

# Reduction of testosterone levels in *Schistosoma haematobium*- or *Schistosoma mansoni*-infected men: a cross-sectional study in two schistosomiasis-endemic areas of the Adamawa region of Cameroon

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## Research Article

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# Abstract

**Background:** The incidence of schistosomiasis-induced male reproductive dysfunction and infertility is probably underestimated compared to female genital schistosomiasis. This study aimed to investigate the impact of *S. haematobium* or *S. mansoni* infection on the reproductive function of adult men in Tibati and Wouldé, two schistosomiasis endemic areas in the Adamawa region of Cameroon.

**Methods:** A total of 89 men of reproductive age (range: 14 – 56 years) from two localities were enrolled in the study, with 51 in Tibati and 38 in Wouldé. Each participant was submitted to a questionnaire to document data on sociodemographic and stream contact behaviors. A medical examination was performed to measure the circumference of the testes and to evaluate genital tract pathologies. Stool and urine samples were collected and screened for the presence of *S. haematobium* or *S. mansoni* ova. Blood serum was used to evaluate the levels of transaminases and testosterone.

**Results:** *S. haematobium* was present only in Tibati, with a prevalence of 31.37%. The *S. mansoni* prevalence was 3.92% at Tibati and 44.71% in Wouldé. The intensity of infection was  $22.12 \pm 9.57$  eggs/10 mL for *S. haematobium* and  $128.10 \pm 3.76$  epg for *S. mansoni*. Serum transaminase activity and the mean testicular circumference of *Schistosoma*-positive individuals were close to those of *Schistosoma*-negative individuals. However, the testes size was higher in *S. mansoni*-positive individuals than in *S. haematobium*-positive individuals ( $P < 0.05$ ). The serum testosterone levels of *S. haematobium*- and *S. mansoni*-positive men were significantly reduced by 56.07% ( $P < 0.001$ ) and 51.94% ( $P < 0.01$ ), respectively, in comparison to those of *Schistosoma*-negative men. A significant and negative correlation was established between schistosomiasis and the low level of serum testosterone. Male genital tract pathologies such as scrotal abnormalities, varicocele, nodular epididymis, inguinal hernia and hydrocele were recorded in both *Schistosoma*-positive and *Schistosoma*-negative men. However, no significant link was established between schistosomiasis infection and these pathologies.

**Conclusion:** These results demonstrated that infection with *S. haematobium* or *S. mansoni* is associated with low production of the reproductive hormone testosterone and may be a major cause of male infertility.

## Introduction

Schistosomiasis is an acute and chronic disease caused by blood flukes of the genus *Schistosoma*. In Cameroon, three species of human schistosomes occur: *S. haematobium*, *S. mansoni* and *S. guineensis*. People are infected while exposed to infested water during routine agricultural, domestic, occupational, and recreational activities. In 2016, the global burden of schistosomiasis was estimated at 2.50 million disability-adjusted life years (DALYs). Schistosomiasis remains a major public health problem, with at least 229 million people worldwide, and almost 90% of them lived in sub-Saharan Africa, requiring preventive chemotherapy in 2018 [1]. In Cameroon, it was estimated that 47% of the population (9 484 894 million) was at risk of schistosomiasis infection and needed preventive treatment in 2010 [2]. The three northern regions of the country, namely, Far North, North and Adamawa, are the most affected, and some health districts in the South-West, Littoral, West and Centre regions showed a high prevalence of infection. Epidemiological data collected in some schools of the Adamawa region in 2006 revealed that 14.2% of the children were infected with at least one of the schistosome species [3]. The strategy of choice to control schistosomiasis remains preventive chemotherapy with praziquantel. School-aged children are the primary target of these therapeutic interventions since they are the most vulnerable group and the most affected by the infection [4]. In Cameroon, fishermen, farmers and irrigation workers are also high-risk groups for schistosome infection, but they are not enrolled in deworming campaigns with praziquantel [3,5]. *Schistosoma*

infected adults generally suffer from chronic schistosomiasis with severe consequences such as liver fibrosis, portal hypertension, ascites, calcification of the bladder, kidney failure and genital dysfunction [2]. Genital schistosomiasis occurs when *Schistosoma* circulating eggs invade the reproductive tissues of the host. It has been associated with female and male reproductive health problems such as ectopic pregnancies, abortion, low sperm count, coitus pain, vaginal bleeding, genital organ enlargement and infertility [6–8]. Female genital schistosomiasis (FGS) is well documented, and its prevalence is considerable in *S. haematobium* endemic areas (33 to 75%) [6,9–12]. In contrast to FGS, male genital schistosomiasis (MGS) is underreported, and its burden is underestimated. *S. haematobium* and *S. mansoni* are the two species involved in MGS. The main findings reported in patients who have travelled or lived in schistosomiasis endemic areas are swelling of scrotum and other genital organs, dilatation and calcification of the prostate and seminal vesicles, haemospermia, hydrocele, changes in semen/ejaculate, infertility and urethral discharge [7,13]. Case reports have mentioned the presence of *S. haematobium* or *S. mansoni* eggs in male genital organs and semen of some young and adult patients [14–24]. Variation in the levels of sex hormones was also reported in some male patients with *S. haematobium* and/or *S. mansoni* [25–29].

