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Water, sanitation and schistosomiasis mansoni: a study based on the Brazilian National Prevalence Survey (2011-2015)

Água, saneamento e esquistossomose mansoni: um estudo baseado no Inquérito Nacional de Prevalência do Brasil (2011-2015)

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Abstract *This study aimed to explore the association between water, sanitation, and the prevalence of schistosomiasis mansoni in students aged 7 to 17 years from all 27 federative units in Brazil. It was a cross-sectional study conducted based on data on the prevalence of schistosomiasis mansoni referring to 197,567 students from 521 Brazilian municipalities, who participated in the National Survey on the Prevalence of Schistosomiasis Mansoni and Soil-transmitted Helminth Infections (2011-2015). Univariable and multivariable generalized linear models of the negative binomial type were adjusted using 25 and 5% significance levels, respectively, considering municipalities as the unit of analysis. While a protective association was found between access to filtered water in schools and schistosomiasis mansoni prevalence, sanitation in schools was indicated as a risk factor. The collection of wastewater through a network is not universal in Brazil, and even when present, it is not necessarily carried out by the treatment of collected effluents, thus often resulting in the direct discharge of raw sewage into water resources. Regarding septic tanks, only the presence of infrastructure alone does not guarantee its correct use by the population.*

Keywords *Drinking water, Sanitation, Schistosoma mansoni, Brazil*

Resumo *O presente trabalho teve como objetivo explorar a associação entre água, saneamento e a prevalência de esquistossomose mansoni em estudantes de 7 a 17 anos de todas as 27 unidades federativas do Brasil. Tratou-se de um estudo transversal, conduzido com base nos dados de prevalência de esquistossomose mansoni referentes a 197.567 estudantes de 521 municípios brasileiros que participaram do Inquérito Nacional da Prevalência de Esquistossomose Mansoni e Geo-helmintoses (2011-2015). Modelos lineares generalizados do tipo binomial negativo, univariável e multivariável foram construídos considerando níveis de significância de 25% e 5%, respectivamente, e os municípios como unidade de análise. Embora os resultados tenham indicado associação protetora entre o acesso à água filtrada nas escolas e a prevalência de esquistossomose mansoni, o acesso ao saneamento nas escolas foi apontado como um fator de risco. A coleta de águas residuais por rede não é universal no Brasil e, mesmo quando presente, não é necessariamente procedida pelo tratamento dos efluentes coletados, resultando, muitas vezes, no lançamento direto do esgoto bruto em matrizes aquosas. Com relação a soluções individuais como fossa sépticas, a presença da infraestrutura por si só não garante o seu uso correto pela população.*

Palavras-chave *Água potável, Saneamento, Schistosoma mansoni, Brasil*

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Introduction

Faced with a dilemma of a country in the midst of a series of illnesses, doctor Miguel Pereira in 1916 declared that "Brazil is an enormous hospital"[1]. More than a century after his testimony, the country still faces difficulties in changing this reality.

According to data published by the World Health Organization (WHO)[2], in 2016, Brazil was the country in Latin America with the highest number of people requiring interventions against Neglected Tropical Diseases (NTDs). It was estimated that in the same year, NTDs accounted for 475,410 Disability Adjusted Life Years (DALYs) in the country, with schistosomiasis being the second-largest contributor[3]. Still, according to the WHO data[4], in 2018, 1,535,838 Brazilians required preventive chemotherapy for schistosomiasis. This last estimate, however, was based on the stipulated number of people at risk of infection and did not take into account national parasitological surveys.

Hitherto, Brazil faced a lack of statistical data showing the real national prevalence of schistosomiasis mansoni. From 1949 to 1978, only two nationwide surveys on the prevalence of schistosomiasis mansoni in school-aged children were conducted in Brazil, and none of them covered all Brazilian Federation Units[5]. After this period, all the studies conducted in Brazil regarding the prevalence of schistosomiasis mansoni were local studies (community, cities, villages). Bearing that in mind, the first National Survey on the Prevalence of Schistosomiasis mansoni and Soil-transmitted helminth infections (2011-2015) in Brazil was carried out covering all the 27 Brazilian Federation Units[5]. It was a school-based cross-sectional study with the objective of determining the current prevalence of schistosomiasis mansoni, trichuriasis, hookworm, and ascariasis, in schoolchildren from 7 to 17 years old. It was also intended to verify whether the prevalence of schistosomiasis mansoni in endemic areas was lower than that observed in the two previous surveys. For this purpose, 197,564 school-aged children living in 521 municipalities distributed in all five geographical regions of the country were examined[5].

