Prevalence of *Schistosoma* mansoni–*Salmonella* coinfection among patients in southern Ethiopia

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Abstract

Concurrent infection with *Schistosoma mansoni* and *Salmonella* species is not uncommon in the endemic area of sub-Saharan Africa, although its prevalence may have regional variations. We discuss such coinfection and associated factors in an Ethiopian context. We assessed the prevalence of *S. mansoni* and *Salmonella* coinfections among patients attending two hospitals in southern Ethiopia. A facility-based cross-sectional study was carried out between 1 October and 30 November 2019. In total 271 participants with gastrointestinal complaints were selected through a systematic sampling technique. *S. mansoni* was detected using direct microscopy and formalin–ether concentration techniques, whereas *Salmonella* was identified by conventional culture methods and the Widal test. Antibiotic susceptibility test for *Salmonella* isolates was performed. The prevalence rates of *S. mansoni* and *Salmonella* infections were 17.30% and 7.70% respectively. The prevalence of *S. mansoni*–*Salmonella* coinfection was 7.7%. Of the factors analysed in connection with coinfection, male sex, age and frequency of exposure to contaminated water bodies were found to be statistically significant. *S. mansoni*–*Salmonella* coinfections pose a grave health problem in the study area, especially among children. Our conclusions can be used by the medical community to frame and implement intervention strategies for the management of *S. mansoni*–*Salmonella* coinfections.
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Introduction

Schistosomiasis is a neglected tropical disease and it remains the second most afflicting parasitic illness especially in sub-Saharan African countries [1]. According to some recent reports, schistosomiasis has been documented in more than 40 nations in Africa, specifically in poor communities without safe drinking water or adequate sanitation [1]. The distribution and prevalence of schistosomiasis have increased over the past few decades, mainly because of construction of hydroelectric projects and dams as well as the existence of floating populations [2]. A recent estimate in this context by the World Health Organization (WHO) indicated that about 240,000,000 people are infected worldwide, another 700,000,000 are at greater risk in Africa alone and more than a quarter of a million perish annually [3]. It has been reported that in the second largest continent, per year, loss of half a billion US dollars is due to the menace of schistosomiasis [4]. Also, it has been estimated that about 54,000,000 are infected with, and more than seven times this number are living with an immediate risk of being affected by, *Schistosoma mansoni* [5].

The coinfection of *Schistosoma* with other microorganisms is a common phenomenon and often presents a clinical picture of schistosomiasis [6]. Among them, enterobacterial coinfections by *Salmonella* species has been reported for more than 50 years, causing morbidity [6,7]. *Salmonella* is a frequently found bacteria which results in invasive infection, especially in the least developed nations of Africa and their poor healthcare systems, including Ethiopia [8]. The WHO estimates that 16,000,000–33,000,000 cases of typhoid fever with almost a

quarter of a million deaths happen annually, and those who die are mostly juveniles [9].

S. mansoni—*Salmonella* coinfection is considered to be a public health problem and a challenge to clinical management [10]. It is estimated that more than 20 species of *Salmonella* of human or animal origin may be associated with schistosomes [11]. A recent study in coinfected patients hints at the symbiotic relationship existing between the bacteria and the parasite [12]. Concurrent infections occur when enteroinvasive *Salmonella* penetrates into the systemic circulation of the victim and adheres to the tegument of adult *Schistosoma* [13]. The coinfection produces a set of clinical manifestations, such as indolent febrile illness, weight loss, abdominal pain, pallor, edema of lower limbs, marked hepatomegaly and splenomegaly [13]. Therapy for *Salmonella* infection without treating the underlying schistosomiasis may later result in a relapse of bacteraemia and related symptoms [14]. In addition, *Salmonella* bacteraemia has been associated with glomerulonephritis and nephrotic syndrome in individuals infected with *S. mansoni* [15]. Some evidence substantiates the notion that that schistosomes and *Salmonella* share antigens responsible for immunologic tolerance to the bacterial infection [13]. Furthermore, latent bacteria in the parasite lead to ineffective antibiotic therapy, and such bacteria cannot be completely eliminated, eventually resulting in drug resistance and the emergence of multidrug-resistant *Salmonella* [11,16].