In Cameroon, investigations on the association of schistosomiasis and the male reproductive tract have drawn no attention from researchers. To the best of our knowledge, this is the first report on male genital schistosomiasis in Cameroon. The aim of this study was to evaluate the impact of infection with *S. haematobium* or *S. mansoni* on the reproductive tract of adult men in Tibati and Wouldé, two schistosomiasis endemic areas in the Adamawa region of Cameroon.

## Methods

### Study area

Cameroon is divided into 10 regions at the first level, 58 divisions at the second level, and 360 subdistricts at the third level. According to the United Nations, the population of Cameroon was estimated to be 25 876 380 inhabitants in 2019, with 1 200 970 inhabitants in the Adamawa region [30]. The Adamawa region is divided into five divisions: Vina, Mbéré, Mayo Banyo, Djerem and Faro et Déo. Tibati, the capital of the “Djerem” division, is situated between 6°47' N and 12°63' E. It is a semi-urban area with a population density of 7 inhabitants/km<sup>2</sup>. Situated in the “Pagneré” neighborhood, Lake Pagneré is the largest in the city. Trading, fishing and fish mongering are the main activities in Tibati. Wouldé is a village in the Mayo-Baléo subdistrict in the “Faro et Déo” division. It is situated between 7°43' N and 12°47' E and surrounded by volcanic hills. At the entrance of this rural area flows the Wouldé River with its thermal source. The population density is 6.6 inhabitants/km<sup>2</sup>, and the major occupations in this community are farming, livestock and trading (Figure 1). The vegetation of the Adamawa region falls within the rainforest-savannah mosaic, and the climate is a sudano-guinean type with an annual rainfall of 1500 mm. The transmission of schistosomiasis presumably takes place in lake, river, pond and marshy fields. Fulbe and Kutin ethnic groups are predominant in Tibati and Wouldé, and they are mainly Muslims.

### Ethical considerations

This study was approved by the National Ethics Committee of Cameroon (N° 072/CNE/DNM/08). Surveys were conducted in the communities with the approval of administrative authorities. The objectives of the study were explained to the populations, and informed consent was signed by each participant. The results were sent to each participant at the end of the study, and all infected persons were treated with praziquantel.

### Study design

People involved in the study were all male volunteers who were residents of Lake Pagneré in Tibati and of the “Chefferie” neighbourhood in Wouldé. Seriously ill individuals showing incapacitation were not included in the study. A questionnaire was administered to each participant for personal information, fertility status and history of sexually transmissible infections. Participants underwent physical examination by a male medical practitioner to assess palpation genital tract pathologies such as varicocele, hydrocele, nodular epididymis, scrotal abnormalities and inguinal hernia. The circumference of the two testes was also measured. Initially planned in the study, sperm collection to search for the presence of schistosome ova and to conduct semen analysis was not carried out because of cultural considerations (masturbation being a taboo in those localities). Urine and stool samples as well as blood were collected from each participant for parasitological and biochemical analyses.

### **Samples collection**

Urine and stool samples were collected in 60 mL plastic screw-cap vials, and blood was collected in 5 mL dry tubes between 10.00 a.m. and 14.00 p.m. The samples were transported to the laboratory of the Divisional Hospital of Tibati or to the Health district of Tignère for processing. In the laboratory, each urine sample was agitated to ensure adequate dispersal of eggs, and 10 mL of urine was filtered through a Nucleopore® filter. The filters were examined by microscopy for the presence of schistosome eggs. Stool samples were examined by a single thick smear technique using a 41.7 mg Kato-Katz template. The number of eggs for each schistosome species was counted, and the intensity of infection was calculated and expressed as eggs per gram of feces (epg) for *S. mansoni* or eggs per 10 ml of urine (eggs/10 ml) for *S. haematobium*. Serum obtained from blood samples after coating was kept at -20°C and transported to the laboratory in a cold ice box for the assay.

### **Evaluation of the level of transaminases**

Serum activities of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were evaluated by colorimetric methods using Fortress Commercial kits (Fortress Diagnostics, UK) according to the protocol given by the manufacturer. Absorbances were read against the blank at 505 nm, and the ALT and AST activities were determined from their respective standard curves.

### **Testosterone assay**

Concentrations of serum testosterone were evaluated by an enzyme immunoassay using the Human Testosterone ELISA kit (Invitrogen). A volume of 50 µL of standards and samples were dispensed in microtiter plates. After adding 100 µL of testosterone – HRP conjugate (testosterone labeled with horseradish peroxidase), plates were incubated for 60 min at room temperature. The competitive reaction was stopped by washing with wash buffer. A chromogenic solution of 3-3', 5-5' tetramethylbenzidine (100 µL) was added to each well, and after incubation for 30 min at room temperature, 100 µL of the stop reagent (HCl 2N) was added. Absorbance was read at 450 nm, and testosterone concentrations were determined from the standard curve.

