 months with a higher risk for travel-related illnesses (Vilkman *et al*. 2016; Lindrose *et al*. 2021). Additionally, the military frequently conducts activities in malaria and helminth-endemic regions. Therefore, only one infected participant is sufficient to re-infect the entire battalion and even the community. A study on this population could significantly influence military health policy and disease control planning for mobile populations. Hence, this study aimed to assess the influence of malaria and soil-transmitted helminthic infections on liver enzymes among the armed forces in the North and South West regions of Cameroon.

2. MATERIAL AND METHODS

2.1. Ethics statement

The study was approved by the University of Bamenda's Faculty of Health Sciences Ethical Review Committee (2022/0786H/Uba/IRB) and administratively authorized by the Minister of Defense (06068/DV/MINDEF/024/4), the North and South West Regional Delegations of Public Health (R11/MPH/SWR/RDPH/PS/680/520), and participants were informed about the study's aim and purpose through an information sheet written in English and French. Blood and stool samples were collected after participants gave written informed consent. The results were communicated to the participants, and those who tested positive were referred to medical professionals for appropriate management and treatment. Additionally, participants received health education on self-protection against intestinal helminths and malaria, as well as preventive measures. All methods were performed in accordance with the relevant guidelines and regulations of the ethical review board.

2.2. Description of the study area

This study was military-based, conducted in the North West and South West regions of Cameroon, focusing on the Legions, Air Force Military Units, Rapid Intervention Units, and the Amphibious Military Base of Tiko. The North West Region is located between longitude 5˚56' N and latitude 10˚10'E, with a cosmopolitan population of 2 million inhabitants and a surface area of 17910 Km2 (Letouzey 1980). It is characterized by cold, tropical climatic conditions, with an annual rainfall of about 2,145mm and an annual temperature range of 16˚C–25˚C (Mojoko 2011). The South West Region is located between longitude 4˚01′N and latitude 9˚13′E (Mojoko, 2011). It has a surface area of 25.410 km2 and a population of 1.153.125 inhabitants (Council Development Plan, TIKO, 2011). The North West and South West Regions of Cameroon fall in the large equatorial forest, where malaria and helminthic parasite transmission are high and perennial (Mugob *et al* 2024). The study was conducted in Bafut, Buea, Limbe, Idenao, and Tiko, as shown in Figure 1 below.

2.3. Study design, study population, and selection criteria

This study was a Military-based cross-sectional study, conducted in the North West and South West Regions of Cameroon, which involved the collection of samples from May 2023 to April 2024, to include a good number of participants since they are redeployed every three months.

The population sample size was estimated at a 50% prevalence rate since the prevalence was unknown in the calculation (Pourhoseingholi *et al*. 2013). The minimum sample size was determined and adjusted by 11% as described by Cochran (1977) below. Only the Armed Forces coming immediately from an operational service, who did not take anthelminthic or antimalarial drugs and consented to take part in the study, were recruited. Participants who were unable to provide stool or blood samples were not included in the study. The sample size was calculated using the formula: n = Z2 P [1-P] / D2

Where D = Margin of error between the sample and the population (5%), n = Sample size, Z = 95% confidence interval (1.96 at 95% confidence interval), P = Prevalence rate based on previous study. N = (1.96)2×0.5 (1-0.5) ÷ (0.05)2 = 384.N = 384 + 384 = 768. A total of eight hundred and twelve (812) participants were recruited for the study.

