Original Research Article

Geographical Distribution of Soil Transmitted Helminths and *Plasmodium falciparum* co-infections among school children in Bugesera District, Rwanda

ABSTRACT

Aims: Soil Transmitted Helminths and Plasmodium infections are ubiquitous within the tropical and subtropical regions. However, the extent and consequences of Helminth-Plasmodium co-infection at different spatial scales are poorly understood. This study defines the medical field of soil transmitted helminths and plasmodium coinfection among schoolchildren in Eastern Republic of Rwanda and studies the related risk factors.
Study design: Cross Sectional Survey
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 variation within the geographical distribution of STH was dominated by *A. lumbricoides*. The co-infection exhibited geographical variation and was higher in provinces with high *A. lumbricoides* prevalence.
Conclusion: The highest prevalence of the respective infections in Nyiragiseke and Shami provinces calls for critical analysis to establish the ultimate cause. This would inform the appropriate action plan.

Keywords: Geographical Distribution, Plasmodium falciparum, Soil transmitted helminths and Co - infections

1. INTRODUCTION

A recent WHO report shows that 228 million cases of malaria occurred, with sub-Saharan Africa and South East Asia accounting for 97% of the burden [4]. *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 [4]. Helminth and Plasmodium infections proliferate underneath the favorable climatically and environmental conditions especially among the poorest communities, while malaria infection is ruled by climatic factors connected to vector ecology and parasite life cycle [15], [22], [32]. In Cameroon, Plasmodium-helminth co-infection was related to altitude [17]. It is important to note, however, that climatic, environmental, and socioeconomic factors influence the distribution of single and multiple species parasite infections.

2. MATERIAL AND METHODS

2.1 Study setting

The survey was conducted in Bugesera District, Rwanda, between May and December 2020. Bugesera District is one of the seven Districts that constitute the Eastern Province in Rwanda. It is located in the South West of the Province, ranging between 30^{o} 05' Eastern longitude, and 2^{o} 09' Southern Latitude, and covers the surface of 1337 km^2. 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 20^{0} and 30°C. It 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 are exploited for fishing, tourism, transportation, power generation, agricultural irrigation and farming among others. The district was selected due to the high rate of protozoal infections and high prevalence of STH in Rwanda [24,27].

2.2 Choice of school children

Representative school children of the 79 public primary schools in Bugesera District were purposively selected for screening with the help of the district education and health officers. Initially, 21 schools were screened for the study. Children were enrolled irrespective of the infections.

2.3 Survey procedures and sample collection

Parents/guardians were invited to attend sensitization conferences at the chosen colleges. The study procedures were explained in the language that they felt most comfortable with. Written consent was obtained from all parents/guardians who were willing to have their children enrolled into the study.

3. RESULTS

3.1 Single infections

Overall, 5.35 % of the children were infected with any soil transmitted helminths species. The primary common species was *A. lumbricoides* (4.43%); followed by *T. trichiura* (0.76%) and Hook worm (0.16 %) as shown in table 2. The prevalence of *P. falciparum* was 3.15%. The prevalence of *A. lumbricoides* and *P. falciparum* differed by sex. The prevalence of *A. lumbricoides* was highest among children aged 5–8 years whereas the prevalence of *P. falciparum* differed with with age ($P < 0.001$).

3.2 Coinfections

Overall, the prevalence of STH-Plasmodium coinfection was 36.15%. *A. lumbricoides*-Plasmodium coinfection was the only coinfection recorded (Table three). The prevalence of *A. lumbricoides*-Plasmodium coinfection was different among age groups, though, more common in the age group (13-18), ($p < 0.05$).

3.3 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%). The variation within the geographical distribution of STH was dominated by *A. lumbricoides*. The co-infection exhibited geographical variation and was higher in provinces with high *A. lumbricoides* prevalence.