### **Data analysis**

The data for this study were entered into Excel and exported to R version 3.5.0 software for statistical analysis. In univariate analysis, measures of central tendency and dispersion were reported for quantitative variables, while the frequencies and percentages were reported for the modalities of qualitative variables. In bivariate analysis, frequencies and percentages were determined for *Schistosoma*-infected and noninfected subjects, respectively, to evaluate its prevalence across groups of other qualitative variables. Equality of prevalence rates was tested using Pearson's chi-squared test for equality of proportions. Differences in distributions for quantitative variables between

SCH-positive and SCH-negative subjects were tested using the Kolmogorov-Smirnov test. Univariate logistic regression models were used to identify factors that were affected by *Schistosoma* infection. For the quantitative results of biochemical parameters, data were analysed using GraphPrism 8.0.1 by one-way analysis of variance (ANOVA), and differences between groups were assessed using the Tukey multiple comparison post-test. In all, level of significance was set at 5%. The intensity of individual infection for *S. mansoni* (light: 1 - 99 epg; moderate: 100 - 399 epg; and heavy  $\geq$  400 epg) and for *S. haematobium* (light: < 50 eggs/10 mL and heavy:  $\geq$  50 eggs/10 mL) was classified according to the WHO guidelines [31].

## Results

### Socio-demographic characteristics of the participants

A total of 89 men of reproductive age (range: 14 – 56 years) were enrolled in this study, with 51 in Tibati and 38 in Woukdé. The mean age of the population was  $32.21 \pm 1.16$  years. Regarding the marital status of the participants, 53 (58.43%) were married, 32 (35.96%) were single with girlfriends, 4 (4.49%) were divorced and 1 (1.12%) was widowed. The results revealed that 49.44% of the population was permanently in contact with schistosomiasis transmission sites (STSs). Considering the study population per locality, 76.32% of the participants in Woukdé and 29.41% in Tibati were exposed to STS. (Table 1).

**Table 1** Sociodemographic characteristics of the population of Tibati and Woukdé

Sociodemographic indicators	Category	Study areas	SCH-negative (n=54)	SCH-positive (n=35)	Total	Mean $\pm$ SEM / Prevalence
Age (years)	Mean number		33.87	29.66	89	$32.21 \pm 1.16$
Weight (kg)	Mean number		64.37	61.43	89	$63.21 \pm 0.89$
Height (cm)	Mean number		169.22	166.17	80	$167.89 \pm 0.88$
Profession	No frequent contact with water	Tibati	21	15	36	70.59%
		Woukdé	2	7	9	23.68%
		Total	23	22	45	51.68%
	Frequent contact with water	Tibati	12	3	15	29.41%
		Woukdé	19	10	29	76.32%
		Total	31	13	44	49.44%
Marital status	Single		16	16	32	35.96%
	Divorced		4	0	4	4.49%
	Married		34	18	52	58.43%
	Widowed		0	1	1	1.12%

Considering the indicator “profession”, the prevalence is the percentage of people by locality whose occupation exposes them or not to frequent contact with water.

SCH-negative: negative to *Schistosoma* infection

SCH-positive: positive to *Schistosoma* infection

## Prevalence and intensity of infection

Table 2 summarizes the prevalence and intensity of *S. haematobium* and *S. mansoni* infection in the male adult individuals involved in this study. *S. haematobium* was the most prevalent species in Tibati, with 31.37%, while the prevalence of *S. mansoni* was 3.92%. In Wouldé, *S. haematobium* was absent among the population of study, and the prevalence of *S. mansoni* was 44.74%. The egg count for urinary schistosomiasis ranged from 2 to 2620 eggs/10 mL and from 24 to 1224 epg for intestinal schistosomiasis. The geometric mean infection intensity was  $22.12 \pm 9.57$  eggs/10 mL for *S. haematobium* and  $128.10 \pm 3.76$  epg for *S. mansoni*. According to the degree of intensity of infection, 47.37% of *S. mansoni*-infected men presented light-intensity infection, 31.58% moderate-intensity infection and 21.05% heavy-intensity infection. Light-intensity infection with *S. haematobium* represented 68.75%, while heavy-intensity infection was 31.25%. Hematuria was present in 80% of the men presenting *S. haematobium* heavy-intensity infection (Figure 2).

**Table 2** Prevalence and intensity of *Schistosoma* infection in the male adult population of Tibati and Wouldé

**Fig. 2** Degree of *Schistosoma* infection intensity in the adult male population of Tibati and Wouldé

### Legends of Fig. 2

Light-infection intensity: 1 - 99 epg; moderate-infection intensity: 100 - 399 epg; and heavy-infection intensity  $\geq 400$  epg for *S. mansoni* and for *S. haematobium*, light-infection intensity:  $< 50$  eggs/10 mL and heavy-infection intensity:  $\geq 50$  eggs/10 mL

## Serum activity of transaminases

The serum activity of transaminases was evaluated in the study population. The alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities of *S. haematobium* and *S. mansoni*-positive men were close to those of SCH-negative men. There was thus no significant difference in the serum activity of transaminases between SCH-positive men and SCH-negative men (Table 3).