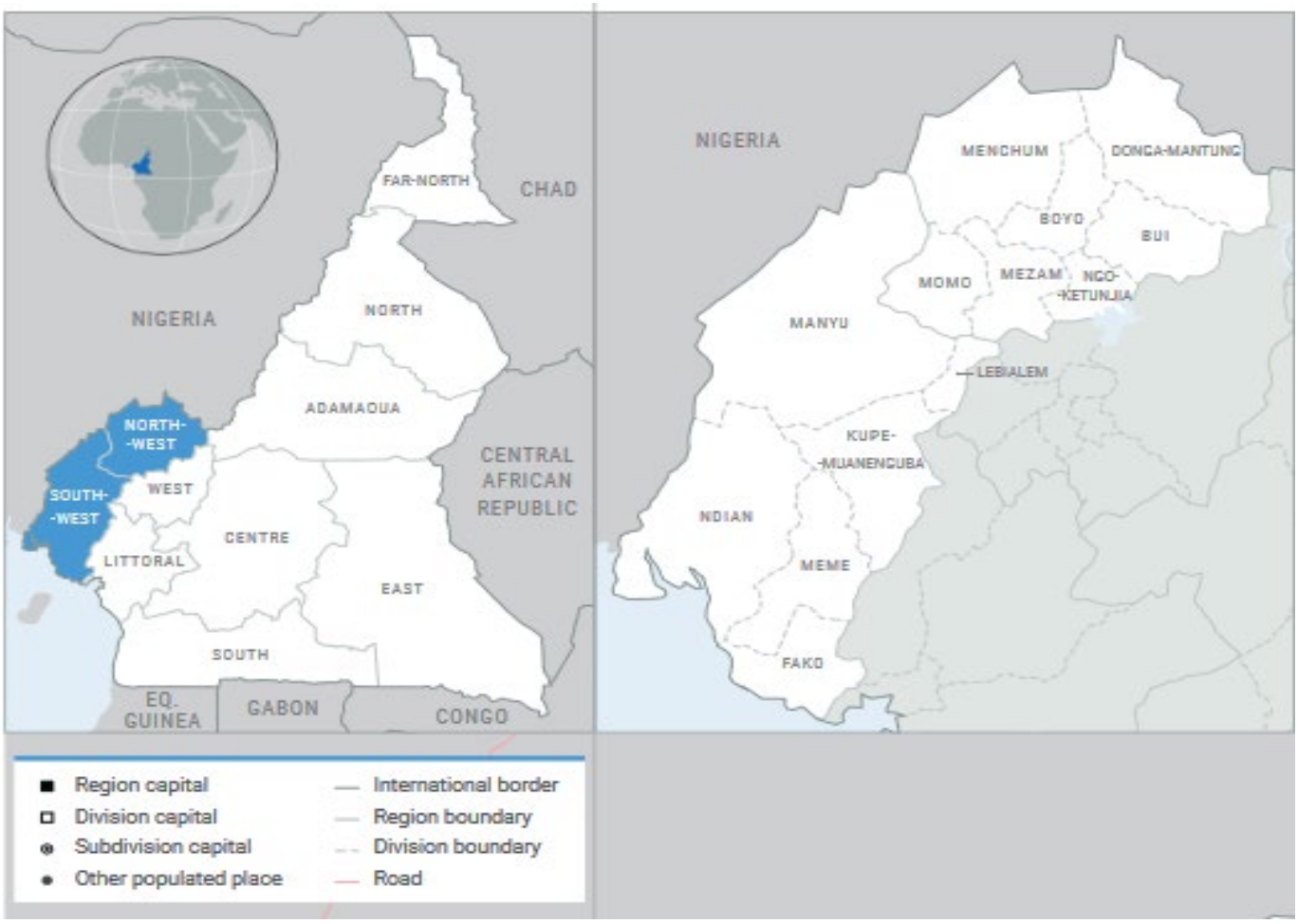

Figure 1: Map of North West and South West regions of Cameroon, adapted from an open-source web image

2.4. Collection of blood samples

Approximately 4mL of venous blood sample was collected from each participant into labelled Ethylene diamine tetraacetate test tubes using a Vacutainer. The Blood samples were centrifuged and Plasma was collected and stored at 20ºC in a fridge for the evaluation of liver parameters.

2.5. Collection of Stool samples

Fresh stool specimens were collected into clean, dry airtight containers bearing serial numbers from each participant. The stool samples were examined using the Kato-Katz method (Katz *et al*. 1972, WHO 2019) for the detection and quantification of soil-transmitted helminths.

2.6. Malaria parasite detection

Approximately 8µl of blood collected in the EDTA tubes was used to prepare the thick (6µl) and thin (2µl) blood films on the same grease-free, slide labelled with the participant's code, following the techniques recommended by Cheesbrough (2009). Both thick and thin blood films were dried using a dryer and the thin films fixed using May Grunwald stain for 10 seconds. Both the thin and thick films were later stained with 10% Giemsa for 10 minutes. (Cheesbrough, 2009; WHO, 2010). The slides were carefully washed, dried and observed under the x100 (oil immersion) objective of a compound microscope (Olympus CX22, Olympus Corporation, Tokyo, Japan). The World Health Organization bench aid for the diagnosis of malaria parasite (WHO, 2019) was used to identify any of the *Plasmodium spp*. Thin films were used for the identification of the malaria parasitic species and the thick films used to quantify the malaria parasite density per microliter (µL) of blood. This was done by counting the asexual

stages (trophozoites) and sexual stages (gametocytes) against 200 leukocytes assuming Total White Blood Cell (WBC) count of 8000 leukocytes/µL of blood (WHO, 2010). Slides with no asexual or sexual stages of malaria parasite were reported as negative after observing up to 100 high power fields.