Compared with previous surveys, the results of this research, published in 2018, showed a significant reduction in the schistosomiasis mansoni prevalence. However, high rates of schistosomiasis positive results were still found in the municipalities of the Northeast and Southeast regions of the country[5]. The improvement of the access to water, sanitation, and hygiene (WASH) that occurred in the last decades in Brazil, was one of the conjectures to explain the new epidemiological profile of the country.

Although studies have already reported the protective effect of access to WASH against schistosomiasis mansoni[6-9], the relationship between these determinants and the occurrence of the disease is not entirely clear. The effectiveness of WASH relies on its combination with other factors, such as social, cultural, educational aspects and the particular way in which solutions are designed and implemented.

Therefore, in order to better understand the role that WASH has played in the control of schistosomiasis mansoni infection in the recent decades in Brazil, as indicated by the data of the third National Survey, the present study aimed to assess the existence of association between water, sanitation and the prevalence of schistosomiasis mansoni in schoolchildren from 7 to 17 years old, in the 27 Brazilian Federation Units.

Methods

Study design

The current epidemiological study can be classified as ecological, explanatory, observational, and non-directional (cross-sectional).

Database

Prevalence of schistosomiasis mansion was used as the outcome variable and municipalities as the geographical unit of analysis. Data were retrieved by the National Survey on the Prevalence of Schistosomiasis mansoni and Soil-transmitted helminth infections (2011-2015)[5]. They are anonymous and available for research purposes by the Brazilian government. Moreover, The National Survey was approved by the Ethics and Research Committee of the René Rachou Research Center – Oswaldo Cruz Foundation and the National Research Ethics Commission – CONEP. Informed consent for participation was obtained from the students' parents.

The National Survey was a school-based cross-sectional study conducted by the Oswaldo Cruz Foundation (FIOCRUZ) in 521 municipalities distributed in all five regions of the country, with the objective of assessing the current prevalence of schistosomiasis mansoni and STH in

schoolchildren aged 7-17 years. Although it was the third national survey of schistosomiasis mansoni carried out in the country, it was the first to cover all Brazilian states. Each municipality was surveyed only once. Details about the survey, including its sample strategy, are presented in Portuguese[5] and English language[10].

Fifteen explanatory variables were examined, namely: (1) seven main explanatory variables expressing the water and sanitary conditions in households as well as in schools; (2) six confounding variables and; (3) two sampling variables related to the National Survey's sampling strategy inserted in order to minimize possible sampling bias (Table 1).

Statistical analysis

The Generalized Linear Model (GLM) with the negative binomial distribution was used to evaluate the statistical association between outcome and explanatory variables.

In the univariable statistical analyses, explanatory variables with a significance level (p-value) less or equal to 0.25 were maintained to compose the multivariable model as suggested by Hosmer and Lemeshow[11] and Dohoo et al., 2009[12]. Adopting a liberal p-value is recommended to prevent an important predictor from being excluded if its effect is masked by another variable.The stepwise procedure was then implemented to select the possible variables to compose the final model. All selected variables were statistically significant at 5%. In addition, variables that were not significant in the univariable analysis were then introduced into the final model, one by one separately and also together, in order to evaluate if any could add some significant contribution when combined with the variables already selected by the stepwise procedure[11]. Data were analyzed using the Stata software, version 14 (Stata Corporation, College Station, TX, USA).

