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Differences between infection with *Schistosoma mansoni, Taenia* spp. and Soil-Transmitted Helminths in Brazil and Africa environments viewed from an evolutionary perspective

M. Chamone[1], G. S. Atuncar[2] & A. L. Melo[3*]

(1) Departamento de Bioquímica-Imunologia, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais
(2) Departamento de Estatística, Instituto de Ciências Exatas, Universidade Federal de Minas Gerais
(3) Departamento de Parasitologia, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais

*** Author for correspondence:** aldemelo@icb.ufmg.br

Abstract. In Brazil, when prevalence data were examined using simple summary statistics, there is a negative association between prevalence of *Taenia* spp. infection and *Schistosoma mansoni* or soil-transmitted helminths (STH) irrespective to routes of infection. That does not occur in African data. However, they vary considerably when plotted. So, in data collected on Brazilian area, it to show in ordered (smallest first) scores prevalence of STH infections both long lag phase in prevalence of STH infecting by oral route (*Ascaris* and *Trichuris*), and into STH infecting by skin route (hookworm and *Strongyloides*). To the other side, African study it show smaller lag phase in prevalence of STH infecting by oral route or into STH infecting by skin route. Darwinian, it was suggested *Taenia* spp. and STH, inhabiting a non-human environment which became so suitable for them according to their biological needs, their develop by means of natural selection.

Keywords: Helminth parasites, Prevalence, *Schistosoma mansoni,* Trematoda, Cestoda, Nematoda

Introduction

The number of human beings infected with *Schistosoma mansoni* as well the counts of eggs in stool were not randomly distribute (Chamone et al., 1990), but they are associated with the presence of soil transmitted helminths (STH) namely *Ascaris lumbricoides, Trichuris trichura* and hookworm (mainly *Ancylostoma duodenale* and/or *Necator americanus*). Although the presence of STH and *Taenia* spp. in the same area surveyed has been registered in literature, the study of the effect of the presence of *Taenia* spp. on prevalence of *S. mansoni* infections or STH, including *Strongyloides stercoralis,* do not holds much interest. Therefore STH were dichotomized into STH infecting by oral route (*Ascaris* and *Trichuris*) and into STH infecting by skin route (hookworm and *Strongyloides*). Leggett et al., (2017) using data from 61 different human pathogens, found that pathogens that infect via skin wounds are more virulent than pathogens that are ingested.

Despite STH and *Taenia* spp. usually are found in the schistosomiasis areas, the importance of the presence of *Taenia* spp. on score prevalence of STH in surveys were all positive for presence of *S. mansoni* eggs were unexplored. Also, in sonme previous studies it were employed statistical significance and graphics to shown how the prevalence of STH chance and some Darwinian reasons to explain the results (Williams & Nesse, 1991; LeGrand & Brown, 2002).

These points were pursued using bibliographic database to obtain Brazilian and African texts that reported prevalence data on STH with correspondent frequency of *Taenia* spp. in those two different schistosomiasis area.

Methods

Details of survey population, diagnostic methods, sample size and numbers infected with schistosomes and soil-transmitted helminths were recorded. Estimates of infection prevalence of schistosomiasis and major STH conducted since 1980 were identified using electronic and manual search strategies of published and unpublished sources (Brooker et al., 2009). According, a number of inclusion criteria were imposed for identified information, which was extracted into a standardized database (Brooker et al., 1999).

A search in the Google and PubMed database was performed for original articles exploring the following combinations used as search words: “prevalence helminths”, “prevalence Schistosoma mansoni”, "Ascaris", "Trichuris", "hookworm" and “Schistosoma mansoni geohelminths” where those words could be or not associate with name of any country. An additional search was performed within the references of the articles. Rural and, or urban communities of Brazilian states and African countries were screened for the presence of *S. mansoni* in area that includes prevalence information about *Taenia* spp., *Ascaris, Trichuris*, hookworm and *Strongyloides* distribution regardless the parasitological method used to assess the presence of parasites. Only were eligible surveys positive for presence of *S. mansoni* eggs on fecal examinations and presented information for *Ascaris lumbricoides, Trichuris trichura,* hookworms, *Taenia* spp. and *Strongyloides stercoralis*.

The reason for exclusion was survey negative for eggs of *S. mansoni*, conduct at hospitalized or ambulatory persons, repeated area, within group of a specific clinic status or disease, one gender only, children aged 0-3 only, older age only and migrated cases of schistosomiasis.

The search included only studies that had sample size higher than 30 (Brooker et al., 1999).