Recently it has become clear that coinfection with *S. mansoni*—*Salmonella* is common in endemic areas where people are exposed to both of the pathogens, resulting in high morbidity and mortality [16]. Schoolchildren younger than 15 in deprived communities are the most affected; however, people of all ages can become infected [17]. In several schools, it is one of the commonest reasons for students' poor academic and physical performance as well as absenteeism [18]. A fragile healthcare system combined with lack of adequate supply of potable water, unsanitary conditions and poor personal hygiene in African countries make *S. mansoni*—*Salmonella* coinfection difficult to contain [19].

Most of the African nations are known for coinfections by *S. mansoni*—*Salmonella*, both of which are waterborne pathogens. A literature survey indicates that the prevalence and distribution of *S. mansoni*—*Salmonella* coinfection in endemic countries of Africa has not been studied extensively so far. *S. mansoni*—*Salmonella* coinfections are endemic in many regions of Ethiopia too, but this fact remains unstudied. All the studies performed to date nationally in Ethiopia focus merely on infections caused by either *S. mansoni* or by *Salmonella*. Routine health surveillance is needed in the case of people living in endemic areas like Jinka, a deep southern Ethiopian valley, as they have poor living conditions and are often exposed to

contaminated water bodies, which makes them highly vulnerable to coinfections. If the coinfection is not properly diagnosed or promptly treated, it can eventually become severe. Therefore, studies related to local prevalence and risk factors associated with *S. mansoni*—*Salmonella* coinfection are relevant.

We performed the present study to assess the prevalence rates of *S. mansoni* and *Salmonella* infections separately and to evaluate more precisely the coinfection rates among patients attending Jinka General Hospital and the Jinka Millennium Health Center, Jinka, a remote southern area in the Southern Nations, Nationalities and People's Region (SNNPR), a regional state of Ethiopia.

Methods

Study area, design, period and study population
A cross-sectional study was designed and carried out at two government health facilities in Ethiopia: Jinka General Hospital and the Jinka Millennium Health Center. These two primary healthcare institutions (located in Jinka, the capital of the South Omo Zone of the SNNPR) receive a large number of patients, approximately 50,000 annually. Jinka prefecture has a river with tributaries, some streams, several rain-fed ponds and shallow water bodies that are utilized commonly by humans as well as wild and domesticated animals. The study area is known for a large number of cases of schistosomiasis and typhoid fever as a result of poor sanitary conditions, with the former being more or less endemic. During the study period between 1 October and 30 November 2019, a total of 271 individuals were selected from a larger group of patients. The inclusion criteria were as follows: suspected cases (i.e. those with gastrointestinal manifestations) for which physicians recommended either stool examination alone or both stool examination and the Widal test. The exclusion criteria were patients (a) undergoing treatments for schistosomiasis and *Salmonella* infection, (b) severely affected but unable to communicate, (c) less than 5 year old, (d) residing outside the study site and (e) who did not submit a written consent to participate. The study was ethically approved by the institutional review board of the College of Medicine and Health Sciences, Arba Minch University (IRB/0203195/11/01/11).

Sample size determination and sampling technique
The sample size was calculated using a single population proportion formula. A p value of 0.2 was chosen from a study performed in Sudan [20]. After considering a confidence interval (CI) of 95% (z = 1.96) and a 5% marginal error (d = 0.05), the initial sample size was estimated to be 256; after computing a 10% nonresponse rate, the final sample size was 271. The selection of

study participants from Jinka General Hospital and the Jinka Millennium Health Center was done by proportional allocation corresponding to each institution. A systematic random sampling technique was chosen to recruit the study participants. The sampling interval was calculated by dividing the total number of target patients by the sample size. The Kth value was inferred from the number of patients on a daily basis who used the stool examination facilities in these two health institutions during the study period. Individuals were selected by lottery.