The goodness-of-fit analysis of the models was performed using the following statistics: Pearson's deviance, natural logarithm of the likelihood function (log-likelihood), Akaike (AIC), and Bayesian (BIC) information criteria, the adjusted generalized variance inflation factors (AGVIF) and residuals correlation[12,13]. Possible outliers were identified by graphical analysis of Pearson residuals from the models and the Cook's distance criterion[12]. As suggested in Stata manuals, any point with Cook's distance greater than 4/n, where n is the number of observations, was examined[14]. Zero-inflated negative binomial model[13] was also fitted to assess the overdispersion induced by the number of zeros in the outcome variable. Logistic distribution was used to adjust for the excess of zero. The statistically significant variables were the same in the inflated and non-inflated models. A comparison of the goodness-of-fit indicated that the non-inflated negative binomial model was preferable.

Results

Database description

The minimum of the prevalence estimates was 0%, reaching a maximum of 50%. The average and the standard deviations were 0.81% and 3.48%, respectively. The estimated prevalence was low in most municipalities as shown by the first, second, and third quartiles (0, 0 and 0.12%, respectively), and also by the high frequency of zero (384 out of 521 municipalities, representing 73.70%).

Most municipalities were small or medium-sized, with 41.65% comprising a population between 20,000 and 150,000 inhabitants, followed by 39.92% below 20,000 inhabitants, 12.09% between 150,000 and 500,000 inhabitants and 6.33% above 500,000 inhabitants. The majority of the municipalities were located in the Northeast region (43.38%) of the country, followed by Southeast (22.27%), North (15.74%), South (10.17%), Midwest (8.25%), and Federal District (0.19%). Regarding the endemic level, 28.60% of the municipalities were in endemic areas (16.32% in low and 12.28 % in high endemic). Approximately half of the sampled municipalities had historical records of the presence of one or more species of the genus *Biomphalaria*. Descriptive statistics of the other variables can be found in Poague et al.[9].

Univariable analysis

The results of the adjusted univariable statistical models are presented in Table 2. Among the water and sanitation variables,"% Population served with adequate water supply at home", "% Population served with adequate sanitation at home" and "% Schools served with adequate water supply" were not statistically significant at a significance level of 25%.

Table 1. Description of variables.

Variable	Variable type	Description	Period	Source
% Population served with adequate water supply at home	Explanatory	Population supplied with piped water in at least one of the rooms of their household from the following sources: general distribution network, well or spring water on or off the property	2013*	IBGE
% Population served with adequate sanitation at home	Explanatory	Population that disposes its sewage in a general sewerage system, rainwater drainage, or septic tank	2013*	IBGE
% Population served with household solid waste collection	Explanatory	Population served with direct and indirect household solid waste collection, regardless of location (urban or rural)	2013*	IBGE
¨% Schools with filtered water	Explanatory	Schools that provide their students with filtered water from filters, such as clay, crockery, plastic, or activated carbon filters, that typically has porous filter elements to retain impurities	2014	INEP
% Schools served with adequate water supply	Explanatory	Schools with adequate water supply, i.e., which are provided with public network, artesian well, and "*cacimba*" / well / cistern	2014	INEP
% Schools served with adequate sanitation	Explanatory	Schools that dispose their sewage into a public sewerage system or septic tank	2014	INEP
% Schools with proper solid waste disposal	Explanatory	Schools whose solid waste produced is periodically collected or recycled	2014	INEP
% Municipality's urbanization	Confounding	Percentage of municipality's inhabitants living in urban areas	2013*	IBGE
% Population served with *Bolsa Família* Program - BFP	Confounding	Percentage of municipality's population served by BFP (used as a poverty and social inequality identifier). The BFP is a conditional direct cash transfer government program created in 2003. It serves families living in poverty and extreme poverty situation, namely: families with per capita income in Brazilian currency up to R$ 89.00 per month (about US$ 22); families with pregnant women, children or adolescents from 0 to 17 years old, with per capita income between R$ 89.00 and R$ 178.00 per month.	2013	MDS
% Population served by primary health care services	Confounding	Percentage of municipality's population attended by Family Health Teams and Primary Care Teams	2013	MS
% Population employed in agricultural sector - 18 years and over	Confounding	Percentage of active population (18 years old and over) of each municipality employed in the agricultural sector	2013*	IBGE
Municipal Human Development Index: Education Component	Confounding	Proxy of municipality's population access to education. Its value ranges from 0 to 1	2013*	IBGE
Presence of snail	Confounding	Represents whether there are historical records of the presence of one or more species of the genus Biomphalaria recognized in Brazil as naturally infected by *S.mansoni* (*Biomphalaria glabrata, B.straminea,* and *B.tenagophila*) within the territorial limits of each municipality (0 - No, 1 - Yes).	2008&	Carvalho *et al.*, 2008; Carvalho *et al.*, 2018
Endemic level	Sampling	Non-endemic (0), Low (1) and High (2)	-	Katz 2018
Natural log of Population in 2010	Sampling	Population size of each municipality in 2010	2010	IBGE