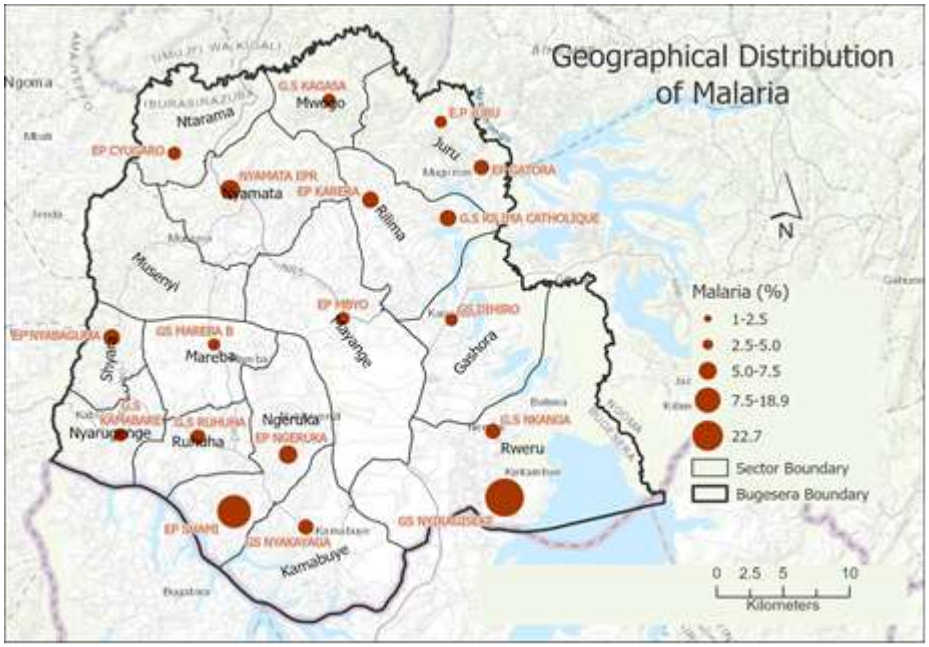
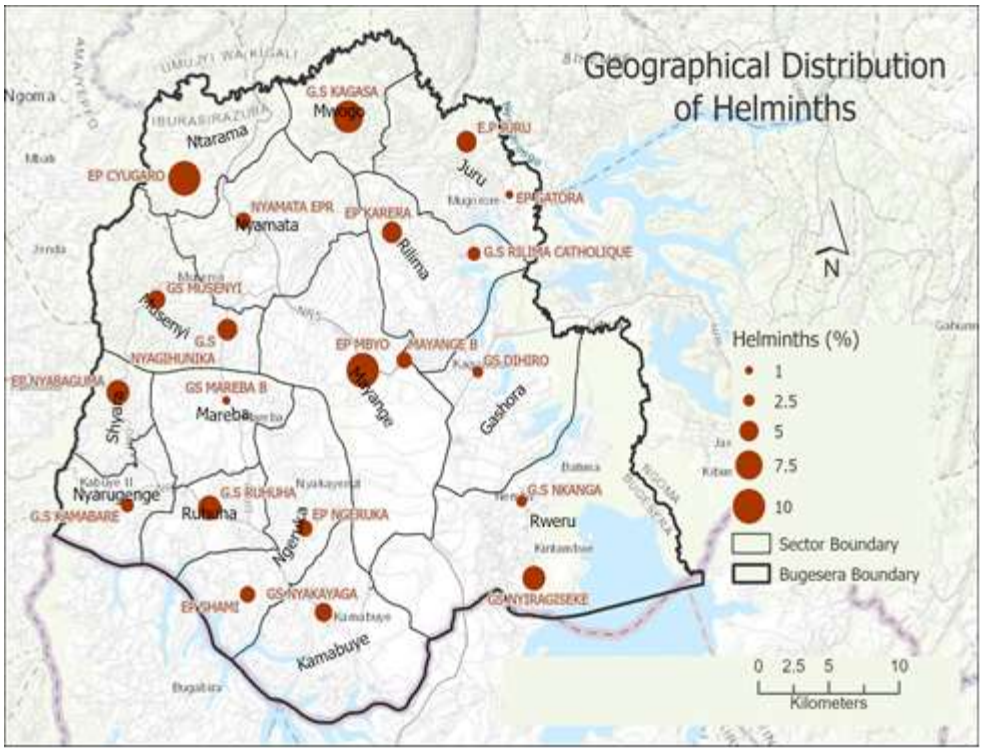
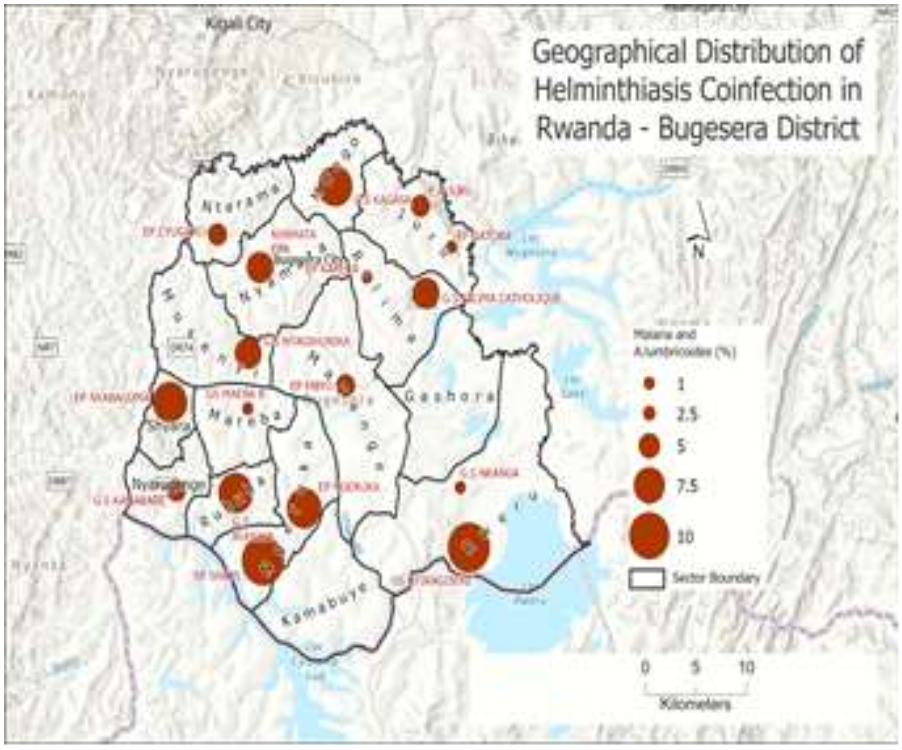