Data and specimen collection
Before data and sample collection, written informed consent was obtained from all the participants, including the parents of children, after receipt of a clear briefing about the purpose of the study. Interviews were conducted with the aid of well-trained health professionals. Relevant details related to the sociodemographic (age, sex, occupation, educational level and residence) and environmental/behavioral (presence of latrine, source of drinking water) status of each participant were solicited by a face-to-face interview by means of a pretested structured questionnaire. Five grams of fresh stool specimen was collected from each participant aseptically into a clean, dry, sterile, wide-mouthed plastic container equipped with a spoon, labeled with an identification code. For the detection of *S. mansoni* eggs, each faecal sample was examined microscopically (10 × and 40 × objectives) using the direct wet mount and stool concentration technique (formalin—ether concentration technique), as described previously by Cheesbrough [21]. The Widal test was used for the diagnosis of enteric fever by using 5 mL of blood. Anti-*Salmonella* antibodies were detected according to the nationally approved standard using the Widal agglutination kit (Murex Biotech, UK) comprising the polyvalent somatic (O) and flagella (H) antigens of *Salmonella enterica* serovar Typhi and *Salmonella enterica* serotypes Paratyphi A, B and C. For the slide agglutination test, a drop of serum from each patient was placed on a clean tile and mixed with antigens, then rocked for 3 minutes. Antibody titration was performed only for slide-reactive samples. The titre values of 1:80 for O and 1:160 for H antigens in a single analysis were considered the cutoff points for a positive results as per standard recommendation [22]. All positive samples were reinspected by an experienced laboratory technologist at the Jinka Regional Public Health Laboratory for further confirmation. A third reader (an experienced microbiologist from the Medical Microbiology and Parasitology Laboratory, Department of Medical Laboratory Science, College of Medicine and Health Sciences, Arba Minch University) also checked the results to eliminate any discordance, if present. To avoid any bias, all the laboratory technologists who were involved were unaware of the results.

To confirm the *Salmonella* infection, stool specimens were cultured [23]. A small portion of the freshly collected stool sample was inoculated into selenite F broth (Oxoid, UK) and incubated at 37°C for 24 hours. After the preenrichment period, the broth was subcultured onto xylose lysine deoxycholate (XLD) agar (Oxoid) and further incubated at 37°C for 24—48 hours. The pure cultures of bacterial isolates were subsequently subjected to species identification and confirmation. Morphologic, biochemical and physiologic characteristics of isolated bacteria were ascertained by using standard laboratory methods as described by Margot et al. [23]. Corresponding American Type Culture Collection strains were utilized as reference standards to validate the biochemical identification of *Salmonella*.

Antimicrobial susceptibility test
The antibiotic susceptibility profiles of all *Salmonella* isolates were determined by the Kirby-Bauer disc diffusion technique according to the criteria set by the Clinical and Laboratory Standards Institute (CLSI) using Oxoid antibiotic discs. Inocula were prepared in sterile normal saline and its density adjusted to 0.5 McFarland standard. The test organisms were inoculated over the Müller-Hinton agar (Oxoid), exposed to a concentration gradient of antibiotic diffusion from an impregnated paper disc and then incubated at 37°C for 24 hours. The diameters of the zones of inhibition around the discs were measured to the nearest millimeter and categorized as sensitive, intermediate and resistant according to the CLSI standardized table. *Salmonella* spp. which exhibited resistance to three classes of antibiotics were considered as multidrug resistant (MDR). A series of antibiotic discs such as ampicillin (10 μg), amoxicillin/clavulanic acid (30 μg), ceftriaxone (30 μg), cefotaxime (5 μg), gentamicin (10 μg), amikacin (30 μg), tetracycline (30 μg), ciprofloxacin (5 μg), chloramphenicol (30 μg), nalidixic acid (30 μg) and cotrimoxazole (25 μg) were used.

Statistical analysis
The data were cleaned, edited, checked for completeness, entered to Epi Info 3.5.3 (Centers for Disease Control and Prevention, USA) and exported to SPSS 20 (IBM, USA). It was then analysed by means of descriptive data; frequencies and percentages were used to describe patient characteristics. Outputs of statistical analysis were presented in the form of tables, charts and graphs. Bivariate logistic regression analysis was used to identify the associated factors among dependent and independent variables. The variables with statistical significance ($p < 0.25$) thus obtained were then subjected to a multivariate logistic regression analysis. The p values which were ≤0.05 at 95% CI were considered to indicate a statistical association.

