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Prevalence and Risk Factors of Human *Taenia solium* Cysticercosis in Mbulu District, Northern Tanzania

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Simple Summary: This study assessed the effect of a school deworming program on *Taenia solium* (the pork tapeworm) which started in 2002 in Tanzania. Mbulu district was selected because several studies including clinical trials were conducted in the district. Despite the school deworming and intervention conducted, the area is reported with high human *T. solium* cysticercosis and related epileptic cases. We assessed the deworming performed by the local government in collaboration with the Neglected Tropical Disease Control (NTD) program among school children. The infection by age, sex, and household along with community and risk factors were assessed. High human *T. solium* cysticercosis was reported along with high household and community risk factors. The deworming seemed to have positive effect amongyounger age groups but with no significant difference in other, older age groups. This shows that there is a re-infection of younger age groups compared to untreated adults. Thus, it is recommended to scale up deworming to adult age groups.

Abstract: Background: Taeniosis and cysticercosis are human infections caused by the pork tapeworm, *Taenia solium*. This study is a baseline for community-based intervention. We determined the prevalence of human cysticercosis and associated risk factors following a deworming program conducted throughout the country, with Mbulu District being among the districts in Northern Tanzania. Methods: Human cysticercosis was determined by enzyme-linked immunosorbent assay (Ag- ELISA). Household interviews and observations were conducted to identify risk factors for cysticercosis transmissions among households and communities. Results: Three hundred individuals participated in this study. The age ranged from 5 to 89 years, with a median of 19 years. The prevalence of human cysticercosis was 23 (7.67%). The prevalence was high with 6 (11.76%) among individuals aged 26 to 35 years and ±45 years. There was no statistically significant difference in the prevalence by age group, sex, or occupation. Among the 300 participants, 82 (27.3%) had received anthelmintics during the previous year; among these, 5 (21.7%) were infected. The likelihood of infection was low among anthelmintic users by 28% [0.72 (0.26–2.01)], but the protection was not significant. The communities differed in risk factors on the availability of a clean and safe water supply; 52.7% (46/86) of households visited had no pit latrine. The cysticercosis prevalence showed a significant difference in communities. Conclusions: The prevalence of human cysticercosis was high and associated with higher age groups. The prevalence was low among those who had taken anthelmintics and was associated with lower age groups. The current school deworming program has a positive effect on school children, while the elderly are at higher risk because the intervention did not target them. It is recommended to scale up anthelmintic intervention to higher age groups.

Keywords: pork tapeworm; anthelmintics; cysticercosis; deworming; Tanzania

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1. Introduction

Taeniosis and cysticercosis are human diseases caused by the pork tapeworm, *Taenia solium*. Cysticercosis in humans is the infection of the larval stage following the ingestion of pork tapeworm eggs [1–3]. Taeniosis usually causes mild symptoms such as abdominal discomfort and weight loss [4]. The pork tapeworm larva in the human central nervous system causes neurocysticercosis (NCC), a serious medical condition in humans [5]. It is a brain disease that presents as epilepsy, chronic headache, visual disorders, dizziness, or nausea, and the clinical manifestation depends on the immune response of the individual, the location of cysts, and their size and number [6–8].

Worldwide pork tapeworm infections prevail in poor-subsistence-farming communities in low- and middle-income countries [9–11]. Taeniosis has been reported in Europe to range from 0.05 to 0.27% and ranges from 0 to 17.25% in Africa, Asia, and Latin America [4]. Neurocysticercosis causes up to 30 percent of all cases of acquired epilepsy in endemic localities [5,12,13], which causes about 61 to 212 deaths annually in East African countries [14,15].

Generally, pork tapeworm diseases in Africa have been estimated to be 0–13.9% for taeniosis and 0.68–34.5% for cysticercosis and have been reported in 29 countries [4,14,16]. About 0.95–3.08 million people are estimated to suffer from symptomatic NCC in sub-Saharan Africa [17]. In Eastern Africa, human *T. solium* cysticercosis is endemic with a pooled prevalence ranging from 14 to 20% [14]. The disease is endemic in Tanzania, with an average seroprevalence of about 17%, and the disease accounted for 212 deaths and 17,853 NCC incident cases for the year 2012 [15,18–20]

Human *T. solium* cysticercosis is associated with community practices and poor sanitation. Open defecation, unsafe water sourcing, and the consumption of uninspected and undercooked infected pork increase the risk of human infections [11,18,21–23]. Studies have shown that clean and safe water reduces infection in both humans and pigs; furthermore, the clean practices of feeding pigs reduce the risks of infecting pigs [24]. The underuse of pit latrines and improperly constructed toilets give pigs access to toilets, thus easily accessing human excreta [21]. The pig-free-ranging practices are another risk factor for pork tapeworm transmission in the endemic communities [19,22].