$$(\text{Parasites/ µL blood}) = \frac{\text{Number of parasites counted}}{\text{Number of white cells counted}} \times 8000 \text{ white cells/µL}$$

2.7. Biochemical analysis for the evaluation of liver parameters

The remaining part of the blood samples (approximately 3.6 mL) in tubes were centrifuged at 3 000 revolutions per minute (rpm) for 15 minutes (Horizon centrifuge, Drunker Diagnostics, USA) and the plasma (approximately 1.8 mL) obtained was pipetted into labelled Eppendorf tubes and stored at -20 0C for liver enzyme analysis. These parameters were analyzed in different samples using ELISA technique according to the manufacturer's instructions (Quantikine Colorimetric ELISA Kits (Quantikine®) obtained from R&D Systems Biotech, USA).

The activities of AST, ALT, ALP, and total bilirubin in the plasma were determined in different samples using the ELISA technique according to the manufacturer's instructions (Quantikine Colorimetric ELISA Kits (Quantikine®) obtained from R&D Systems Biotech, USA). One hundred (100) µl each of the plasma was used with the working reagents to determine the activity of AST, ALT, and ALP in each sample which was directly proportional to the change of absorbance and calculated as follows: Activity of AST (U/L) = Δabs × 3235, Activity of AlT (U/L) = Δabs × 3235, and Activity of ALP (U/L) = Δabs × 2760 while 100 µl of the plasma was used to evaluate total bilirubin using the following formula where Δabs is the absorbance against blank reagent.

$$\text{Concentration} = \frac{\Delta\text{abs sample}}{\Delta\text{abs standard}} \times \text{concentration of standard}$$

The normal values for: AST vary between 8 – 48U/L (Zhang *et al*. 2015), ALT vary between 10 – 40U/L (Zhang *et al*. 2015), ALP vary between 30 – 130U/L (Liu *et al*. 2023), and total bilirubin vary between 1.7 – 20.5µmol/L (Kaplan and Glucose, 1984) for adult males.

2.8. Stool samples and intestinal helminths determination

Five grams of stool were collected from each participant into labelled sterile stool bottles. They were collected void of urine contamination. Approximately 0.2g of the collected stool samples were processed using the Kato-Katz technique following the protocol of the manufacturer (Kato-Katz kit) to diagnose intestinal helminths (Katz *et al*. 1972; John *et al*. 2006). The slides were read within sixty minutes to avoid missing eggs of hookworms that may disintegrate during longer clearing time. Slides that did not have any helminth eggs or larvae were reported as negative.

2.9. Data analysis

Data collected from the field were entered and analyzed using the Statistical Package for Social Sciences (SPSS) version 16. Mean differences between groups for normally distributed variables were assessed using the Student t-test and One-Way ANOVA (analysis of variance). Multiple comparisons within groups were computed using the Tukey Multiple Comparison Test. The binary logistic regression was used to assess the level of association between variables. The cut-off point for assessing all statistical significance between groups was set at a probability level $p< 0.05$.

3. RESULTS

3.1. Prevalence of parasitic species among the study group

Out of the 812 participants examined, the overall prevalence of malaria obtained from the study was 13.7% (111/812), while the overall prevalence of intestinal parasites was 22.8% (185/812). Two species of *Plasmodium*

parasites were identified *Plasmodium falciparum* 11.9% (97/812) and *Plasmodium vivax* 1.7% (14/812) with an overall prevalence of 13.7% (111/812). Five (5) different species of intestinal helminths were identified of which *Ascaris lumbricoides* was the most prevalent (4.7%; 38/812) and the least prevalent species was *Schistosoma intercalatum* (1.2%; 10/812) with an overall prevalence of 11.9% (97/812) as shown in Table 1 below.

