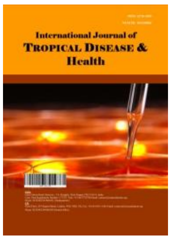

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Geographical Distribution of Soil Transmitted Helminths and *Plasmodium falciparum* Co-Infections among School Children in Bugesera District, Rwanda

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Authors' contributions

This work was carried out in collaboration among all authors. Author UM designed the study, wrote the protocol, and made the first draft. Authors MDH, TD, MJ participated in the study design. Author BJB participated in data analysis and prepared the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Soil Transmitted Helminths and *Plasmodium* infections are ubiquitous within the tropical and subtropical regions. However, the extent and consequences of Helminthic and *Plasmodium* infections and co-infections - geographical distributions are not fully understood. This study aimed determining the geographical distribution of these parasites.
Study Design: Cross Sectional Survey.

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Place and Duration of Study: The survey was conducted in Bugesera District, Eastern Rwanda, between May and December 2020.
Methodology: The survey was conducted among children between ages 5 and 18 years, across 21 randomly selected primary schools. Stool samples were collected and screened for soil transmitted helminths using Kato-Katz, while finger-prick blood samples were examined under the microscope to determine *Plasmodium* infection.
Results: *P. falciparum* was common throughout the study area, with highest prevalence in provinces of Nyiragiseke (22.78%) and Shami (18.99%). The geographical distribution of STH was variably dominated by *A. lumbricoides*. The co-infection exhibited geographical variation consistent with the *A. lumbricoides* prevalence.
Conclusion: The un-proportional distribution of and higher prevalence of *P. falciparum* in the provinces of Nyiragiseke (22.78%) and Shami (18.99%) calls for the review of the control methods, strategies and mechanisms to address the unique conditions and activities in each province. The variably dominant *A. lumbricoides*- *Plasmodium* co-infection calls for targeted control strategies and mechanisms for these parasites since this association has been attributed to severe malaria.

Keywords: Geographical distribution; Plasmodium falciparum; soil transmitted helminthes; Co - infections.

1. INTRODUCTION

It is established that soil-transmitted helminthiasis (STH) and malaria are ubiquitous and endemic in the tropical regions but exaggerated in Africa – South of the Sahara and South East Asia [1-3]. The World Health Organization (WHO) - African Region accounted for about 94 -95% of malaria cases in 2019 – 2020 [4,5]. *Plasmodium falciparum* remains the foremost rife *Plasmodium* within the WHO African Region, causing 99.7% of the cases, and 50% within the South East Asia Region. Globally, children are the foremost vulnerable, accounting for 67% of all malaria mortality [6]. Forty percent of the global burden of NTDs is in Africa, where these diseases cause high morbidity - especially in school children and loss of person years of their caretakers [7]. The African Region has the second highest number of children infested with soil-transmitted helminths of all the WHO regions [3].

Accurate descriptions of the geographical distribution of the said parasitic infections is key to the control methods and mechanisms [8]. Nevertheless, it is important to note that climatic and socioeconomic factors influence the distribution of single and multiple co- infections [9-13]. STHs and *Plasmodium falciparum* co-infection - ubiquity has a long history, though, with discrepant reports. In addition, these coinfections are not uncommon in school children in the East Africa region as it were for the other endemic regions and are consistent with variable consequences [14-29]. The situation is not any different in Rwanda where helminthiasis and malaria remain prevalent in many provinces, in spite of the vigorous and tremendous national control programs [30-33]. Recent reports from the studies in Rwanda show that STH and *Plasmodium* infections are heterogeneously distributed across the country with evidence of signatures of spatial clustering with different risk factors including geographical location [33-37]. We now report the geographical distribution of STHs and *Plasmodium falciparum* single infections and co-infections in Busegera District of Rwanda.

2. MATERIALS AND METHODS

2.1 Study Setting

45 The study was conducted in Bugesera District, Rwanda. Bugesera District is one of the seven Districts that constitute the Eastern Province in of Rwanda. It is ranging between 30o 05’ Eastern longitude, and 2o 09’ Southern Latitude, and covers the surface of 1337 km2. The District is characterized with a mixture of plateaus with an altitude varying between 1,100 m and 1,780m and undulating hills dominated by varying heights. Bugesera climate is dry with temperature varying between 200 and 30°C. The district has two dry seasons and two rainy seasons. The hydrographical network is mainly characterized by 3 rivers, namely; Akanyaru, Akagera and Nyabarongo. Besides these rivers, there are 9 lakes, though, with little effect on rainfall, but important for fishing, tourism, transportation, power generation and agricultural irrigation among others.

2.2 Survey Procedures and Sample Collection

Parents/guardians of the children were invited to attend sensitization meetings. The study procedures were explained in an exceedingly simpler language they felt most comfortable with. Written consent was obtained from all parents/guardians who were willing to have their children participate in the study. Finger prick blood was collected from every child using a capillary tube. Thick and thin blood smears were prepared for the diagnosis of *Plasmodium* parasites. *Plasmodium*-positive slides were re-checked by a senior laboratory technician for quality control and assurance.