Fig 1. Geographical distribution of malaria infection



91

92 **Fig 2. Geographical distribution of helminths**



93

94 **Fig 3. Geographical distribution of coinfection**

Table1: Description of study participants

Characteristic	Overall (n = 2,507)	Boys (n = 1,200), (47.9%)	Girls (n = 1,307), (52.1%)	p-value
Mean age (years, SD)	11.29 (2.96)	11.11 (2.79)	11.45 (3.09)	<0.0001
Age-group (years, n (%))	11.29(2.96)	11.11 (2.79)	11.45 (3.09)	
5-8	452 (18.0)	212 (17.7)	240 (18.4)	0.004
9-10	560 (22.3)	277 (23.1)	283 (21.7)	
11-12	594 (23.7)	334 (27.8)	260 19.9)	
13-18	901 (35.9)	377 (31.4)	524 (40.1)	
Class (n, (%))				
Lower primary (1–3)	1272 (50.7)	638 (53.2)	634 (48.5)	0.33696
Upper primary (4–6)	1235 (49.3)	562 (46.8)	673 (51.5)	

Table 2: Prevalence of helminth infection, malaria infection

Characteristic	Overall (n = 2,507)	Boys (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
Hookworm (%, 95 % CI)	0.16 (0.70-3.30)	0.17 (0.50-8.85)	0.15 (0.61-7.85)	0.04
Intensity of helminth Infection				
A. lumbricoides (epg, 95 % CI)	503 (295-712)	542 (237-846)	467 (172-761)	
T. trichiura (epg, 95 % CI)	119 (63-175)	103 (10-196)	128 (47-209)	
Hookworm (epg, 95 % CI)	48 (17-79)	60 (12 213)	36 (15-188)	
P. falciparum infection (%, 95 % CI)	3.15 (144.57-828.39)	3.33 (156.72-971.08)	2.98 (194.96-414.07)	
Mean parasite density (parasites per µl blood)				
Uninfected (n, %)	2428 (96.85)	1160 (96.67)	1268 (97.02)	
Low (1–999) (n, %)	75 (2.99)	38 (3.17)	37(2.83)	
Medium/high (≥1000) (n, %)	4 (0.16)	2 (0.17)	2 (0.15)	