**Table 3** Transaminase activities of *Schistosoma haematobium* and *Schistosoma mansoni*-positive individuals of Tibati and Wouldé

Transaminases	SCH-negative	<i>S. haematobium</i> -positive	<i>S. mansoni</i> -positive
ALT (UI/L)	$12.84 \pm 1.26$	$12.19 \pm 1.66$	$13.80 \pm 1.52$
AST (UI/L)	$42.03 \pm 4.26$	$43.40 \pm 4.70$	$40.27 \pm 2.44$

## Testicular size and serum level of testosterone

The mean testicular circumference of SCH-negative men was  $9.26 \pm 0.38$  cm, and that of *S. haematobium*- or *S. mansoni*-positive men was  $8.28 \pm 0.49$  cm and  $10.71 \pm 0.62$  cm, respectively. These results revealed no significant difference between SCH-positive individuals and SCH-negative individuals. However, the testicular circumference of *S. mansoni*-positive men was higher than that of *S. haematobium*-positive men ( $P < 0.05$ ) (Figure 3a).

The serum concentrations of testosterone were  $3.40 \pm 0.48$  ng/mL and  $3.72 \pm 0.58$  ng/mL for *S. haematobium*- and *S. mansoni*-positive men, respectively, versus  $7.74 \pm 1.07$  ng/mL for SCH-negative men. In comparison to the SCH-negative group, *Schistosoma* infection induced a significant reduction in the serum level of testosterone by 56.07% in the *S. haematobium*-positive group ( $P < 0.001$ ) and by 51.94% in the *S. mansoni*-positive group ( $P < 0.01$ ) (Figure 3b). A strong correlation was observed between *Schistosoma* infection and the serum level of testosterone in the study population. The Spearman's rho correlation coefficients were -0.54 ( $P = 0.0101$ ) and -0.56 ( $P = 0.0006$ ) for the groups of *S. haematobium*- and *S. mansoni*-infected men, respectively (Figure 4).

**Fig. 3** Mean testes circumferences (A) and serum testosterone levels (B) in *Schistosoma haematobium*- and *Schistosoma mansoni*-positive men in Tibati and Wouldé

### Legends of Fig. 3

Data are expressed as mean  $\pm$  SEM. ANOVA followed by Tukey's multiple comparison post hoc test was used for statistical analysis. <sup>a</sup> $P < 0.05$ : values are significantly different from those of *S. haematobium*-positive men. <sup>\*\*</sup> $P < 0.01$ , <sup>\*\*\*</sup> $P < 0.001$ : values are significantly different from those of SCH-negative men.

**Fig. 4** Correlation curves between *Schistosoma haematobium* (A) or *Schistosoma mansoni* (B) intensity of infection and serum testosterone levels

### Prevalence of genital tract pathologies

Table 4 shows the prevalence of genital tract pathologies in SCH-negative and SCH-positive men. Physical examination of the population of study revealed that some men infected with *S. haematobium* or *S. mansoni* presented one or two of the following pathologies: varicocele, hydrocele, nodular epididymis, scrotal abnormalities and inguinal hernia. Scrotal abnormalities were predominant, with 25 and 52.63% of the cases in *S. haematobium* or *S. mansoni* infection versus 40.74% of cases in noninfected men. Varicocele and nodular epididymis were also detected in approximately 20.00% of SCH-positive men. These pathologies were also present in SCH-negative men. The results of the bivariate logistic regression model show that genital tract pathologies are not related to SCH infection: no significant difference was observed between SCH-negative and SCH-positive men.

**Table 4** Prevalence of genital tract pathologies in *Schistosoma haematobium*- or *Schistosoma mansoni*-positive men of Tibati and Wouldé

## Discussion

In schistosomiasis endemic areas, people are infected during their routine activities when they are exposed to contaminated water. In this study, approximately half of the population was exposed to schistosomiasis transmission sites due their agricultural and fishing activities. Three-quarters of the study population in Wouldé was

made up of farmers working in marshy fields around the Wouldé River. The study population in Wouldé was then a high-risk group for schistosomiasis infection [3]. The prevalence of *S. haematobium* or *S. mansoni* infection was within the interval of 10 – 49%, which reflects a moderate occurrence in the study population in Tibati or Wouldé. Despite this moderate endemicity of schistosomiasis, 80% of men with *S. haematobium* heavy-intensity infection presented hematuria. It reflects the increase in egg population in the urothelium and is sometimes linked to bladder and ureteral calcification and renal failure [32].