Results

Sociodemographic characteristics

A total of 271 eligible participants were included in this study, with a response rate of 100%. The ages of participants ranged from 5 to 70 years with a mean ± standard deviation of 23 ± 9 years. Male-to-female ratio was 1.5:1. More than a third of the participants, 102 (37.60%), were within the age range of 5−15 years, and the student population was 76 (28%). A wafer-thin majority of participants, 141 (52%), were residents of a rural area, and 84.50% of the households in the study area, Jinka, had latrine facilities. A total of 53.5% of the participants had had contact with water bodies on at least some occasions (seldom). The detailed sociodemographic characteristics of individuals are summarized in Table 1.

Prevalence of *S. mansoni* and associated factors

Results of the unstained wet mount examination revealed that of 271 stool samples, only 47 (17.30%) were positive for *S. mansoni*. A total of 37 (13.60%) stool samples from Jinka General Hospital and 10 (3.60%) from the Jinka Millennium Health Center were infected with *S. mansoni* (Fig. 1).

Aspects of the association among sociodemographic and other selected variables with respect to *S. mansoni* infection are summarized in Table 1. Among different factors analysed, gender, age and frequency of contact with contaminated water bodies were found to be independent predictors of infection. Bivariate logistic analysis revealed that *S. mansoni* infection in male participants was 2.70 times greater (Crude Odds Ratio (COD) 2.7 (95% CI, 1.20−6), p 0.14) than in female participants. Likewise, children were found to be 2.20 times more prone to be infected (COD 2.20 (95% CI, 1.05−4.90), p 0.37) with *S. mansoni*. In addition, it was found that those who had frequent contact with contaminated water had a tripled chance of being infected (COD 3.40 (95% CI, 1.30−36), p 0.02) compared to the reference category. However, no statistically significant associations were observed among *S. mansoni* infection and residential status, occupation or presence of a latrine at home.

Prevalence of *Salmonella* infection and associated factors

In the present study, the Widal agglutination test and stool culture techniques were used for the diagnosis of *Salmonella* infection (Table 1). This test had revealed that of the 271 blood

TABLE 1. *Schistosoma mansoni–Salmonella coinfection: sociodemographic characteristics of the study participants, October–November 2019 (n = 271)*