Table 3: 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

Table 4: Prevalence of co-infection by Age group

Characteristic	Overall (n = 2,507)	Boys (n = 1,200), (47.9%)	Girls (n = 1,307), (52.1%)	p-value
Age-group A. lumbricoides-P. falciparum (%, 95 % CI)				
5-8	29.79(8.37-58.63)	42.11 (0.27-33.72)	21.43 (31.89-79.12)	0.04
9-10	14.89(29.24-119.90)	26.32 (0.77-14.37)	7.14 (30-314)	
11-12	17.02(6.57-19.43)	15.79 (2.04-19.96)	17.86 (2.28-26.12)	
13-18	38.30(5.30-12.48)	15.79 (2.81-9.86)	53.57 (5.24-13.56)	
13-18	33.85 (5.78-10.22)	39.68 (3.53-9.59)	35.82 (6.41-12.09)	<0.05

T able 5: Prevalence of helminths, malaria infections by Age group

Characteristic	Overall (n = 2,507)	Boys (n = 1,200), (47.9%)	Girls (n = 1,307), (52.1%)	p-value
Helminths, A. lumbricoides (%, 95 % CI)				
5-8	23.08 (8.14-32.33)	22.22 (2.96-21.61)	20.9 (5.63-55.37)	
9-10	18.46 (14.51-84.99)	15.87 (5.35-101.85)	8.96 (9.02-110.98)	
11-12	24.62 (0.20-31.49)	22.22 (10.80-65.15)	19.41 (2.87-12.36)	
13-18	33.85 (5.78-10.22)	39.68 (3.53-9.59)	35.82 (6.41-12.09)	<0.05
Malaria (%, 95 % CI)				
5-8	31.46 (155.06-1638.78)	38.64 (119.05-400.95)	24.44 (386.09-2587.00)	
9-10	19.10 (277.17-1478.58)	25.00 (59.02-255.89)	13.33 (254.22-2572.44)	
11-12	11.23 (3.45-670.95)	11.36 (129.10-187.70)	11.11 (229.90-802.10)	
13-18	37.07 (4.59-1639.02)	25.00 (671.20-3023.35)	48.89 (157.53-446.83)	<0.05

4. DISCUSSION

Our study reports *A. lumbricoides* as the most predominant STH infection (4.43%) with more infections in boys (p <0.001); followed by *T. trichiura* (0.76%) with more girls infected than boys (P=0.05) and hook worm (0.16 %) with more boys infected than girls, (P=0.04). Overall boys were more infected than girls. The STH results of this study are similar with previous study conducted in the same district but with a significant reduction in the respective prevalence [22]. This is evidence of the positive impact and enforcement of the control programs in the eastern province of Rwanda. This reduction, though, is contrary to a recent

report from the Western province of Rwanda where the prevalence of the STH was respectively higher [14].

The overall prevalence *P. falciparum* infection was 3.15 %, with more boys infected than girls ($P < 0.001$). This is extremely lower than earlier reported [22] but consisted with the tremendous positive trend of the control programs.

Interestingly there was one principal common coinfection of Ascaris - Plasmodium with the overall prevalence of 36.15% but surprisingly with higher prevalence in girls than boys - approximately 42% ($P<0.001$). This is still lower than previously reported from the study in the same district [22]. Nevertheless, the higher prevalence in girls is still striking given that the respective single infections were higher in boys. This outstanding discrepancy could be due additional microbiota infections in girls that have been reported associated with increased plasmodium infection elsewhere [19]. STH – Plasmodium coinfections have been associated with different malaria outcomes including uncomplicated to severe malaria as earlier reported from the study from this district and elsewhere [10,16,18,22,26,27]. nevertheless, our results could differ with the malaria outcome especially from the previous study conducted in the same region now that, there is evidence that additional microbiota infections moderate plasmodium infections differently.

P. falciparum was common throughout the study area, with highest prevalence in provinces of Nyiragiseke (22.78%) and Shami (18.99%). The variation within the geographical distribution of STH was dominated by *A. lumbricoides*. The co-infection exhibited geographical variation and was higher in provinces with high *A. lumbricoides* prevalence. The variation within the geographical distribution of the respective infections could be due to different levels of enforcement of the control program by the policy controllers.