Table 1: Prevalence of parasitic infections among study population

Parasitic species	Number infected	Prevalence (%)
P. falciparum	97	11.9
P. vivax	14	1.7
Overall malaria infection	111	13.7
A. lumbricoides	38	4.7
Hookworms	11	1.4
T. trichiura	20	2.5
S. mansoni	18	2.2
S. intercalatum	10	1.2
Overall intestinal parasites	97	11.9

n=812

3.2. Prevalence of co-infection of *Plasmodium* spp and intestinal helminths

The overall prevalence of co-infection was 3.2% (26/812). The most prevalent co-infections were *P. falciparum*/*A. lumbricoides* and *P. falciparum*/*T. trichiura* (0.9%; 7/812) and the least prevalent were *P. vivax*/ *T, trichiura*; *A. lumbricoides*/ *T. trichiura* and *A. lumbricoides*/*S. mansoni* (0.1%; 1/812) as shown in Table 2.

Table 2: Co-infection prevalence of parasitic infections

Co-infection	Co-infection prevalence n(%)
P. falciparum/*P. vivax*/*S. mansoni*	4 (0.5)
P. vivax/*T. trichiura*	1 (0.1)
P. falciparum/*A. lumbricoides*	7 (0.9)
P. falciparum/*T. trichiura*	7 (0.9)
A. lumbricoides/*T. trichiura*	1 (0.1)
P. falciparum/*S. intercalatum*	2 (0.2)
P. vivax/*S. mansoni*	3 (0.4)
A. lumbricoides/*S. mansoni*	1 (0.1)
Total	26 (3.2)

n=812

3.3. Effect of Malaria parasites on liver enzymes

Table 3 indicated that, the liver parameters were log-transformed in base 10 and malaria parasites showed a significant impact (AST: F = 3.490, *p = 0.003*; ALT: F = 3.595, *p = 0.002*; ALP: F = 10.633, *p = 0.001*; Total Bilirubin: F = 4,095, *p = 0.001*) on all the liver enzymes among infected participants. Total Bilirubin (20.38±6.28µmol/L; *p = 0.001*) concentration level was positively higher and statistically significant compared to the control group that were negative to *P. falciparum*. Also, infected participants to *P. falciparum* were statistically significant to Aspartate aminotransferase (20.89±7.45 U/L; *p= 0001*); Alanine aminotransferase (18.41±8.07U/L; *p= 0*.001) and Alkaline phosphatase (53.44±29.96U/L; *p = 0.000*) concentration levels. The mean concentration levels for Aspartate aminotransferase (21.34±8.25 U/L, *p= 0.002*); Alanine aminotransferase (19.56±9.06U/L, *P= 0.001*), and

Alkaline phosphatase (50.68±26.11U/L, *p = 0.001*) were equally higher and statistically significant in positive participants to *Plasmodium vivax* compared to the healthy cases (Table 3).

Table 3: Variations of liver enzyme activities in relation to *Plasmodium* spp infection status

Parasites		Cases	Mean ± Standard deviation (SD) liver enzymes			
			AST (U/L)	ALT (U/L)	ALP (U/L)	Bilirubin(µmol/L)
P. falciparum	Positive[a]	97	20.89±7.45	18.41±8.07	53.44±29.96	20.38±6.28
	Negative[b]	715	15.07±6.48	12.87±6.44	21.34±13.83	16.36±6.09
	Total	812	15.77±6.86	13.53±6.89	25.18±19.57	16.84±6.25
	Range		7.64 - 74.15	6.40 – 47.85	9.99 – 99.37	5.1 – 17.00
	p-value		*0.001*	*0.001*	*0.001*	*0.001*
P. vivax	Positive[a]	14	21.34±8.25	19.56±9.06	50.68±26.11	19.36±5.81
	Negative[b]	798	15.67±6.80	13.43±6.81	24.73±19.16	16.79±6.25
	Total	812	15.77±6.86	13.53±6.89	25.18±19.57	16.84±6.25
	Range		7.64±74.15	6.40 – 47.85	9.99 - 99.34	5.1 – 17.00
	p-value		*0.002*	*0.001*	*0.000*	0.128
Significance[a]			F=3.490, *p=0.003*	F=3.595, *p=0.002*	F=10.633, *p=0.001*	F=4.095, *p=0.001*
Significance[ab]			F=41.786, *p=0.001*	F=30.510, *p=0.001*	F=159.384, *p=0.001*	F=22.585, *p=0.001*

*Student t-test used to assess the mean difference in means at 95% C.I. with equal variances in mean assumed (2-tailed). AST: Aspartate transaminase, ALT: Alkaline phosphatase, ALP: Alkaline phosphatase. *Statistical significance was set at p < 0.05. Letter a indicates positive for the malaria parasite, and letter b indicates negative for the malaria parasite.