Among other complications of urinary schistosomiasis, male reproductive function impairment and even infertility are quite common. *S. haematobium* is reported to be more involved than *S. mansoni* [33]. The symptoms include epididymitis, haemospermia, pain during urination, prostatitis, dilatation and calcification of seminal vesicles and testicular inflammation [7,34,35]. In the current study, the mean testicular circumference of *S. mansoni*-positive men was significantly higher than that of *S. haematobium*-positive men. The increased size of the testes could presumably be the consequence of numerous eggs trapped in that organ or/and the inflammation induced by their presence in the testes. The presence of *S. haematobium* or *S. mansoni* ova in the testes has effectively been reported in men living in SCH-endemic areas or tourists who have visited these areas [14,19,21–23,36]. *Schistosoma* ova in the testes induces direct damage to the testicular tissue by bilharzial inflammation and granuloma formation [37], which could impair testicular steroidogenesis. The testis is an exocrine and endocrine gland that synthesizes and produces testosterone through the process of steroidogenesis in Leydig cells and sperm through spermatogenesis in the seminiferous tubules [38]. When *Schistosoma* eggs invade the testes, inflammatory cells migrate around eggs and generate granulomatous lesions. Lenzi et al. [39] described the bilharzial granuloma as a structure composed of macrophages, lymphocytes, eosinophils, neutrophils, giant cells and fibroblasts surrounding schistosome eggs. The modulation of Leydig cell steroidogenesis by macrophages has been demonstrated [40–42]. Under normal physiological and noninflammatory conditions, testicular interstitial macrophages play an important role in Leydig cell proliferation and differentiation and stimulate their steroidogenic function [40,41]. When macrophages are activated, they produce inflammatory cytokines such as tumor necrosis factor-alpha (TNF- $\alpha$ ) and interleukin-1 (IL-1) that inhibit Leydig cell steroidogenesis and thus testosterone production. They also act as transcriptional repressors of steroidogenic enzyme gene expression [40,43]. In fact, the exposure of TM3 Leydig cells to the inflammatory cytokines TNF- $\alpha$ , IL-1 $\beta$  and IL-6 resulted in a decrease in Leydig cell viability and testosterone concentrations [42]. Moreover, the endocrine function of the testis is perturbed by the reactive oxygen species (ROS) generated by macrophages. They impair Leydig cell mitochondria by inhibiting steroidogenic acute regulatory (StAR) protein expression [40]. The significant decrease in testosterone concentration recorded during the current study in *S. haematobium*-positive men and in *S. mansoni*-positive men could be linked to the inhibition of Leydig cell steroidogenesis by secretory products of granuloma inflammatory cells. In addition, a significant correlation between *S. haematobium* or *S. mansoni* infection and reduced testosterone levels was established in our study. Hormonal imbalance in SCH-infected individuals is less reported. Authors have recorded decreased levels of hydroxyprogesterone, testosterone and dihydrotestosterone in boys and men presenting hepatosplenic schistosomiasis [26–29]. This was associated with an increased concentration of estradiol, estrone and estriol [25,29], suggesting an intense aromatization of androgens to estrogens in SCH-infected persons. Such sex steroid imbalance has led to delayed puberty in young boys and to hypogonadism in men [27,29].

Authors have described hydrocele, testicular atrophy and nodular scrotum in patients presenting testicular schistosomiasis [21]. In this study, we denoted genital tract pathologies such as scrotal abnormalities, nodular epididymis, varicocele, hydrocele and inguinal hernia in SCH-positive men. Since the prevalence of these pathologies was statistically comparable between SCH-positive and SCH-negative men, it would have become a challenge to establish a correlation between schistosomiasis or reduced testosterone levels and these pathologies. The

testosterone level of SCH-negative men in this study was, however, similar to that of a control group of men of reproductive age involved in a study on the effect of agropesticides on the male reproductive function of farmers in a village in the West region of Cameroon [44].

The consequence of testosterone depletion in SCH-positive men in Tibati and Wouldé would be poor semen quality since spermatogenesis relies on the ability of Leydig cells to produce testosterone [38]. Due to traditional and cultural beliefs, it was not possible to conduct semen analysis in this study; the population of our study areas considered masturbation (method of sperm collection) as a taboo. Some authors have, however, reported *Schistosoma* egg excretion in the semen, low volume of ejaculate, decreased sperm viability, oligoasthenoteratozoospermia, azoospermia and sperm apoptosis [15–18,20,36,45–47]. Leukocytospermia, mainly eosinophilia, and secretion of inflammatory cytokines in the semen were also reported in SCH-infected men [15,17,20,36,45]. A clinical scheme presenting a low testosterone level and/or poor semen quality could presumably be conducted for subfertility or infertility.

## Conclusion

The results from this study demonstrated that *S. haematobium* and *S. mansoni* infections are associated with a reduction in the male reproductive hormone testosterone of adult men living in schistosomiasis endemic areas in Cameroon. The recommendations from this study are that the national control programme for schistosomiasis and intestinal helminthiasis in Cameroon should accelerate the extension of schistosomiasis treatment to reach all individuals at risk in communities. In addition, a program of sensitization and surveillance of young people and adults suffering from male genital schistosomiasis should be set up in endemic areas.