4. CONCLUSION

The highest prevalence of the respective infections in Nyiragiseke and Shami provinces calls for critical analysis to establish the ultimate cause. This would inform the appropriate action plan.

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).

REFERENCES

1. BANOO S, BELL D, BOSSUYT P, HERRING A, MABEY D, POOLE F, ET AL. EVALUATION OF DIAGNOSTIC TESTS FOR INFECTIOUS DISEASES: GENERAL PRINCIPLES. NAT REV MICROBIOL. 2006;4(12 SUPPL):S20–32.

2. BROOKER S, AKHWALE W, PULLAN R, ESTAMBALE B, CLARKE SE, SNOW RW, ET AL. EPIDEMIOLOGY OF PLASMODIUM-HELMINTH CO-INFECTION IN AFRICA: POPULATIONS AT RISK, POTENTIAL IMPACT ON ANEMIA, AND PROSPECTS FOR COMBINING CONTROL. THE AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE. 2007;77(6_SUPPL):88–98. HTTPS://DOI.ORG/10.4269/AJTMH.2007.77.88 PMID:18165479

3. BROOKER S, MIGUEL EA, MOULIN S, LUOBA AI, BUNDY DA, KREMER M. EPIDEMIOLOGY OF SINGLE AND MULTIPLE SPECIES OF HELMINTH INFECTIONS AMONG SCHOOL CHILDREN IN BUSIA DISTRICT KENYA. EAST AFR MED J. 2000;77(3):157–61.

4. BROOKER, S., AKHWALE, W., PULLAN, R., ESTAMBALE, B., CLARKE, S.E., SNOW, R.W., AND HOTEZ, P.J. (2007). EPIDEMIOLOGY OF PLASMODIUM-HELMINTH CO-INFECTION IN AFRICA: POPULATIONS AT RISK, POTENTIAL IMPACT ON ANEMIA, AND PROSPECTS FOR COMBINING CONTROL. AM. J. TROP. MED. HYG., 77(SUPPL 6), PP. 88–98.

5. BRUTUS L, WATIER L, BRIAND V, HANITRASOAMAMPIONONA V, RAZANATSOARILALA H, COT M. PARASITIC CO-INFECTIONS: DOES ASCARIS LUMBRICOIDES PROTECT AGAINST PLASMODIUM FALCIPARUM INFECTION? AM J TROP MED HYG. 2006;75(2):194–8.

6. BRUTUS L, WATIER L, HANITRASOAMAMPIONONA V, RAZANATSOARILALA H, COT M. CONFIRMATION OF THE PROTECTIVE EFFECT OF ASCARIS LUMBRICOIDES ON PLASMODIUM FALCIPARUM INFECTION: RESULTS OF A RANDOMIZED TRIAL IN MADAGASCAR. AM J TROP MED HYG. 2007;77(6):1091–5.

7. CENTER FOR INFECTIOUS DISEASES CONTROL RWANDA,2007

8. HANDZEL T, KARANJA DM, ADDISS DG, HIGHTOWER AW, ROSEN DH, COLLEY DG, ET AL. GEOGRAPHIC DISTRIBUTION OF SCHISTOSOMIASIS AND SOIL-TRANSMITTED HELMINTHS IN WESTERN KENYA: IMPLICATIONS FOR ANTHELMINTHIC MASS TREATMENT. AM J TROP MED HYG. 2003;69(3):318–23.

9. HIGH PREVALENCE OF HOOKWORMS IN THE EASTERN PART OF THE COUNTRY(NADINE ET AL.,2017)

10. HUMPHRIES D, MOSITES E, OTCHERE J, TWUM WA, WOO L, JONES-SANPEI H, ET AL. EPIDEMIOLOGY OF HOOKWORM INFECTION IN KINTAMPO NORTH MUNICIPALITY, GHANA: PATTERNS OF MALARIA COINFECTION, ANEMIA, AND ALBENDAZOLE TREATMENT FAILURE. AM J TROP MED HYG. 2011;84(5):792–800.