3.4. Influence of intestinal helminthic infections on Liver enzymes

We equally observed that patients infected with *Trichuris trichiura* recorded a significant effect (*p = 0.001*) on Alkaline phosphatase activity (45.09±32.32U/L) against the non-infected participants (24.67±18.91U/L (Table 3). This study equally reports that *Aspartate transaminase* activity was higher and significant (19.55±5.45U/L, *p = 0.018*) in *Schistosoma mansoni* positive cases in contrast to *Schistosoma mansoni* negative cases (15.68±6.87U/L). *Alkaline phosphatase* was equally higher and significant (37.44±26.37U/L, *p = 0.007*) in positive cases to *Schistosoma mansoni* compared to healthy cases (24.89±19.32U/L) (Table 4).

3.5. Variation of Liver parameters with *Plasmodium* spp/Intestinal Helminthic co-infection

Findings from this study showed that, co-infected participants with *Plasmodium*/IHs had the highest values of AST (20.73 ± 5.27) U/L, ALT (20.37 ± 8.34) U/L, ALP (59.26 ± 29.98) U/L respectively, and that of Total Bilirubin (20.25 ± 5.32) µmol/L was slightly lower than for those infected with *Plasmodium* spp (20.40 ± 6.44). Equally, participants infected with *Plasmodium* spp had elevated values of all the liver parameters: AST (20.34 ± 7.60) U/L, ALT (17.73 ± 7.83) U/L, ALP (51.91 ± 30.58) U/L, and Total Bilirubin (20.40 ± 6.44) µmol/L compared to the uninfected participants (Table 5).

One-way ANOVA used to evaluate these parameters between groups showed that infected participants with *Plasmodium* spp alone, intestinal helminths alone, and co-infections had a statistically significant value at *p* = 0.001 on all liver parameters, as indicated on Table 5. Also, the Tukey HSD used for multiple comparisons within groups showed that co-infected participants had a significant impact on AST (*p* =0.012), ALT (*p* = 0.001), and ALP (*p* = 0.001) compared to the uninfected participants.

Table 4: Variations of liver enzymes based on intestinal helminthic infection status

Parasites		Cases	Mean ± Standard deviation (SD) liver enzymes AST (U/L)	ALT (U/L)	ALP (U/L)	Bilirubin (µmol/L)
A. lumbricoides	Positive[a]	38	16.37±5.04	14.53±8.45	23.19±15.51	16.56±2.32
	Negative[b]	774	15.74±6.94	13.48±6.81	25.27±19.75	16.85±6.38
	Total	812	15.77±6.87	13.53±6.89	25.18±19.58	16.84±6.25
	Range		7.64 – 74.15	6.41 - 47.85	9.99 – 99.34	9.99 – 76.56
	p-value		0.583	0.363	0.523	0.780
Hookworms	Positive[a]	11	16.04±4.04	11.89±1.41	17.88±4.24	15.91±2.73
	Negative[b]	801	15.76±6.89	13.56±6.93	25.28±19.69	16.85±6.28
	Total	812	15.77±6.86	13.53±6.89	25.18±19.57	16.84±6.25
	Range		7.64 – 74.15	6.40 – 47.85	9.99 – 99.34	9.99 – 76.56
	p-value		0.894	0.427	0.213	0.621
T. trichiura	Positive[a]	20	17.53±6.79	15.67±5.09	45.09±32.32	19.46±5.56
	Negative[b]	792	15.72±6.86	13.48±6.92	24.67±18.91	16.77±6.25
	Total	812	15.77±6.86	13.53±6.89	25.18±19.57	16.84±6.25
	Range		7.64 – 74.15	6.41 – 47.85	9.99 – 99.34	9.99 – 96.56
	p-value		0.244	0.161	*0.001*	*0.058*
S. mansoni	Positive[a]	18	19.55±5.45	14.73±4.25	37.44±26.37	18.51±4.32
	Negative[b]	794	15.68±6.87	1.50±6.40	24.89±19.32	16.79±6.28
	Total	812	15.76±6.86	13.53±6.89	16.84±6.25	16.83±6.25
	Range		7.64 – 74.15	6.41±47.85	9.99 – 99.34	9.99 – 76.56
	p-value		*0.018*	0.457	*0.007*	0.250
S. intercalatum	Positive[a]	10	15.63±5.85	12.68±4.15	28.23±22.02	17.33±6.89
	Negative[b]	802	1577±6.88	13.54±6.92	25.14±6.24	16.83±6.24
	Total	812	15.77±6.86	13.53±6.89	25.18±19.57	16.84±6.25
	Range		7.64 – 74.15	6.41 – 47.85	9.99 – 99.34	9.99 – 76.55
	p-value		0.948	0.696	0.620	0.801
Significance[a]			F=3.490, *p=0.003*	F=3.595, *p=0.002*	F=10.633, *p=0.001*	F=4.095, *p=0.001*
Significance[ab]			F=41.786, *p=0.001*	F=30.510, *p=0.001*	F=159.384, *p=0.001*	F=22.585, *p=0.001*