Score prevalence of parasites was registered (in some cases the prevalent rate was recalculated). Score prevalence of Brazilian publications between 1985 and 2012 for children-based survey available in Portuguese and English language reported in thesis, meetings or journals were eligible for inclusion. Also, African publications between 1989 and 2013 for children-based survey available in English language reported in journals were eligible for inclusion. After we have completed the collection of data from the literature we classified routes of infection used by STH as entry through skin or ingestion (Leggett et al., 2017), and the *Taenia* spp. sample was dichotomized into negative and positive groups. Prevalence data from schistosomiasis mansoni, *Taenia* spp., or STH classified in one situation is compared to data collected in a different situation with the aim of seeing if the first situation produces statistical different results from the second situation. It was applied analysis of scores by the Kolmogorov - Smirnov two - sample (KS) test (available at http://www.physics.csbsju.edu/stats/KS-test.n.plot_form.html). Significance was tested at the 5% level. To view the data graphically it was necessary to rearrange the score of prevalent data into order of magnitude (smallest first) according some authors (Jacoby, 2010; Kozak, 2010).

Results and discussion

For study conducted in Brazil the method of sampling attempt to total 17,402 children-based surveys positive for *S. mansoni* infection composed by 13 surveys of 8580 children positive for *Taenia* spp. and 22 surveys negative with 8822 persons. The prevalence of Schistosomiasis in positive cases and negative was 1.80 and 9.10, respectively. For surveys conducted in Africa the method of sampling attempt to total 112,389 children-based surveys positive for *S. mansoni* infection composed by 40 surveys of 96,560 children positive for *Taenia* spp. and 11 surveys negative with 15,829 persons. The prevalence of Schistosomiasis mansoni in positive cases and negative was 6.02 and 6.70, respectively.

According to these results it can be observed, also in Table 1, that in Brazil there is a negative association between prevalence of *Taenia* spp. infection and *S. mansoni* or STH. That does not occur in Africa.

In another stage the investigation we first need to rearrange the score of prevalent data of both oral or skin route infection agents into order of magnitude (smallest first). In Brazil study, with the presence of *Taenia* spp. (Figure 1), in both oral and skin route infecting helminths, when the ordered scores of prevalence is graphed one obtains a curve with a long and slow increasing slope, constituting the Lag phase. However in second stage the scores values increases explosively (exponential or Log phase). The representative curve with absence of *Taenia* spp. does not increases explosively. In African area the Lag phase is short and the explosive increase in scores prevalence of oral or skin route infecting helminths was seen in absence of *Taenia* spp.

Contrasting to Africa, in Brazil the prevalence of *S. mansoni* infection seemed susceptible under a *Taenia* spp. factor in a form sufficiently for indicate that comparing *Taenia* positive group to negative, the scores prevalence for *S. mansoni* infection exhibit lower value than that group where *Taenia* spp. is absent. Unfortunately there were no studies applying collective analysis in *S. mansoni* areas with *Taenia* spp. and STH to be compared. The coexistence of *S. mansoni* infections and oral route infection agents (*Ascaris lumbricoides, Trichuris trichura*) and skin route ones (hookworm and *Strongyloides*) is a fact well known. They have different biological characteristic groups. In fact, Leggett et al (2017) using data from human pathogens found that pathogens that infect via skin wounds are significantly more virulent than pathogens that are ingested. *Strongyloides* regardless the infective larvae are active skin penetrators, infection *per os*, while possible, is probably of limited importance (Nutman, 2017). In respect to the co-infection with *S. mansoni* and *Strongyloides* the majority of the studies have been performed mainly in HIV infection (Blatt & Cantos, 2003; Paula & Costa-Cruz, 2011; Sadlier et al., 2013).

In terms of prevalence or intensity of infection with *S. mansoni* in other line of study it was referred on the possible existence of negative association between *S. mansoni* and *Ascaris* or *Trichuris* (Chamone et al., 1990; 2012; Fleming et al., 2006). Also, Brutus et al (2006) suggest that *Ascaris* protect against *Plasmodium falciparum* infection. In human *Ascaris* infection is report as associated with protection from cerebral malaria (Nacher et al., 2000; 2011). Similar, other studies have suggested positive interaction between *S. mansoni* species and hookworm (Chamone et al., 1986; 1990; 2006; Webster et al., 1997; Keiser et al., 2002; Raso et al., 2004; Pullan et al., 2010).