Characteristic	Total samples	S. mansoni–infected patients (n = 47) n (%)	p	Salmonella-positive patients (n = 21) n (%)	p	Salmonella and S. mansoni coinfection (n = 21) n (%)	Adjusted OR (95% CI)	p
Gender								
Male	165	38 (23.30)	0.014	17 (10.30)	0.60	17 (10.30)	2.51 (1.109−4.62)	0.010
Female	106	9 (8.49)	Ref	4 (3.70)	Ref	4 (3.77)	Ref	
Age category								
5−15 years	102	31 (65.90)	0.037	9 (8.80)	0.27	9 (8.82)	3.19 (1.10−9.20)	0.008
16−30 years	93	11 (23.40)	0.27	9 (9.60)	0.89	9 (9.67)	2.03 (0.62−6.65)	NS
31−45 years	70	5 (10.60)	0.29	3 (4.20)	0.29	3 (4.28)	1.23 (0.27−5.59)	NS
>46 years	6	0	Ref	0	Ref	0	Ref	
Place of residence								
Rural	141	44 (31.20)	0.75	13 (9)	0.77	13 (28.88)	Ref	0.177
Urban	130	3 (2.30)	Ref	8 (6.10)	Ref	8 (6.15)	2.40 (0.84−6.81)	
Occupational status								
Employed	7	0	0.29	0	Ref	0	Ref	
Housekeeper	55	2 (3.63)	Ref	4 (7.20)	0.776	4 (7.27)	3.42 (1.12−10.43)	NS
Merchant	68	1 (1.47)	0.75	3 (8.60)	0.37	3 (8.68)	6.23 (0.57−67.12)	NS
Student	76	39 (51.31)	0.14	12 (15.70)	0.64	12 (15.78)	1.8 (0.40−6.90)	NS
Other	65	5 (7.69)	0.37	2 (3.07)	0.77	2 (3.07)		NS
Educational status								
Illiterate	92	13 (14.13)	0.08	8 (8.80)	0.86	7 (7.6)	0.25 (0.01−3.54)	NS
Can read and write	136	28 (20.50)	0.24	34 (65.30)	0.53	11 (8.08)	3.40 (0.59−19.50)	NS
Grade (1−10)	37	6 (16.21)	0.54	5 (11.60)	Ref	3 (22.50)	Ref	NS
Tertiary-level education	6	0	Ref	8 (8.80)	0.86	0	0.717 (.12, 3.99)	NS
Habit and frequency of contact with water body								
Frequently	57	34 (59.64)	0.02	8 (8.80)	0.86	13 (9)	2.78 (0.81−9.68)	0.001
Seldom	145	13 (8.96)	0.72	34 (65.30)	0.53	8 (5.50)	0.25 (0.019−3.49)	NS
Not at all	69	0	Ref	5 (11.60)	Ref	0	Ref	
Drinking water source								
Bono water	86	0	Ref	0	Ref	0	Ref	
Standpipe	90	8 (8.80)	0.64	5 (5.50)	0.77	5 (5.50)	3.54 (1.09−11.5)	NS
River water	52	34 (65.38)	0.58	13 (25)	0.68	13 (25)	0.04 (0.008−1.2)	NS
Well	43	5 (11.62)	0.81	3 (6.97)	0.62	3 (6.97)	2.69 (2.31−183.1)	NS
Latrine present	42	38 (90.4)	0.74	19 (90.40)	0.66	19 (90.47)	0.016 (0.001−0.8)	NS

CI, confidence interval; OR, odds ratio; NS, not significant. Reference, p ≤ 0.05.
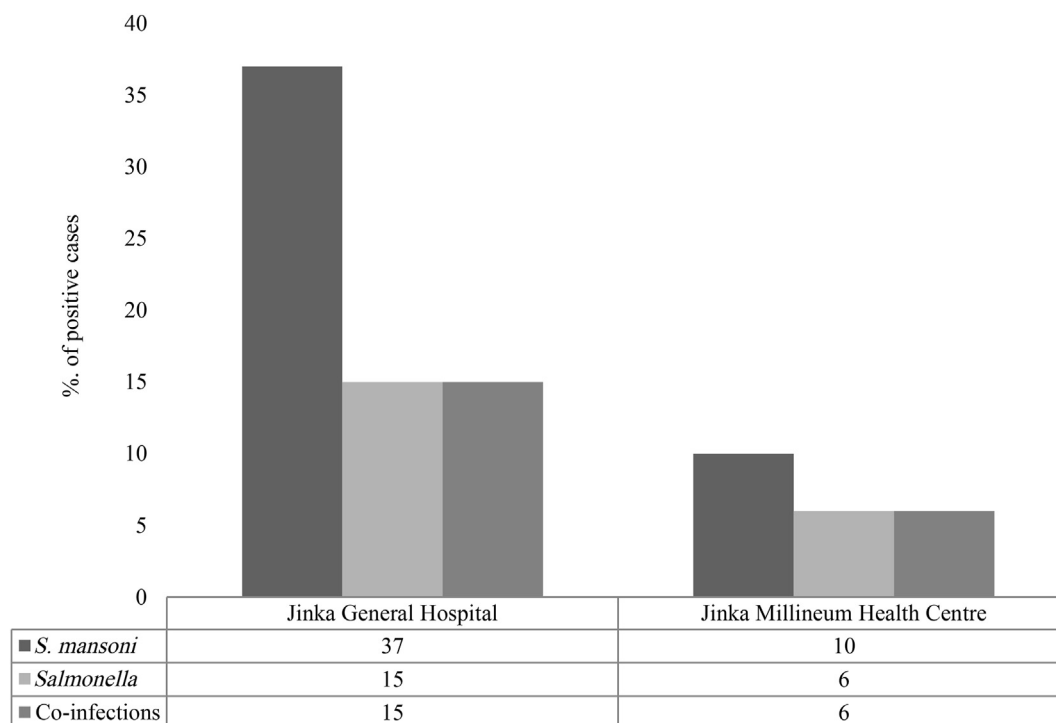
FIG. 1. Distribution of *Schistosoma mansoni*, *Salmonella* and their coinfection in relation to health institutions. Out of 47 intestinal schistosomiasis patients, 37 (78.70%) were from Jinka General Hospital and ten (21.30%) were from Jinka Millennium Health Center. Results demonstrated that of 21 *Salmonella*-positive patients, 15 (71.40%) were from Jinka General Hospital and six (28.57%) were from Jinka Millennium Health Center. Number of coinfected patients was 15 from Jinka General Hospital and 6 from Jinka Millennium Health Center.