*Values were obtained through population projections. IBGE: Brazilian Institute of Geography and Statistics; INEP: National Institute for Educational Studies and Research Anísio Teixeira; MS: Ministry of Health; MDS: Ministry of Social Development; &: Updated with 2012 and 2014 data for municipalities from Paraná, Minas Gerais, Bahia, Pernambuco, and Rio Grande do Norte states.

Source: Authors.

Multivariable analysis

Table 3 presents the results of the multivariable analysis. The significant explanatory variables (at 5% level) were: "Endemic Level", "Natural log of Population in 2010", "Presence of Snail", "% Schools with filtered water", "% Schools served with adequate sanitation", "% Municipality's urbanization", "% Population served by primary health care services" and "Municipal

Table 2. Univariable analysis results for the outcome schistosomiasis mansoni (n = 521).

Variable	Category	Intercept	Coefficient	P-value	RR	RR (75%CI)
Endemic level	Non-endemic (0)			Reference		
	Low (1)	-6.230	0.93	0.001	2.536	1.825 – 3.523
	High (2)		3.183	< 0.001	24.125	16.917 – 34.406
Natural log of population in 2010	Continuous	-2.061	-0.267	0.002	0.765	0.692 – 0.846
Presence of Snail	Dichotomous	-5.934	1.692	< 0.001	5.428	4.039 – 7.294
% Population served with adequate water supply at home	Continuous	-4.005	-0.009	0.348*	0.991	0.980 – 1.002
% Population served with adequate sanitation at home	Continuous	-4.592	-0.004	0.400*	0.996	0.990 – 1.002
% Population served with household solid waste collection	Continuous	-4.088	-0.010	0.138	0.991	0.983 – 0.998
% Schools with filtered water	Continuous	-3.276	-0.018	0.016	0.983	0.974 – 0.991
% Schools served with adequate water supply	Continuous	-4.244	-0.006	0.413*	0.994	0.986 – 1.002
% Schools with proper solid waste disposal	Continuous	-4.211	-0.009	0.062	0.991	0.986 – 0.997
% Schools served with adequate sanitation	Continuous	-7.606	0.030	0.067	1.030	1.011 – 1.049
% Municipality's urbanization	Continuous	-3.585	-0.019	0.001	0.981	0.975 – 0.988
% Population served by *Bolsa Família* Program	Continuous	-6.438	0.037	< 0.001	1.038	1.029 – 1.047
% Population served by primary health care services	Continuous	-7.238	0.028	< 0.001	1.028	1.022 – 1.035
% Population employed in the agricultural sector - 18 years and over	Continuous	-5.184	0.013	0.056	1.014	1.005 – 1.022
Municipal Human Development Index: Education Component	Continuous	-0.987	-6.408	< 0.001	0.002	0.000 – 0.010

Significance level: 25%. 75%CI: 75% confidence interval. *Variables that were not statistically significant. RR: rate ratio.

Source: Authors.

Table 3. Multivariable analysis results for the outcome schistosomiasis mansoni (n = 521).

Variable	Category	Coefficient	P-value	RR	RR (95%CI)
Endemic level	Non-endemic (0)		Reference		
	Low (1)	0.878	0.005	2.406	1.302 – 4.444
	High (2)	2.654	< 0.001	14.206	7.551 – 26.726
Natural log of population in 2010	Continuous	-0.071	0.552*	0.931	0.736 – 1.178
Presence of Snail	Dichotomous	1.287	< 0.001	3.622	2.171 – 6.043
% Schools served with adequate sanitation	Continuous	0.045	0.006	1,046	1.013 – 1.081
% Schools with filtered water	Continuous	-0.018	0.005	0.982	0.970 – 0.995
% Municipality's urbanization	Continuous	0.021	0.022	1.021	1.003 – 1.039
% Population served by primary health care services	Continuous	0.013	0.042	1.013	1.000 – 1.026
Municipal Human Development Index: Education Component	Continuous	-6.741	0.002	0.001	0.000 – 0.076
Model's constant (intercept)	Continuous	-7.538	< 0.001	0.001	0.000 – 0.036

Significance level: 5%. 95%CI: 95% confidence interval. *Variables not statistically significant. RR: rate ratio.