## Declarations

### *Ethics approval and consent to participate*

The protocol of the current study was approved by the National Ethics Committee of Cameroon (N° 072/CNE/DNM/08). All participants signed an informed consent.

### *Consent for publication*

All presentations of data have consent for publication.

### *Availability of data and materials*

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

### *Competing interests*

The authors declare that they have no competing interests.

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### ***Authors' contributions***

HBJ, LATT and PK conceived and design this study. HBJ and RIKN conducted field study. HBJ, UMF and CND computerized the raw data from the surveys and performed statistical analysis with BNF. HBJ performed biochemical assays and wrote the first draft of the manuscript with UMF. All authors read and approved the final manuscript.

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## Tables

**Table 2** Prevalence and intensity of *Schistosoma* infection in the male adult population of Tibati and Wouldé

Localities	<i>Schistosoma haematobium</i>				<i>Schistosoma mansoni</i>			
	Number of subjects	Number of positive	Prevalence (%)	Intensity of infection (eggs/10 mL)	Number of subjects	Number of positive	Prevalence (%)	Intensity of infection (eggs/g)
Tibati	51 (57.30%)	16	31.37	22.12 (6.64 - 73.72)	51	2	3.92	24
Wouldé	38 (42.70%)	0	0	/	38	17	44.74	128.10 (67.66 - 242.60)

The geometric mean with 95% CI is used to express the intensity of infection.

**Table 4** Prevalence of genital tract pathologies in *Schistosoma haematobium*- or *Schistosoma mansoni*-positive men of Tibati and Wouldé

Ecology	SCH-negative (n = 54)	<i>Schistosoma</i> -infected individuals							
		<i>S. haematobium</i> (n = 16)				<i>S. mansoni</i> (n = 19)			
		Proportion	Proportion	Odds ratio	CI (95%)	P-value	Proportion	Odds ratio	CI (95%)
Total	22 (40.74%)	4 (25.00%)	0.4848	0.1565 - 1.6790	0.3782	10 (52.63%)	1.6160	0.5820 - 4.6740	0.4267
Sexualities									
Male	13 (24.07%)	2 (12.50%)	0.4734	0.0968 - 2.1130	0.4919	5 (26.32%)	1.3990	0.4457 - 4.568	0.7461
Female	11 (20.37%)	3 (18.78)	0.9020	0.2407 - 3.3764	> 0.9999	4 (21.05%)	1.0424	0.3250 - 3.9692	> 0.9999
Age									
Adult	7 (12.96%)	1 (6.25%)	0.4387	0.0365 - 3.0033	0.6694	4 (21.05%)	1.8901	0.5449 - 7.9074	0.4508
Child	4 (7.41%)	1 (6.25%)	0.7678	0.05893 - 5.4633	> 0.9999	2 (10.53%)	1.6538	0.2865 - 7.8212	0.6257