samples screened, 21 (7.70%) were positive for *Salmonella* infection. The prevalence of *Salmonella* infection among *S. mansoni*—infected patients was 2.20% according to the results of the stool culture (Supplementary Data). However, compared to the results of the stool culture, the number of positive cases detected by the Widal test was quite high, making the Widal test a more effective method for the diagnosis of *Salmonella* in the present scenario. Extrapolation found the overall prevalence of *Salmonella* infection to be 7.70%. Regarding the detection of *Salmonella* infection, 15 cases (5.50%) from Jinka General Hospital and 6 (2.20%) from the Jinka Millennium Health Center were found to be positive (Fig. 1).

Table 1 shows the association among sociodemographic status and other selected variables with the infection rate of *Salmonella* spp. Bivariate analysis revealed that the prevalence of *Salmonella* was significantly associated with *S. mansoni* (COD 2.50 (95% CI, 5—19), p 0.04). However, no significant association was found for sociodemographic variables (age, residential status, occupation and source of drinking water) and *Salmonella* spp. infection.

Prevalence of coinfection by *S. mansoni*—*Salmonella* spp. and associated factors
The number of coinfections reported from Jinka General Hospital and the Jinka Millennium Health Center were 15 (5.50%)

and 6 (2.20%) respectively (Fig. 1). This means that the total number of coinfected cases from the present study is 21 (7.70%). The total number of cases of *S. mansoni* infection for both study sites is 47 (17.30%), whereas the combined figure for the positive cases of *Salmonella* infection is 21 (7.70%). It is evident from Fig. 1 that all positive cases of *Salmonella* (inclusive of both study settings) are invariably coinfected with *S. mansoni*.

Various factors were analysed to elucidate the association between *S. mansoni* and *Salmonella* spp. existing in coinfected individuals. In the logistic regression analysis, male sex (adjusted odds ratio (aOR) 2.50 (95% CI, 1.10—4.60), p 0.01), children (age ≤ 15 years) (aOR 3.19 (95% CI, 1.10—9.20), p 0.008) and frequency of contact with contaminated water bodies (aOR 2.78 (95% CI, 0.81—9.68), p 0.001) were the factors found to be statistically significant (Table 1).

Antibiotic susceptibility patterns
Antibiotic susceptibility patterns of all *Salmonella* isolates were confirmed using 11 antibiotics (Table 2). We found that the isolates varied considerably in their susceptibility to all the antimicrobials tested. The percentage of isolates resistant to ampicillin was 100%. However, 66% of the isolates showed resistance to both cotrimoxazole and tetracycline, and 50% exhibited resistance to ciprofloxacin. For the most part, all the

TABLE 2. Antibiotics susceptibility pattern of six *Salmonella* isolates

Antimicrobial agent	Resistant	Intermediate	Susceptible
Ampicillin	6 (100)	0	0
Amoxicillin/clavulanic acid	0	0	6 (100)
Ceftriaxone	2 (33)	1 (16)	3 (50)
Cefotaxime	0	0	6 (100)
Gentamicin	1 (16)	2 (33)	3 (50)
Amikacin	0	0	6 (100)
Tetracycline	4 (66)	1 (16)	1 (16)
Ciprofloxacin	3 (50)	1 (16)	2 (33)
Chloramphenicol	2 (33)	2 (33)	2 (33)
Nalidixic acid	2 (33)	1 (16)	3 (50)
Cotrimoxazole	4 (66)	0	2 (33)

Data are presented as *n* (%).

isolates were susceptible to amoxicillin/clavulanic acid, cefotaxime and amikacin. In this study, we defined MDR as resistance to three or more groups of the antibiotics tested. A notable result obtained from the present study is that 50% (n = 3) of the isolates can be considered MDR.