*Student t-test used to assess the mean difference in means at 95% C.I with equal variances in the mean assumed (2-tailed). Statistical significance was set at $p < 0.05$. Letter a indicates positive for Intestinal Helminths and b indicates negative for the Intestinal Helminths.

Table 5: Effect of *Plasmodium* spp/intestinal helminths co-infection on liver parameters.

Infection status	Number Analyzed	Mean ± Standard deviations of liver enzyme levels AST (U/L)	ALT (U/L)	ALP (U/L)	Bilirubin (µmol/L)
Plasmodium only[a]	72	20.34 ± 7.60	17.73 ± 7.83	51.91 ± 30.58	20.40 ± 6.44
IHsonly[b]	53	15.54 ± 5.08	12.96 ± 5.77	20.96 ± 12.90	16.60 ± 2.99
Co-infection[c]	14	20.73 ± 5.27	20.37 ± 8.34	59.26 ± 29.98	20.25 ± 5.32
Uninfected	673	15.19 ± 6.72	12.98 ±6.61	21.94 ± 14.85	16.40 ± 6.29
ANOVA (one way) – between groups		F= 15.493	F=15.862	F=86.815	F=10.727
		p= 0.001	p= 0.001	p= 0.001	p= 0.001
Tukey HSD multiple comparison within groups		$p=0.001^{ab}$, $p=0.997^{ac}$,	$p=0.001^{ab}$, $p=0.532^{ac}$,	$p=0.001^{ab}$, $p=0.453^{ac}$, $p=0.001^{ad}$,	$p=0.004^{ab}$, $p=1.000^{ac}$,
a = infected with *Plasmodium*spponly,b = infected with IHs only, c = co-infections and d = uninfected)		$p=0.001^{ad}$, $p=0.049^{bc}$, $p=0.983^{bd}$, $p=0.012^{cd}$	$p=0.001^{ad}$, $p=0.001^{bc}$, $p=1.000^{bd}$, $p=0.001^{cd}$	$p=0.001^{bc}$, $p=0.978^{bd}$, $p=0.001^{cd}$	$p=0.001^{ad}$, $p=0.196^{bc}$, $p=0.996^{bd}$, $p=0.093^{cd}$

3.6. Correlation of *Plasmodium* spp densities with Liver parameters

Results obtained from this study (Table 6), using the Pearson correlation coefficients to evaluate the degree of correlation between *Plasmodium* spp densities with liver parameters, indicated that AST and ALT levels positively correlated with the parasite densities. These results were statistically significant at $p = 0.0008$ (*Plasmodium* parasite densities with AST), $p = 0.0004$ (*Plasmodium* parasite densities with ALT).

Table 6: Correlation of Parasite densities with Liver parameters

***Plasmodium* spp Density Against Liver Parameters**				
	AST (U/L)	**ALT (U/L)**	**ALP (U/L)**	**T.B (µmol/L)**
r	0.321	0.337	-0.135	-0.0910
***p*- value**	**0.0008**	**0.0004**	0.1688	0.3558
Number	111	111	111	111
***Ascaris lumbricoides* Density Against Liver Parameters**				
	AST(U/L)	**ALT (U/L)**	**ALP (U/L)**	**T.B (µmol/L)**
r	-0.0968	-0.270	-0.275	-0.224
***p*- value**	0.5632	0.1013	0.0953	0.1755
Number	38	38	38	38
Hookworm Density Against Liver Parameters and Hb				
	AST(U/L)	**ALT (U/L)**	**ALP (U/L)**	**T.B (µmol/L)**
r	0.246	-0.167	-0.345	0.181
***p*- value**	0.4658	0.6233	0.2990	0.5952
Number	11	11	11	11
***Trichuris trichiura* Density Against Livers Parameters And Hb**				
	AST(U/L)	**ALT (U/L)**	**ALP (U/L)**	**T.B (µmol/L)**
r	0.164	0.180	0.161	0.0210
***p*- value**	0.4885	0.4489	0.4964	0.9300
Number	20	20	20	20
***Schistosoma mansoni* Density Against Liver Parameters and Hb**				
	AST(U/L)	**ALT (U/L)**	**ALP (U/L)**	**T.B (µmol/L)**
r	0.276	0.0970	-0.176	0.0888
***p*- value**	0.2683	0.7018	0.4836	0.7261
Number	18	18	18	18
***S. intercalatum* Density Against Livers Parameters and Hb**				
	AST(U/L)	**ALT (U/L)**	**ALP (U/L)**	**T.B (µmol/L)**
r	-0.294	-0.237	-0.0966	-0.156
***p*- value**	0.4093	0.5105	0.7905	0.6662
Number	10	10	10	10