Prophylaxis treatment is among the means of reducing the transmission of intestinal and tissue worms. The current treatment guideline for pork tapeworm diseases gives directives for treatment in humans [25]. Prophylaxis and vaccines in pigs targeting *T solium* are not practiced in communities, but the result showed the high efficacy of combined TSOL18 and oxfendazole (Kabululu et al., 2020) [21]. The current prophylactic treatment using praziquantel and albendazole for schistosomiasis and soil-transmitted helminths targets school children only [26].

Although pork tapeworm is listed by the World Health Organization (WHO) as the main cause of food-borne diseases [12], it is not considered a priority disease in Tanzania, thus receiving less attention in terms of surveillance and interventions [27]. The current nationwide intervention among school children using praziquantel and albendazole targets schistosomiasis and soil-transmitted helminths but not pork tapeworm [26,28]. We conducted this study to determine the effect of anthelminthic treatment among school children on the transmission of pork tapeworm in communities of Mbulu district in Tanzania.

2. Material and Methods

2.1. Study Area

This study was conducted in the Mbulu District of northern Tanzania in March–April 2020. The district is among six districts of Manyara region in Tanzania located at latitude 3°45′ and 4° S and longitude 35°20′ and 36° E at an altitude ranging from 1000 to 2400 m above mean sea level. The district has an area of 3800 square kilometers and a population of 320,279; among these, 161,548 are males and 158,731 are females. About 48,976 are in urban and 271,303 are in rural areas [29]. Crop farming and livestock keeping are the main economic activities for 96% of the population [30]. The district administers anthelmintics to school children annually as part of the national deworming program using praziquantel and albendazole targeting schistosomiasis, as well as soil-transmitted helminths which started in 2002 in Tanzania [26,28]. Primary school children in all villages in the district including those selected for the study received the intervention conducted by the Neglected Tropical Diseases Control program in Tanzania collaborating with local governments. The study area was selected as a result of the high prevalence and cysticercosis burden of pork tapeworm from previous studies of 16.3% [18,31].

2.2. Study Design

This was a community-based cross-sectional study conducted in Mbulu district, Northern Tanzania, from March to April 2020.

2.3. Household and Participant Selection

A total of 3 wards, namely Maghang, Dinamu, and Bashay, were randomly selected from 15 pig-keeping wards, and the inclusion criteria were pig-keeping communities; 3 out of 18 wards were excluded. From each of the three wards, one village was randomly selected and included in this study (Figure 1). The households were conveniently sampled based on the presence of pigs, a history of keeping pigs, and the consent of the household leader. The consented adult and assented minor participants from households aged five years and above were recruited for this study because they were enrolled in preschool and primary school and were targeted by the deworming program (Figure 2). Pregnant women and the severely sick were excluded. The head of household had a separate questionnaire from other participants. This is because the household at risk is mainly under the control of the head of the household. The study villages selected were Maghang Juu, Diyomat, and Harsha. The sample size was computed using Fisher's formula [32], Z = 1.96, p = 16.3%, and d = 0.0418, estimating a sample size of 300 participants (Mwang'onde et al., 2012) [18].