11. KINUNG'HI SM, MAGNUSSEN P, KAATANO GM, KISHAMAWE C, VENNERVALD BJ. MALARIA AND HELMINTH CO-INFECTIONS IN SCHOOL AND PRESCHOOL CHILDREN: A CROSS-SECTIONAL STUDY IN MAGU DISTRICT, NORTH-WESTERN TANZANIA. PLOS ONE. 2014;9(1):E86510.

12. KINUNG'HI SM, MAGNUSSEN P, KAATANO GM, KISHAMAWE C, VENNERVALD BJ. MALARIA AND HELMINTH CO-INFECTIONS IN SCHOOL AND PRESCHOOL CHILDREN: A CROSS-SECTIONAL STUDY IN MAGU DISTRICT, NORTH-WESTERN TANZANIA. PLOS ONE. 2014;9(1):E86510.

13. KRAUTH SJ, COULIBALY JT, KNOPP S, TRAORE M, N'GORAN EK, UTZINGER J. AN IN-DEPTH ANALYSIS OF A PIECE OF SHIT: DISTRIBUTION OF SCHISTOSOMA MANSONI AND HOOKWORM EGGS IN HUMAN STOOL. PLOS NEGL TROP DIS. 2012;6(12):E1969.

14. 14. KABATENDE J, MUGISHA M, NTIRENGANYA L, BARRY A, RUBERANZIZA E, MBONIGABA JB, ET AL. PREVALENCE, INTENSITY, AND CORRELATES OF SOIL-TRANSMITTED HELMINTH INFECTIONS AMONG SCHOOL CHILDREN AFTER A DECADE OF PREVENTIVE CHEMOTHERAPY IN WESTERN RWANDA. PATHOGENS. 2020;9(12).

15.

16.

17. MAIZELS RM, BALIC A, GOMEZ-ESCOBAR N, NAIR M, TAYLOR MD, ALLEN JE. HELMINTH PARASITES–MASTERS OF REGULATION. IMMUNOL REV. 2004;201:89–116.

18. MAZIGO HD, WAIHENYA R, LWAMBO NJ, MNYONE LL, MAHANDE AM, SENI J, ET AL. CO-INFECTIONS WITH PLASMODIUM FALCIPARUM SCHISTOSOMA MANSONI AND INTESTINAL HELMINTHS AMONG SCHOOLCHILDREN IN ENDEMIC AREAS OF NORTHWESTERN TANZANIA. PARASIT VECTORS. 2010;3:44.

19. MWANDAWIRO C, NIKOLAY B, KIHARA JH, OZIER O, MUKOKO DA, MWANJE MT, ET AL. MONITORING AND EVALUATING THE IMPACT OF NATIONAL SCHOOL-BASED DEWORMING IN KENYA: STUDY DESIGN AND BASELINE RESULTS. PARASIT VECTORS. 2013;6:198.

20. ODIERE MR, OPISA S, ODHIAMBO G, JURA WG, AYISI JM, KARANJA DM, ET AL. GEOGRAPHICAL DISTRIBUTION OF SCHISTOSOMIASIS AND SOIL-TRANSMITTED HELMINTHS AMONG SCHOOL CHILDREN IN INFORMAL SETTLEMENTS IN KISUMU CITY WESTERN KENYA. J PARASITOL. 2011;138(12):1569–77.

21. PULLAN RL, GETHING PW, SMITH JL, MWANDAWIRO CS, STURROCK HJ, GITONGA CW, ET AL. SPATIAL MODELLING OF SOIL-TRANSMITTED HELMINTH INFECTIONS IN KENYA: A DISEASE CONTROL PLANNING TOOL. PLOS NEGL TROP DIS. 2011;5(2):E958.

22. PULLAN RL, KABATEREINE NB, BUKIRWA H, STAEDKE SG, BROOKER S. HETEROGENEITIES AND CONSEQUENCES OF PLASMODIUM SPECIES AND HOOKWORM COINFECTION: A POPULATION BASED STUDY IN UGANDA. J INFECT DIS. 2011;203(3):406–17.