Source: Authors.

Human Development Index: Education Component". No interaction variable was statistically significant to be included in the model.

The variables "Endemic Level", "Presence of Snail", "% Schools served with adequate sanitation", "% Municipality's urbanization" and, "% Population served by primary health care services" presented Rate Ratio (RR) values greater than 1. These results indicate that low and high endemic levels and the presence of snails, compared to non-endemic levels and the absence of snails, lead to the increase of the prevalence average of schistosomiasis mansoni. For the continuous variables, these results indicate that the increase of these variables leads to the increase of the prevalence average of schistosomiasis mansoni. The AGVIF values were smaller than 2, indicating no presence of multicollinearity. The residuals were not correlated.

Discussion

The results from the multivariable statistical model suggest that adequate sanitation in schools (sewage disposal into a public sewerage system or septic tank) is related to *S. mansoni* infections as a risk factor. Particularly in Brazil, the collection of sewage does not necessarily imply its subsequent treatment and adequate disposal. Sewage collection by networks reaches 61.4% of the Brazilian urban population[15], but the percentage served with wastewater treatment represents only 42.6% of the urban population. In other words, 30.6% of the sewage collected in urban areas by networks is not sent to sewage treatment plants. It is discharged somewhere else, as in water collections or on the soil. Besides releasing the *S. mansoni* eggs into the water bodies, the discharge of the untreated wastewater also provides nutrients (nitrogen and phosphorus), which favors the multiplication of phytoplankton, food for mollusks, which leads to a marked proliferation of snails[16].

In addition, the presence of sanitary infrastructure alone does not guarantee the proper use of the facilities. For instance, a study using survey data from school-aged children in Burkina Faso, Mali, and Ghana (2003-2008) showed a positive association between having toilets in homes and an increased risk of *S. mansoni* infections[17]. The authors attributed this result to the "incorrect disposal of human excreta, even in the presence of adequate toilet facilities"[16]. Chimbari et al.[18] also showed that young children might, for example, avoid the use of latrines due to fear of falling inside the toilet. People can also choose not to use the facilities, either because they are not convinced of their benefits or because of ingrained social behaviour[19].

In Barreto[20], it was pointed out that although most of the houses in the municipality of Santo Antonio de Jesus (Bahia, Brazil) were equipped with a sewage disposal system, there was a high percentage of snails infected with *S. mansoni*, suggesting persistent environmental contamination. The author concluded that there was no guarantee that some of the existing cesspits were safe enough to prevent fecal contamination of the environment.

Furthermore, some studies performed to explore the impact of the presence or absence of sanitary facilities on the occurrence of schistosomiasis mansoni have shown mixed results due, partly, to the difference among the indicators used to describe the concept of "adequate sanitation"[21]. Most of the epidemiological studies that identified adequate sanitation as a protective factor for *S. mansoni* infection used the presence of a latrine, toilet, and septic tank as indicators of "adequate sanitation", without an accurate capacity to discriminate between safe and unsafe facilities[7]. Few studies included the collection of sanitary effluents by network indicator, as presented in this paper. Regarding septic tanks, the misclassification of this type of individual sanitation solution is well-known, leading to the inclusion of well-built and well-operated facilities together with very precarious ones, which could have been the case of our study.

Results may also vary between surveys due to the heterogeneity of the study participants' ages, location of water source, the study setting, the presence or absence of intermediate snail hosts, reasons for water contact, the input of miracidia into the water, and the absence of socioeconomic confounding variables[7]. Soares Magalhães et al.[17] also acknowledge that the lack of consideration of some confounding variables, such as community participation in the planning, construction, maintenance, and financing of infrastructures, may lead to different results.