Table 1. Summary of parameters found in Brazil and Africa in Schistosomiasis area where *Taenia* spp. were present or absent, dichotomized according route of soil transmitted helminths infection

Country	N⁰ areas	N⁰ children	*S. mansoni*	*Taenia* spp.	Oral route STH**	Skin route STH#
Brazil[1]	22	8.822	9.0 (21.2)*	-	21 (27)[a]	4 (8)[c]
	13	8.580	1.8 (3.1)	0.2 (0.8)	6 (13)[b]	1 (4)[d]
Africa[2]	11	15.829	6.7 (14.6)	-	10 (18)[a]	3 (9)[c]
	40	96.560	6.0 (12.0)	3.0 (5.0)	13 (20)[b]	6 (12)[d]

*Median (Arithmetic mean) prevalence. **Oral route agents: *Ascaris* and *Trichuris*. #Skin route agents: hookworm and *Strongyloides.* [1]Brazil, a vs b: KS test, p=0.002 and c vs d: KS test, p=0.035. [2]Africa, a vs b: KS test, p=0.301 and c vs d: KS test, p=0.450.

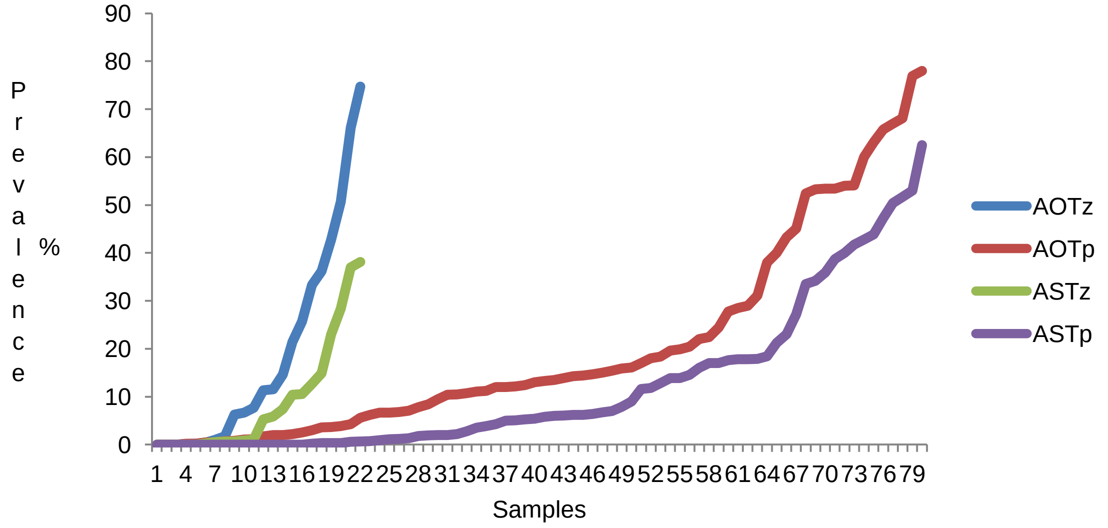
A graphical presentation of the ordered score prevalence of *S. mansoni* infection data, enables us to view the data graphically which can help us understand how the *S. mansoni* data are distributed under the influence of *Taenia* spp. and STH. So, to view how the numbers change, it needed to rearrange the scores of prevalent data into order of magnitude (smallest first) (Anscombe, 1973; Cohen, 1994). It is clear by merely inspecting graphs, the form of the curve due to ordered scores of prevalence series conducted in Africa are not distributed on same form with ordered scores from survey conducted in Brazil. Both in Brazil and in Africa areas, the representative lines of cases where *Taenia* spp. is negative or positive tending to move away from each other as the ordered prevalence of STH groups increases. When score prevalence of infection is ordered, it begins a latent period that appears to be different between Brazil (long Lag phase type) and Africa (short Lag phase type) areas. Lag phase is a distinct phase that prepares prevalence of STH infection in Brazilian and Africa areas for exponential developmental.

Since *S. mansoni* and studied intestinal parasites do not interact directly with one another, the effects of immunological response cannot be excluded (Correa-Oliveira et al., 1988). In fact, structures of the *S. mansoni* have immunological properties in common with antigen *Taenia saginata* (Lurie & Meillon, 1951, cited by Kagan & Pellegrino, 1961) or of the *Taenia solium* (Laclette et al., 1991). Additionally, anti-complement system activity has been demonstrated in the *Taenia taeniaeformis* (Hammerberg & Williams, 1978) as well was separated from sera of a *S. mansoni* infection, Chagas's disease and Hansen's disease (Nascimento & Chamone, 1988; Nascimento et al., 1989).