*Pearson correlation coefficients r used to assess the correlation between parasite densities and cytokine values at 95% C.I with equal variances in mean assumed (2-tailed).*Statistical significance set at $p < 0.05$

3.7. Correlation of Intestinal Helminthic densities with Liver parameters

Results indicate that the parasite densities of *A. lumbricoides* negatively correlated with all the liver parameters (Table 6). Hookworm densities negatively correlated with ALT and ALP but positively correlated with AST and total bilirubin. The densities of *Trichuris trichiura* positively correlated with all liver parameters. Also, the parasite densities of *Schistosoma mansoni* negatively correlated with ALP only. *Schistosoma intercalatum* densities negatively correlated with all the liver parameters.

4. DISCUSSION

In developing countries, notably in Sub-Saharan Africa, where a higher prevalence of parasitic diseases has been observed, parasitic infections, especially intestinal parasites and malaria, remain a serious public health concern (WHO 2020, WHO 2024). People of all ages are susceptible to infection, although those living with HIV, pregnant women, and children under five years of age continue to have a higher burden of intestinal parasitic infections and malaria (Imboumy-Limoukou *et al*. 2020; Mekachie *et al*. 2021; Temesgen & Feysal 2024). This study was a community-based cross-sectional study carried out among the Armed Forces of the North West and South West of Cameroon to determine the influence of Malaria and Soil-Transmitted Helminths on liver enzymes.

The overall prevalence of malaria obtained from the study was 13.7%; this prevalence was higher compared to what was obtained by Gontie *et al*. (2020) in west Ethiopia (10.2%). This variation could be because the population of the study is constantly intervening in the bushes and in areas that are endemic to the vectors of malaria parasites. Most of the time, the participants during their deployments are exposed to mosquitoes and do not have mosquito repellents or impregnated bed nets; therefore, it is possible that only one infected participant can be the transmitting factor to the whole group. This prevalence was lower than the released national prevalence (30.3%) of malaria in Cameroon (WHO 2020); along the slope of Mount Cameroon in the South West Region (33.8%) (Kimbi *et al*. 2013) and in the North West region of Cameroon (34.7%) (Ntonifor *et al*. 2023). This decline may have resulted from the government of Cameroon's persistent efforts over the years to put malaria control measures into place to reduce malaria morbidity and mortality throughout the country (Minsante 2018). All of these variations could be due to differences in weather conditions, intervention measures, and environmental or behavioural risk factors (Nyasa *et al*. 2021).

Intestinal parasitic infections continue to pose a global health concern, particularly for children, pregnant women, and immune-depressed people (Mekachie *et al*. 2021; Ebai *et al*. 2023), but they equally affect other people residing in endemic and low-income nations due to factors such as poverty, low literacy rates, inadequate hygiene, and malnourishment.

The overall prevalence of intestinal parasites was 21.4%. The prevalence in this study was higher compared to that obtained in outpatients attending two public hospitals (17.6%) in Bamenda, North West Cameroon (Ntonifor *et al*. 2021) and that reported by Peter *et al*. (2021). This variation could be because the population of study is constantly on the move. Most of the time, the participants have a shortage of food and drinking water during their deployments and so they make do with very unclean water in the villages and roadside foods that are available. During their deployments, the most available toilet facility is the bush and so it is possible that only one infected participant can reinfect the whole battalion after their source of water is contaminated. This higher prevalence could therefore be attributed to variation in exposure to risk factors. The risk factors assessed in this study were selected based on the fact that transmission of intestinal parasites is related to poor sources of drinking water, hygienic practices, faecal disposal systems, socioeconomic status, and the existence of wide variations of parasites within human communities. These findings were, however, lower than those observed in outpatients in Bafoussam II, West Region, Cameroon: 29.1% (Tchinde *et al*. 2021).