2.3 Statistical Analysis

The data were entered in EPI INFO 7, and statistical analysis was done using SPSS and EXCEL. Chi-square test including odd ratios at 95% CI and One-way ANOVA was used to test for differences in proportions and means, respectively. Values were considered statistically significant when *P*-values are <0.05.

3. RESULTS

3.1 Geographical Distribution of Single Infection and Coinfection

P. falciparum was common throughout the study area, with highest prevalence in provinces of Nyiragiseke (22.78%) and Shami (18.99%), Fig 1. The geographical distribution of STH was dominated by *A. lumbricoides*, Fig 2. The STH – *Plasmodium* co-infection exhibited geographical variation and was higher in provinces with high *A. lumbricoides* prevalence, Fig 3.

3.2 Single Infections

Overall, the children were variably infected with any soil transmitted helminth species. The most prevalent species was *A. lumbricoides* (4.43%), *P* <0.001; followed by *T. trichiura* (0.76%) and *Ancylostoma duodenale* (0.16 %). The prevalence of *P. falciparum* was 3.15%. These data are as shown in Table1.

3.3 Co-infections

Overall, the prevalence of STH - *Plasmodium* co-infection was 36.15% and, *A. lumbricoides-Plasmodium* co-infection was the only significant co-infection *P* <0.05, Table2.