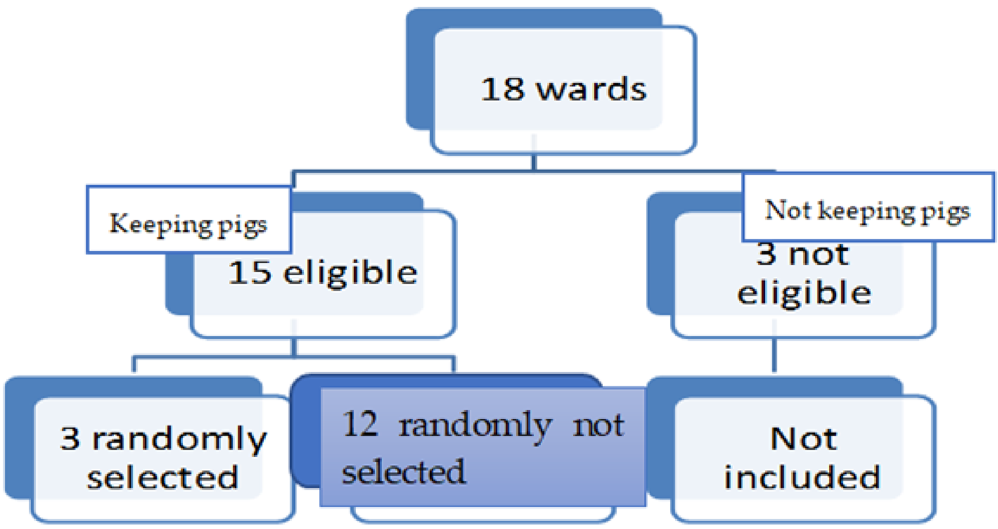

Figure 1. Selection of the study communities.

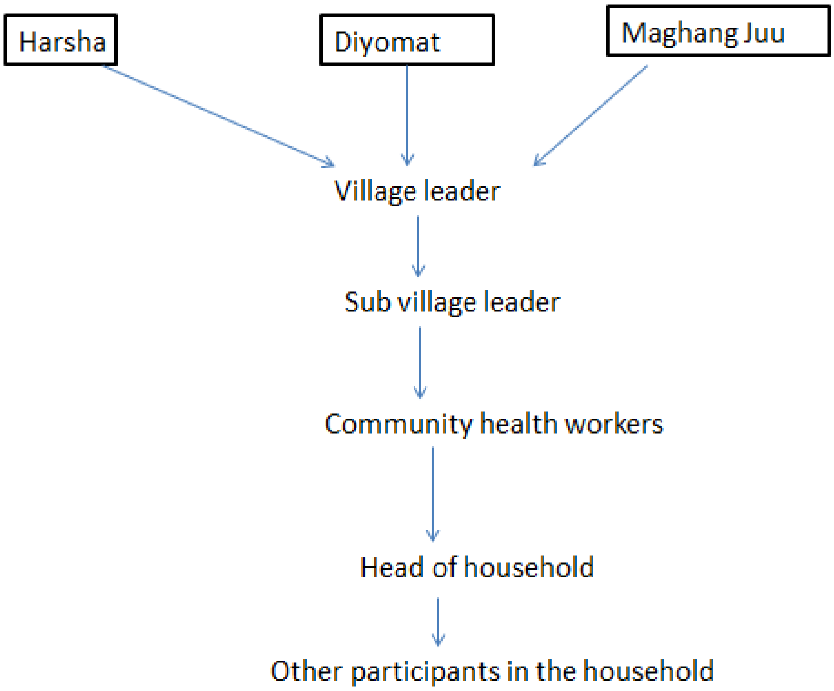

Figure 2. Study participant recruitment approach.

2.4. Data Collection

2.4.1. Questionnaire and Observational Check List

The household leaders were asked about risk factors related to cysticercosis on the source of water and participation in previous deworming programs. Observations and responses on the availability of pit latrines, water sources, and pigkeeping were recorded. The data were collected electronically using tablets installed with koBocollect software version 2020, kf.kobotoolbox.org accessed on 10 March 2020. The information recorded among study participants was on education, occupation, and participation in deworming programs by swallowing anthelmintics in the last deworming program.

2.4.2. Sample Collection

Five milliliters of blood were drawn from the median cubital vein by a medical laboratory technician of Mbulu district council from each recruited participant including the head of households who consented and including assented children in the household before being transferred into a plain vacutainer tube and stored in a cool box packed with ice cubes. The blood samples were centrifuged at 1500 rounds per 15 min and the supernatant was transferred into cryovials and stored in a −20° freezer until laboratory tests were performed.

2.4.3. ELISA Method

Cysticercosis was detected using ApDia Ag ELISA (Reference number 650505; apDia, Raadsherenstraat 3 2300 Turnhout, Belgium) for the determination of viable metacestode of *Taenia* species [33]. The ELISA cut-off value for antigen was calculated (cut-off value = mean optical density (OD) negative × 2). A positive reaction corresponded to an antigen index above or equal to 1.3, while an antigen index value below or equal to 0.8 was negative. A grey zone between 0.8 and 1.3 was considered dubious and was retested.