## Figures

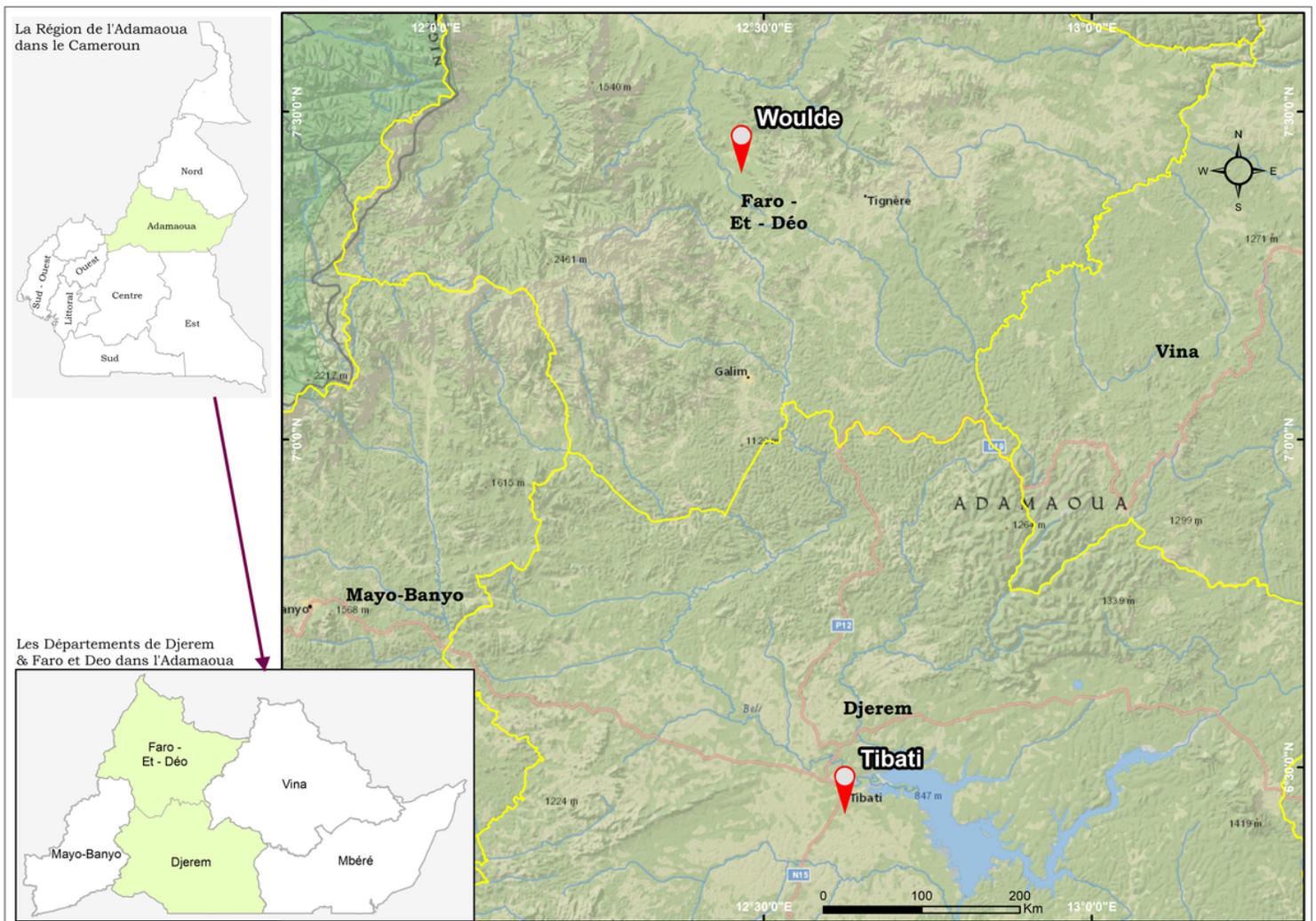
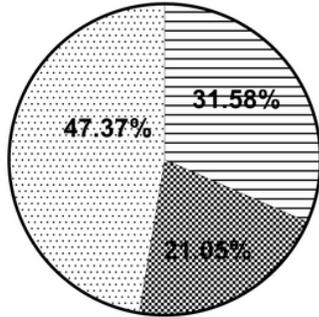


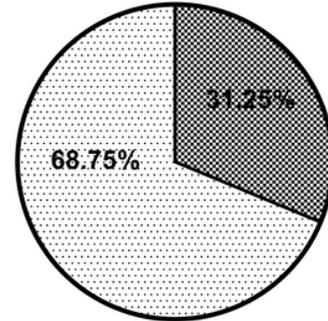
Figure 1

The vegetation of the Adamawa region falls within the rainforest – savannah mosaic and the climate is a sudano – guinean type with an annual rainfall of 1500 mm. Transmission of schistosomiasis presumably takes place at the lake, river, ponds and marshy fields. Fulbe and Kutin ethnic groups are predominant in Tibati and Wouldé and they are mainly Muslims.

### ***S. mansoni* intensity of infection**



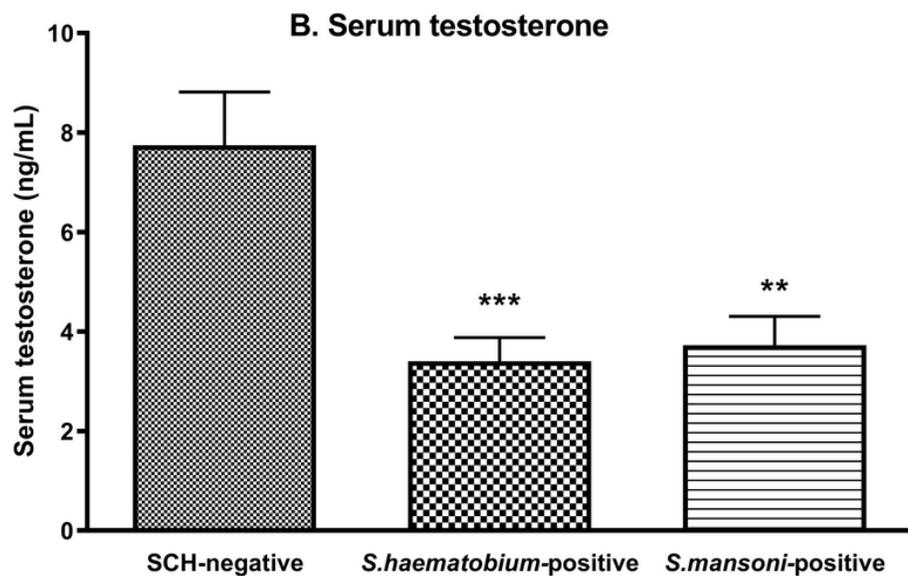
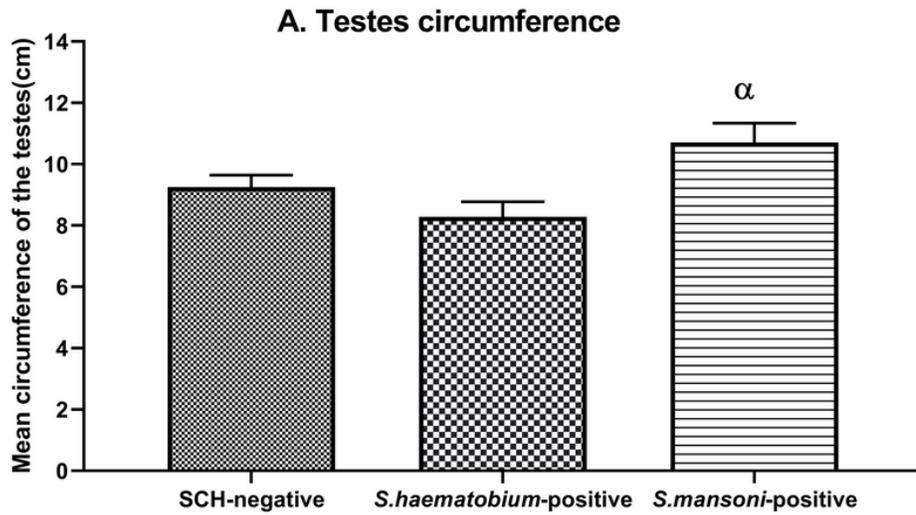
### ***S. haematobium* intensity of infection**