In addition, it is necessary to consider that epidemiological studies usually take into account the relationship between exposure and health outcome at the individual level, and therefore, have a low capacity to capture the complex links between sanitation and schistosomiasis, which occur in the aquatic environment and not in the household. People without access to adequate infrastructure and sanitation services in their

homes may remain uninfected due to the lack of the intermediate host in the locality, and, conversely, people with adequate sanitation can be infected when they have contact with snails in the aquatic environment, even far from their homes.

Among the other sanitary variables, a protective association was found between "% Schools with filtered water" and schistosomiasis mansoni prevalence. Pieces of evidence suggest that a safe water supply, at the household or school level, is an efficient way to avoid contact with contaminated water sources, whether at domestic, recreational, or occupational activities, lowering the chances of contracting the disease[6,9,22-25]. As the longevity of cercaria usually varies between 36 and 48 hours[16], reaching up to 100 hours depending on the environmental conditions[26,27], water storage represents a possible transmission route. The existence of filters in schools or houses, often supplied by piped water, might have two positive effects: (i) the availability of water reducing the need to collect it elsewhere, and therefore, the contact with possible contaminated watercourses; (ii) the efficiency of filters in removing large pathogens, such as *Schistosomosa* cercaria.

Access to a safe water supply also prevents freshwater contamination by *S. mansoni* eggs through the hygienic washing route. Despite sanitation and hygiene measures, eggs of *S. mansoni* can remain on the perianal folds, being able to survive for a long time due to the moisture of the environment, and so providing a transmission risk[19,28-30]. Without water and sanitation infrastructure for hygiene practices after defecation (such as sinks and showers), people get used to hygienic washing in streams. In this process, eggs of *S. mansoni* can be transferred through bathing, hand washing, and perianal cleaning.

The set of the statistically significant variables in the final multivariable model of the current study reflects that improvements must be addressed both in infrastructure and in social determinants with regard to schistosomiasis mansoni. As pointed out by Grimes et al.[6] the counterintuitive results, such as those found in Soares Magalhães et al.[17] and also in this current research, perhaps reflect that sociocultural factors are as strong predictors of *S. mansoni* infection as WASH. On the other hand, although health education has been reportedly successful in promoting behavioral changes, its impact on worm prevalence and intensity is limited to access to adequate sanitary infrastructure[19,9,31].

Likewise, promoting adequate water and sanitation solutions, while critical, is only part of a complex chain of interventions to control or eliminate the disease. Regardless of the implementation of safely managed sanitation, as promoted by the Sustainable Development Goals, occupational and leisure activities related to contaminated water bodies may persist due to cultural and socioeconomic norms, and therefore additional preventive measures are needed to address these forms of exposure[8]. As suggested by the latest WHO Guideline on control and elimination of human schistosomiasis[32], WASH interventions are strongly recommended as a complementary measure to reduce the prevalence of schistosomiasis. They should be implemented in integration with other measures (such as behavioural change interventions) and always take into account the local context[32].

The results found for the water and sanitation variables debated above are of major concern considering the implementation of the new Brazilian law that regulates the sanitation sector in the country (Law nº 14.026/2020)[33], known in Brazil as the "*novo marco regulatório do saneamento*". The new regulation aims for the universalization of water and sanitation services in the country, with goals of serving 99% and 90% of the Brazilian population with drinking water and sewage collection, respectively, by the end of 2033[33]. The law also includes a series of mechanisms to expand the role of the private sector in water and sanitation services[33]. In the haste of achieving the established goals, if the water and sanitation services are not provided with quality and safety, we might witness an increase in the prevalence of schistosomiasis mansoni and other health-related outcomes as well.

Moreover, schistosomiasis is known to affect the poorest and most vulnerable communities, which are less likely to be able to afford the costs related to water and sanitation services[32]. If private companies decide to marginalize those that have the inability to pay for the services, inequalities will increase leading to the aggravation of not only schistosomiasis mansoni transmission but also on multiple infectious diseases.