Discussion

Despite the control measures in place, the magnitude and impact of *S. mansoni*−*Salmonella* coinfections are gradually rising in Ethiopia. Our findings provide some baseline information on the individual prevalence of *S. mansoni* and *Salmonella* infections as well as the coinfection rates among patients attending Jinka General Hospital and the Jinka Millennium Health Center, Jinka, Ethiopia. It was found that the individual prevalence rates of *S. mansoni* and *Salmonella* and their coinfection rates differ only slightly as far as these two health institutions are concerned.

The rate of *S. mansoni* infection in the study area was 17.30% – a result similar to an earlier study conducted in the same locality with another study population [24]. Results of a previous meta-analysis showed that the pooled prevalence of *S. mansoni* among Ethiopians was 18.30%; also, it is region specific [24]. For instance, an earlier study conducted in southern Ethiopia had reported a higher regional prevalence of 33.60% [25]; this was comparatively much higher than our results. However, the prevalence rate we found is above the values reported from Nigeria (12%) [26] and Sudan (12%) [27]. These fluctuations could be connected to the method used for the diagnosis of *S. mansoni*, type of study participants and sample size. We have found that infection by *S. mansoni* had a statistical association with some variables. Male patients (n = 38) outnumbered female patients; this is in agreement with the findings of previous studies conducted in another region of

Ethiopia [28] and also Sudan [27]. It was also found that a majority (n = 31) of positive cases occur in children aged 5 to 15; this finding is by and large consistent with the data in the existing literature [29,30]. A possible reason for the higher prevalence rate of *S. mansoni* in children might be attributed to their frequent recreational activities in muddy, contaminated and stagnant water bodies, which are laden with snails infected with *S. mansoni*. In addition, the rate of infection was pronounced among respondents who have frequent contact with contaminated water bodies; the extent is comparable to the results reported from other regions of Ethiopia [28,31]. Nevertheless, higher prevalence rates were observed among participants from rural areas without household latrines, although this result was not statistically significant.

The prevalence rates of *Salmonella* observed by Widal agglutination and stool culture techniques were 7.70% and 2.20% respectively. By extrapolation, the overall prevalence of *Salmonella* infection was 7.70%. These data are more or less similar to the previous findings of two independent studies from Ethiopia and Nigeria [29,30] but is much lower than the extent of prevalence described by some other authors in Ethiopia [32,33]. Nevertheless, the rate of *Salmonella* infection currently observed was relatively lower than *S. mansoni* infection, and almost all *Salmonella*-infected patients were positive for *S. mansoni*, considering both health institutions. Indeed, *Salmonella* infection is statistically significant in patients already infected with *S. mansoni*. It has been reported that patients with *Schistosoma* infection are more vulnerable to concurrent infection with *Salmonella* than patients without *Schistosoma* infection [34].

Our results indicate a higher coinfection rate compared to that reported by a series of studies performed in the Democratic Republic of Congo and Sudan (2.20%, 3.40%, 3.80%) [12,27,35]. In contrast, the currently observed rate of coinfection is lower than that reported from Nigeria [16], with the latter showing a prevalence of 8.80%. In addition, another study performed earlier in Sudan showed a higher prevalence rate of coinfection (22.60%) [20]. Furthermore, a study performed in Nigeria about coinfection among patients with typhoid fever reported a prevalence of 12.50% [26]. The comparatively lower rate of coinfection observed by us could be attributed to variations in sample sizes, sociodemographic characteristics, degree of sanitation and hygiene among the study populations as well as the nonuniformity in studies duration. However, further comprehensive evaluations are required to arrive at the exact reason.