There is some limitation of the study. It is possible that suitable conditions for adaptation of studied parasites do not exist in all areas since biogeographical areas varied considerably, the inhabitants were not ethnically identical and data collection does occurs in varying time interval. Lastly, the lack of accurate diagnostic tools is an important consideration can also affect the results for helminth interactions in each setting.

Finally, because "... nothing in biology makes sense except in the light of evolution..." (Dobzhansky, 1973), the Darwinian reasons seem to explain that observed difference. The differences in non-human environments cause diversity in the parasites species that survive in Brazil and African schistosomiasis areas. Under a Darwinian point of view area differences may be related to differences in an evolutionary ecology, then constitute the environments to which any particular organism has become adapted to over time (Pianka, 2000; Nesse, 2001; Poulin, 2007). Regarding area, since it is accepted that human beings originated from Africa this means that contact between humans, *Taenia* spp. and STH started long ago in Africa, perhaps in the early emergence of the human lineage (Lenzi et al., 1997). Darwinian, *Taenia* spp. and STH adapt to the environment according to their biological needs forming a favorable to life.

All together, the present model of collective analysis may be important to obtain overall information about the prevalence of *S. mansoni* infection and other associated worm parasitic infections. Finally, the present study only is a pilot investigation to stimulate investigations rather than an epidemiological study and await further studies.



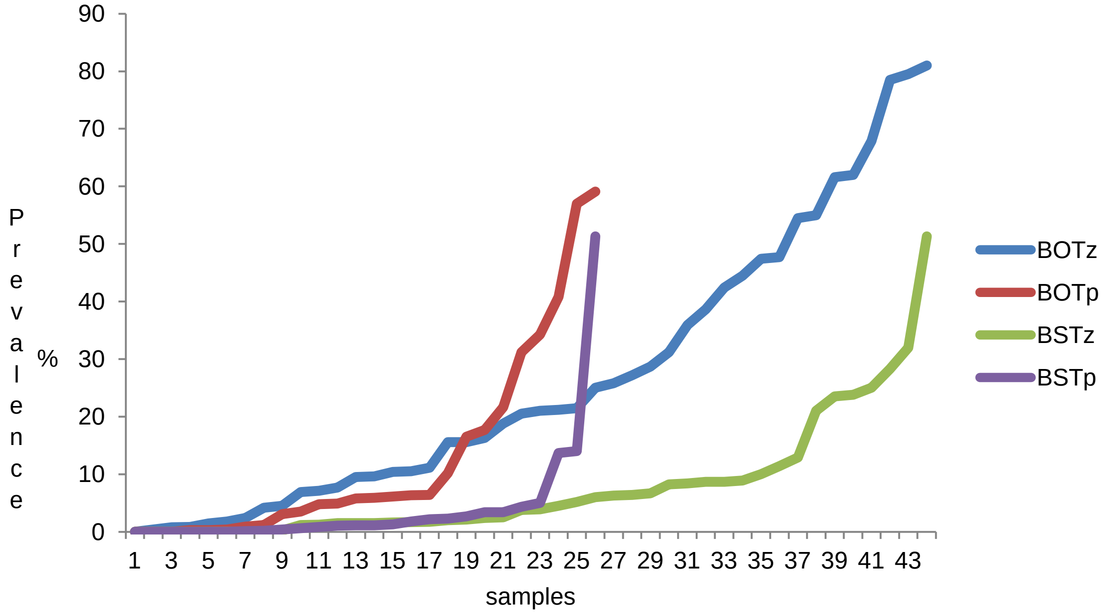


Figure 1- Brazilian and African children-based survey: Graphics relationship between prevalence of oral route infection helminths (*Ascaris* and *Trichuris*) and skin route (hookworm and *Strongyloides*) and *Taenia* spp. on area where are present or absent. (A = Africa; B = Brazil. O = Oral route; S = Skin route; Tz = *Taenia* absent; Tp = *Taenia* present); 1 to 44 and 1 to 80 = Sample number from bibliographic data

Conclusion

So, we conclude there is a negative association between prevalence of *Taenia* spp. infection and *S. mansoni* or STH. That does not occur in Africa, and differences between Brazil and Africa suggests that hosts were evolved with pressure from parasites with acquired characteristics from area, and the parasites were evolved with pressure from human.

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MC conceived, designed the study, compiled the data and with ALM drafted the first version of manuscript; GSA analyzed and interpreted the data. All authors read, critically revised and approved the final manuscript.

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The authors declare that they have no conflict of interest.

Data availability
The authors declare that the data supporting the findings of the present study are available within the article and if necessary for further information, from the corresponding author upon request

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