- ⋯ Light-intensity infection
- Moderate-intensity infection
- ▣ Heavy-intensity infection

**Figure 2**

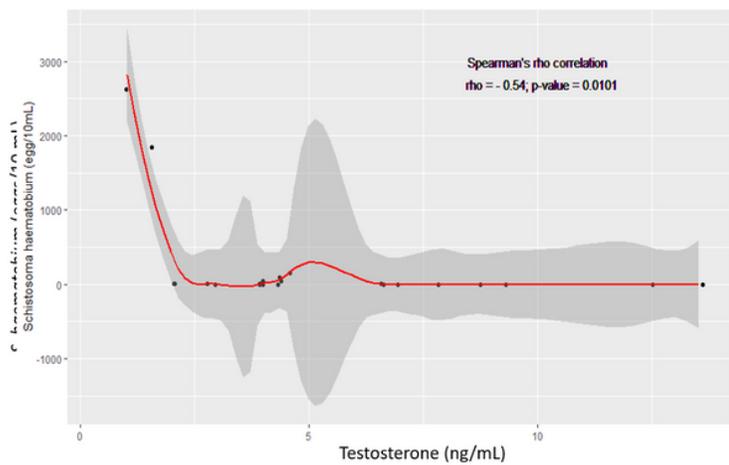
Degree of *Schistosoma* infection intensity in the adult male population of Tibati and Wouldé. Light-infection intensity: 1 - 99 epg; moderate-infection intensity: 100 - 399 epg; and heavy-infection intensity  $\geq$  400 epg for *S. mansoni* and for *S. haematobium*, light-infection intensity:  $<$  50 eggs/10 mL and heavy-infection intensity:  $\geq$  50 eggs/10 mL



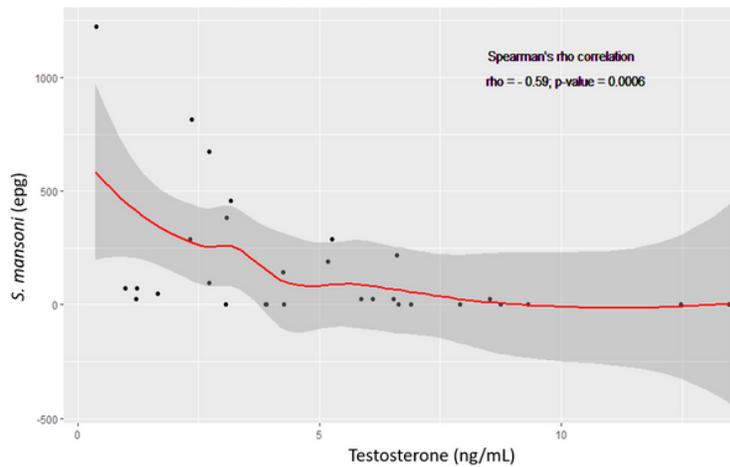
**Figure 3**

Mean testes circumferences (A) and serum testosterone levels (B) in *Schistosoma haematobium*- and *Schistosoma mansoni*-positive men in Tibati and Wouldé. Data are expressed as mean  $\pm$  SEM. ANOVA followed by Tukey's multiple comparison post hoc test was used for statistical analysis.  $\alpha P < 0.05$ : values are significantly different from those of *S. haematobium*-positive men.  $**P < 0.01$ ,  $***P < 0.001$ : values are significantly different from those of SCH-negative men.

**A. Correlation between *S. haematobium* infection and serum testosterone level**



**B. Correlation between *S. mansoni* infection and serum testosterone level**



**Figure 4**

Correlation curves between *Schistosoma haematobium* (A) or *Schistosoma mansoni* (B) intensity of infection and serum testosterone levels