Another important aspect of our study is our finding that the utilization of molecular diagnostic techniques (e.g. quantitative PCR) for quantification of the extent of infection by *S. mansoni* or

and *Salmonella* always resulted in rapid detection and accurate estimation, providing exact and higher rate of prevalence compared to conventional microscopic and serologic methods [36,37]. These techniques, particularly quantitative PCR, are more sensitive and provide an accurate measurement of the intensity of infections, especially in large-scale epidemiologic surveys; they are also useful in monitoring therapeutic responses [36].

We found that factors that influence coinfection are sex, age and frequency of contact with contaminated water bodies. Widely differing percentages of *S. mansoni*–*Salmonella* coinfections were observed when comparing the number of cases by sex, with 17 male (10.30%) and four female (3.70%) subjects, which is similar to the results reported from Sudan [27]. The reason for this male preponderance could be attributed to a higher degree of exposure among men as a result of their occupational, domestic and leisure activities [27]. In contrast with our results, a study conducted in Nigeria showed that the extent of coinfection was higher among female subjects (28.60%) [16]. Also, it can be inferred that the age of participants can affect the prevalence and severity of *S. mansoni*–*Salmonella* coinfection. We found that the coinfection rate was higher among schoolchildren; these data are comparable to the results of several studies conducted earlier in Nigeria [16,30]. The infection rate was pronounced among study subjects frequently exposed to contaminated water bodies. It is a well-acknowledged fact that lack of hygiene, frequent recreational activities in muddy riverbanks and contaminated, stagnant water bodies make humans vulnerable to infections [18]. Prevention of infection is highly related to improved sanitation, including effective sewage treatment, as well as avoiding contact with contaminated water bodies.

For the effective treatment of enteric fever, understanding the drug susceptibility patterns of *Salmonella* spp. is essential. Development of MDR among *Salmonella* isolates is a major crisis which limits the drug of choice for the treatment of enteric fever. In the present study, a high degree of resistance was found, particularly against three antibiotics (i.e. ampicillin, tetracycline and cotrimoxazole). This finding is similar to a recent meta-analysis performed on the drug resistance patterns of *Salmonella* spp. from different regions of Ethiopia. All the *Salmonella* isolates showed resistance to ampicillin. This result is in line with earlier Ethiopian studies [38,39]. In addition, 66% *Salmonella* spp. isolates exhibited resistance to both cotrimoxazole and tetracycline. This is in line with results documented in earlier studies performed in various regions of the country [38–41]. According to the WHO, MDR exhibited by species of *Salmonella* is currently a serious global concern. In the present study, 50% of the isolates were found to be MDR; we think that this is likely to be correlated with the long-term use of the above mentioned antibiotics. In addition, a notable result of the present study is that all the isolates showed 100% sensitivity to amoxicillin/clavulanic acid, cefotaxime and amikacin, indicating the possibility of using these drugs to manage enteric fever in Jinka.

Conclusions

This is the first report on the prevalence of *S. mansoni*–*Salmonella* coinfection among patients attending two health institutions in Jinka, Ethiopia. The individual prevalence rate of *S. mansoni* and *Salmonella* infections in the present study were 17.30% and 7.70% respectively. The overall prevalence of *S. mansoni*–*Salmonella* coinfection was found to be 7.70%. It was identified that all cases of *Salmonella* infection at both health institutions had *S. mansoni* coinfection. In addition, sex, age and frequency of contact with contaminated water bodies were identified as independent predictors of coinfection. Fifty percent of *Salmonella* isolates were found to be MDR. Overall results indicate that *S. mansoni*–*Salmonella* coinfection is a growing health problem in the study area, especially among children. Therefore, large-scale control programs such as screening, diagnosis, treatment and surveillance as well as improved sanitary and hygiene practices, along with provision for safe water sources, are essential in the study area. Further, an in-depth and broader approach to research on disease epidemiology is also warranted.

Shortcomings of the present work include the cross-sectional design with a relatively small sample size and short duration. In addition, in the clinical context, the results of the Widal test cannot be considered conclusive. Finally, for the antisera, species-level identification was not performed to differentiate among the *Salmonella* spp. isolates.

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Conflict of interest

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.nmni.2021.100842.

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