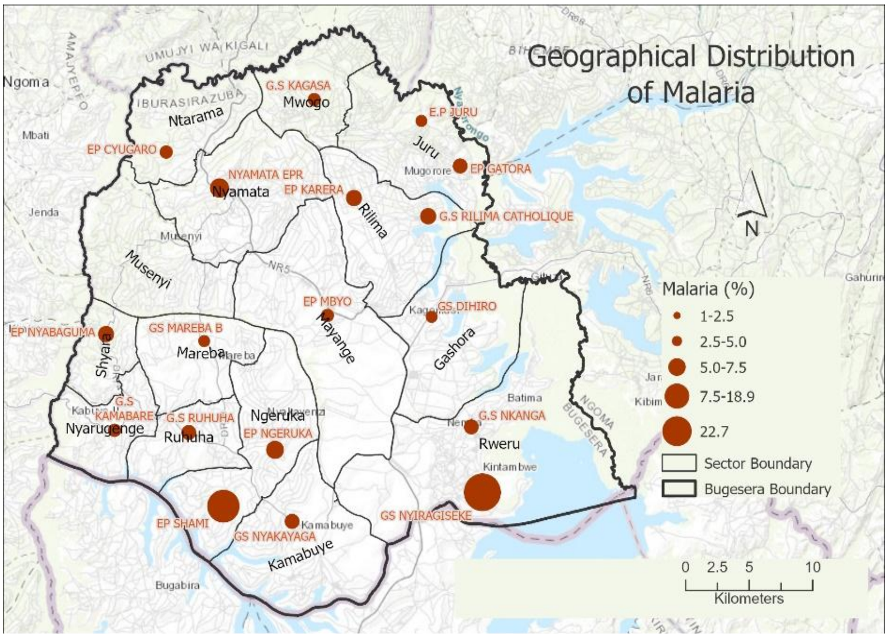

Fig. 1. Geographical distribution of malaria infection

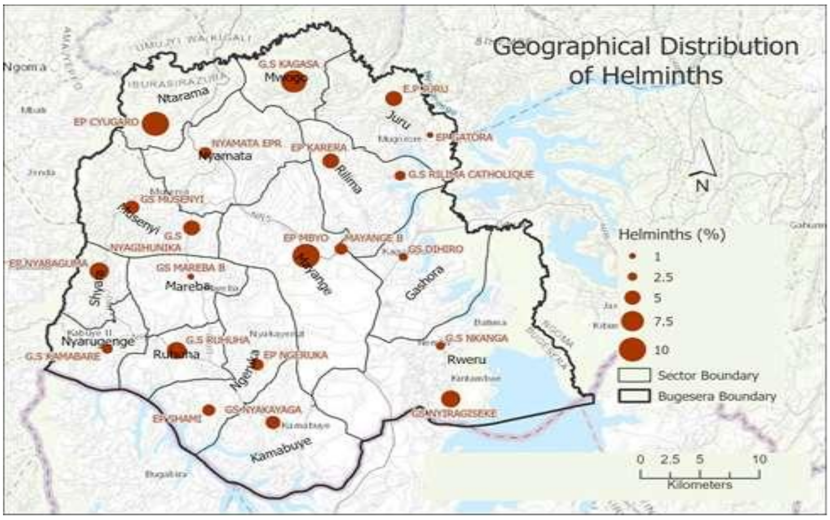

Fig. 2. Geographical distribution of helminths

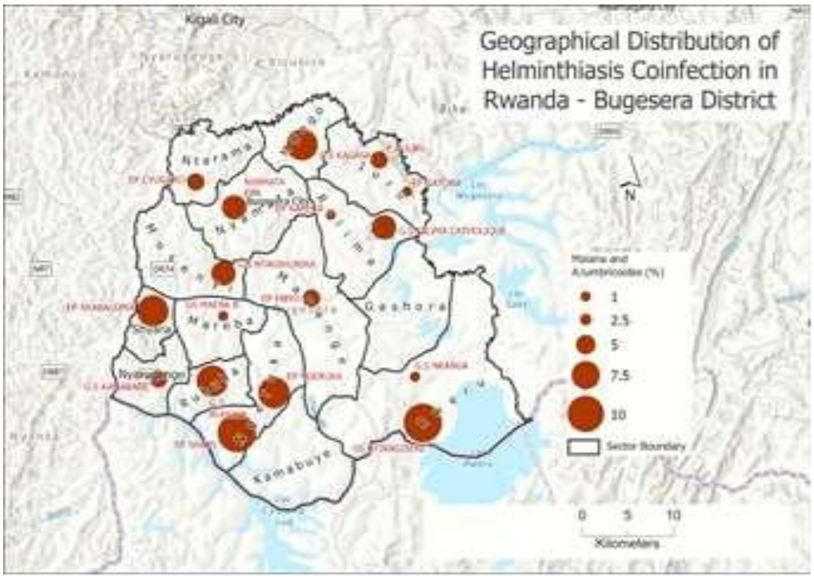

Fig. 3. Geographical distribution of coinfection

Table 1. Prevalence of Helminth and *Plasmodium* single infections

Characteristic	Overall (n = 2,507)	(n = 1,200), (47.9%)	Girls (n = 1,307), (52.1%)	p-value
Prevalence of helminth infection				
A. lumbricoides (%, 95 % CI)	4.43 (12.28-29.65)	4.50 (9.89-35.26)	4.36 (7.17-31.71)	<0.001
T. trichiura (%, 95 % CI)	0.76 (2.62-7.27)	0.58 (0.41-8.16)	0.92 (1.97-8.70)	0.05
A. duodenale (%, 95 % CI)	0.16 (0.70-3.30)	0.17 (0.50-8.85)	0.15 (0.61-7.85)	0.04
Prevalence of *Plasmodium* infection				
P. falciparum (%, 95 % CI)	3.15 (144.57-828.39)	3.33 (156.72-971.08)	2.98 (194.96-414.07)	

Table 2. Overall Prevalence of Co-infections

Characteristic	Overall (n = 2,507)	Boys (n = 1,200), (47.9%)	Girls (n = 1,307), (52.1%)	p- value
Coinfection				
T. trichiura-A. lumbricoides (%, 95 % CI)	3.08 (4.34-17.16)	0	5.97 (4.34-17.16)	0.432
A. lumbricoides-P. falciparum (%, 95 % CI)	36.15 (9.90-11.89)	30.16 (8.08-11.08)	41.79 (10.50-13.07)	<0.05

4. DISCUSSION

Reports from the studies in Rwanda and elsewhere show that STH and *Plasmodium* infections are heterogeneously distributed across the country with evidence of signatures of spatial clustering with different risk factors including geographical location [19,33-37]. Our finding of the distribution of *P. falciparum* is actually in phase with the previous reports. However, the prevalence in provinces of Nyiragiseke (22.78%) and Shami (18.99%) is far much higher than the overall prevalence of the district in the same study population [33]. Our finding calls for the review of the control methods, strategies and mechanisms to address the unique conditions and activities in each province.

The geographical distribution of single STH was variably dominated by *A. lumbricoides*, and the STH – *Plasmodium* co-infection followed the same pattern since there was only one significant *A. lumbricoides- Plasmodium* co-infection, *P* <0.05. This association has been consistently reported from the studies in the same district in Rwanda and elsewhere [14,30,33,38,39]. Most importantly and interestingly, this particular co-infection has been attributed to severe malaria [22,30,40]. There is, therefore, need for targeted control methods, strategies and mechanisms for these parasites.

5. CONCLUSION

The un-proportional distribution of and higher prevalence of *P. falciparum* in the provinces of Nyiragiseke (22.78%) and Shami (18.99%) calls for the review of the control methods, strategies and mechanisms to address the unique conditions and activities in each province. The variably dominant *A. lumbricoides- Plasmodium* co-infection calls for targeted control strategies and mechanisms for these parasites since this association has been attributed to severe malaria.

CONSENT

All participants and parents/guardians gave consent to participate.

ETHICAL APPROVAL

The approval was provided by the University of Rwanda IRB (No. 380/CMHS).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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