23. PULLAN RL, KABATEREINE NB, BUKIRWA H, STAEDKE SG, BROOKER S. HETEROGENEITIES AND CONSEQUENCES OF PLASMODIUM SPECIES AND HOOKWORM COINFECTION: A POPULATION BASED STUDY IN UGANDA. J INFECT DIS 2011;203(3):406–17. EPUB 2010/12/27

24. RIGHETTI AA, GLINZ D, ADIOSSAN LG, KOUA AY, NIAMKE S, HURRELL RF, ET AL. INTERACTIONS AND POTENTIAL IMPLICATIONS OF PLASMODIUM FALCIPARUM-HOOKWORM COINFECTION IN DIFFERENT AGE GROUPS IN SOUTH-CENTRAL COTE D'IVOIRE. PLOS NEGL TROP DIS. 2012;6(11):E1889.

25. MARCELLINE U, NOELLA U, THARCISSE M, CORINE K, JOSEPHAT M, BANSON B. THE IMPACT OF MALARIA AND GASTROINTESTINAL HELMINTHIASIS CO-INFECTION ON ANAEMIA AND SEVERE MALARIA AMONG CHILDREN IN BUGESERA DISTRICT, RWANDA. INTERNATIONAL JOURNAL OF TROPICAL DISEASE & HEALTH. 2016;13(4):1-7

26.

27. RWANDA MALARIA INDICATOR SURVEY FINAL REPORT, 2017

28. SALIM N, KNOPP S, LWENO O, ABDUL U, MOHAMED A, SCHINDLER T, ET AL. DISTRIBUTION AND RISK FACTORS FOR PLASMODIUM AND HELMINTH CO-INFECTIONS: A CROSS-SECTIONAL SURVEY AMONG CHILDREN IN BAGAMOYO DISTRICT, COASTAL REGION OF TANZANIA. PLOS NEGL TROP DIS. 2015;9(4):E0003660.

29. SANG HC, MUCHIRI G, OMBOK M, ODIERE MR, MWINZI PN. SCHISTOSOMA HAEMATOBIUM HOTSPOTS IN SOUTH NYANZA, WESTERN KENYA: PREVALENCE, DISTRIBUTION AND CO-ENDEMICITY WITH SCHISTOSOMA MANSONI AND SOIL-TRANSMITTED HELMINTHS. PARASIT VECTORS. 2014;7:125.

30. TRAC PLUS (MINISTRY OF HEALTH) AND THE ACCESS PROJECT. REPORT OF THE NATIONAL SCHOOL PREVALENCE SURVEY ON SOIL-TRANSMITTED HELMINTHIASIS AND SCHISTOSOMIASIS IN SCHOOL AGED CHILDREN, KIGALI, RWANDA. 2008

31. TSHIKUKA JG, SCOTT ME, GRAY-DONALD K, KALUMBA ON. MULTIPLE INFECTION WITH PLASMODIUM AND HELMINTHS IN COMMUNITIES OF LOW AND RELATIVELY HIGH SOCIO-ECONOMIC STATUS. ANN TROP MED PARASIT. 1996;90(3):277–93.

32. 29. UMWANANKUNDI MARCELLINE, UMULISA NOELLA,MUNYANEZA THARCISSE

33. KAREMA CORINE, MANIGA JOSEPHAT AND BARUGAHARE JOHN BANSO

34. THE IMPACT OF MALARIA AND GASTROINTESTINAL HELMINTHIASIS CO-INFECTION ON ANAEMIA AND SEVERE MALARIA AMONG CHILDREN IN BUGESERA DISTRICT,RWANDA. INTERNATIONAL JOURNAL OF TROPICAL DISEASE & HEALTH 13(4): 1-7, 2016

35.

36. 30.WHO. ACCELERATING WORK TO OVERCOME THE GLOBAL IMPACT OF NEGLECTED TROPICAL DISEASES – A ROADMAP FOR IMPLEMENTATION. GENEVA: WORLD HEALTH ORGANIZATION; 2012.

37. 31.WHO. ANTHROPLUS: GROWTH REFERENCE 5–19 YEARS. GENEVA: WHO; 2007.

38. 32.YAPI RB, HURLIMANN E, HOUNGBEDJI CA, NDRI PB, SILUE KD, SORO G, ET AL. INFECTION AND CO-INFECTION WITH HELMINTHS AND PLASMODIUM AMONG SCHOOL CHILDREN IN COTE D'IVOIRE: RESULTS FROM A NATIONAL CROSS-SECTIONAL SURVEY. PLOS NEGL TROP DIS. 2014;8(6):E2913.