Furthermore, the promotion of successful health education activities carried out by the Unified Health System (SUS), the Brazilian health public system, as pointed out by the literature, faces a series of obstacles: (i) current educational activities are based on the expository method, not integrating the common sense and concrete experiences of the local community served[34], an educational strategy that has already proved to be inefficient[35]; (ii) lack of scientific rigor of ed-

ucational materials, with some even presenting incorrect information about the parasite cycle and the transmission pathways[36];(iii) the information provided about infectious diseases is offered in a single block, prompting people's mind to mix elements of each disease[34]. In the case of schistosomiasis, the population tends to consider that, as with other worm infections, the disease is transmitted by ingestion of contaminated water. Sousa[37] argues that these failures do not originate in the SUS, but rather in the curricula of health courses that prioritize the teaching of other specialties, marginalizing primary health care and preventive medicine. Activities to combat parasite infections require cross-sector collaborations[19]. Therefore, the responsibility to address a complex health issue, such as schistosomiasis, should not be only a role of a single sector.

The results of the present study also suggest that *S.mansoni* is now reaching the urban dimension of public health. The increased prevalence in urban districts can be a reflection of the under-reporting of the infection in rural areas. Although the National Survey was carried out with schoolchildren from rural and urban areas, most of them were students from schools located in urban areas. Access to and use of health services in Brazil is greater in urban than in rural areas[38]. In addition, as a result of the decentralization of the Schistosomiasis Control Program (SCP) and its integration process into the primary health care system, which started in the 1990s, health-seeking behavior changed, and the access to diagnosis and treatment was weakened in some rural areas[38].

Limitations

Finally, some limitations of the current study have to be highlighted. In addition to the limitations pointed out by Poague et al.[10], which also apply to this research, in the present study, the prevalence rate was adopted as the outcome variable rather than measures of infection intensity, which are widely recognized as better indicators of transmission and public health impact than just prevalence. Even though the Kato-Katz technique has become the standard for studies on intestinal schistosomiasis, it has serious sensitivity limitations depending on aspects such as the faecal consistency, number and frequency of sample collection, number of slides examined etc., which might lead to the possibility of underestimation of prevalence in areas with low intensity of infection. Moreover, although schistosomiasis mansoni typically occurs with focal transmission, the current study assessed the relationship among variables at the municipality level. Some aspects of the association between WASH and schistosomiasis mansoni, therefore, may not have been observed due to this difference in spatial scale. Furthermore, approximately 88% of the municipalities that were part of the National Survey on the Prevalence of Schistosomiasis mansoni and Soil-transmitted helminth infections (2011-2015) were located in non-endemic areas or in areas with low endemic level for schistosomiasis mansoni, which means that the National Survey might have underestimated the real prevalence of schistosomiasis mansoni. This possibility is reinforced by the fact that approximately half of the sampled municipalities had no historical records of the presence of one or more species of the genus *Biomphalaria*. In addition, variables that express hygiene practices and sociocultural factors, such as the migratory flow of people, frequency of domestic and leisure activities in water bodies, number of water bodies in the territory of each municipality and their distance from the population nearby, irrigation areas, construction of dams, among others were absent. Variables of this type should be included in future works.

Conclusion

Although there is evidence in the literature that water and sanitation have positive effects in preventing schistosomiasis mansoni, the results found in our study suggest that, in Brazil, while access to filtered water in schools is a protective factor, sanitation in schools is a risk factor. Wastewater collection by sewerage is not universal in Brazil, and when present, it is not necessarily proceeded treatment, often leading to direct discharge into water resources, with potential intensification of disease occurrence. With regard to septic tanks, the presence of infrastructure alone does not guarantee their correct use by the population.

Our findings support that the human right to water and sanitation should be provided with quality. Otherwise, poor sanitation can intensify disease transmission. Special attention should be given to improving water and sanitation services in schools, not just in households.

The results also suggest that, even though schistosomiasis is classically described as a rural disease, it is now reaching the urban dimension of public health, and, therefore, control and elimina-

tion strategies also need to be adapted to combat parasite and snails spread in suburban environments. Finally, the set of significant explanatory variables in the multivariable model reflects the importance of combining structural measures and actions for water and sanitation in the control of schistosomiasis mansoni, in particular, promoting the improvement of general and health education and the universalization of the primary health care services available in the country.

Collaborations

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