The prevalence of co-infection with one or two species of parasites was 3.2%. This value was higher than that obtained in two communities in Senegal (2.2%) reported by Afolabi *et al*. (2023). The higher prevalence of co-infection in Cameroon could be because the study population is intervening in rural areas that are endemic for mosquito vectors and intestinal helminthic parasites due to living conditions in their temporary camps that encourage the reproduction and transmission of these parasites.

Liver enzyme activities were evaluated, and the results indicated that the mean AST ($p= 0001$); ALT ($p= 0$.001); ALP ($p = 0.001$) and Total Bilirubin ($p = 0.001$) concentration levels were extremely significant in positive participants to *Plasmodium falciparum* compared to non-malaria-*falciparum* participants. Our findings concur with those of other research, which found that most patients had elevated serum activities (AST, ALT, and ALP). These elevations are indicative of liver damage because transaminases (AST and ALT) and ALP are the biomarkers of liver disorders, which concur with the studies reported by Nyasa *et al*. (2021) and Okafor *et al*. (2022). These findings could be explained by a major disruption of the hepatocyte membrane that occurs during the hepatic stage of the parasite's life cycle in the human host and causes the liver enzymes to leak into the extracellular fluids. The significant impact

of *Plasmodium* parasites on Total Bilirubin concentration was identical to that reported by Al-Salahy *et al*. (2016). Raised bilirubin levels in cases of uncomplicated malaria are typically caused by hepatocyte damage and/or haemolysis of both parasitized and non-parasitized red blood cells (Okafor *et al*. 2022). In this study, hepatic dysfunction was the primary cause of elevated bilirubin.

Participants infected with *Trichuris trichiura* recorded a significant effect ($p = 0.001$) on Alkaline phosphatase activity. *T. trichiura*, a common parasite in the large intestine, is not known to directly invade the liver, and there are few reports of it affecting liver function, so its overall impact on the liver remains unclear. The persistent infections can alter host immune responses, which might result in systemic inflammation and subsequently affect hepato-biliary function as reported by Yousefi *et al*. (2021) and Chou *et al*. (2025). This study equally reported that, *Aspartate transaminase* ($p = 0.018$) and *Alkaline phosphatase* ($p = 0.007$) activities were significant in *Schistosoma mansoni* positive participants. The elevated values of liver parameters in participants infected with *S. mansoni* may be the result of liver function impairment caused by the deposition of *S. mansoni* eggs in the liver, which later causes early granuloma formation, portal fibrosis, and an enlarged fibrotic portal tract. This is in line with that reported by Dessie *et al*. (2020) and Bisetegn *et al*. (2022).

Results also indicated that co-infected participants had higher mean values of liver parameters compared to the uninfected group of participants. This was identical to the observations of Al-Salahy *et al*. (2016), Kouam *et al*. (2023). These elevations may be indicative of liver damage because transaminases (AST and ALT), ALP and Total bilirubin are the biomarkers of hepatocellular dysfunction. This is in line with the findings reported by Okafor *et al*. (2022). This could be explained by a major destruction of the hepatocytic membrane that occurs during the hepatic stage of the *Plasmodium* life cycle in the human host and causes the liver enzymes to leak into the extracellular fluids. Also, co-infection with intestinal helminthic parasites could worsen the situation**.** Co-infection of malaria and IHs can exacerbate malaria-induced liver damage, leading to elevated liver enzymes like AST and ALT**.**

Also, *Plasmodium* parasite density positively correlated with liver parameters (AST and ALT). These correlations are indicative of liver damage because transaminases (AST and ALT) are the biomarkers of liver disorders, which concords with the studies reported by Al-Salahy *et al*. (2016) and Nyasa *et al*. (2021). This is explained by a major disruption of the hepatocyte membrane that occurs during the hepatic stage of the parasite's life cycle in the human host and causes the liver enzymes to leak into the extracellular fluids, as reported by Al-Salahy *et al*. (2016) and Nyasa *et al*. (2021).

5. CONCLUSION

This study illustrates the pathophysiological consequences of intestinal helminths and malaria on the liver, which clearly highlights the need for improved monitoring and early treatment. Malaria and intestinal helminths are usually asymptomatic or misdiagnosed; the burden of these parasites may be higher than that observed in this study. In addition to the brain and blood, other body parts are impacted by intestinal helminths and malaria. Also, liver enzyme monitoring should be a routine in co-infected individuals.

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