2.5. Data Analysis

Data were analyzed using SPSS software, version 20. Continuous variables are summarized by the measure of central tendency and their respective dispersion. Household clustering was considered during the analysis. Categorical variables are summarized by proportions and frequencies, and they were compared by chi-square test. Odds ratio and 95% confidence interval were used and a *p*-value of less than 5% was considered significant.

2.6. Ethical Consideration

This study was approved by the Medical Research Coordinating Committee of the National Institute for Medical Research in Tanzania (Reference No. NIMR/HQ/R.8c/Vol.1/1612). Written informed consent was obtained from all subjects ≥18 years, and consent was obtained from parents or guardians of the respective individuals below 18 years old following the subject's assent.

3. Results

3.1. Demographic Characteristics

A total of 300 individuals were involved in this study. The median age was 19 years and the mode was 7, with a maximum of 89 and a minimum of 5 years; the mode was lower than the median; thus, the tail pointed to the right. Female and male participants were almost equally represented (Figure 3 and Table 1).

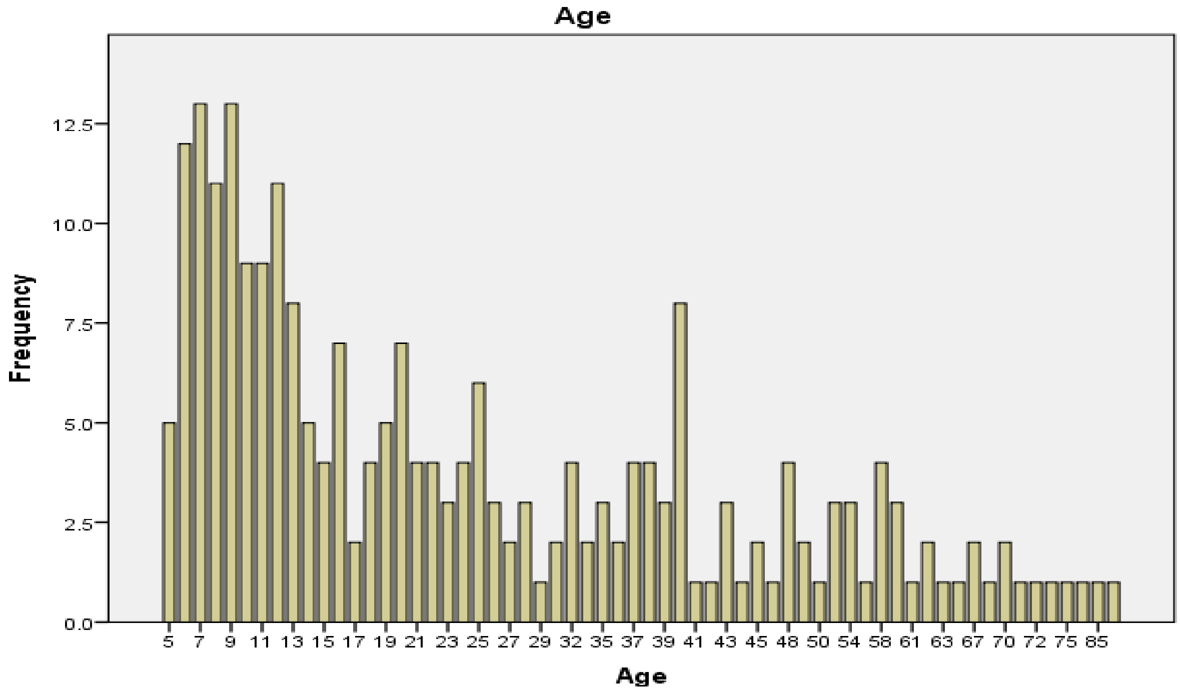

Figure 3. Demographic characteristic of study participants; age distribution was positively skewed.

Table 1. Demographic characteristics of participants by sampling village.

Variable		Total N (%)	Harsha A (%)	Maghang Juu B (%)	Diyomat C (%)
			Village		
Sex	Male	155 (51.7)	43 (51.1)	66 (62.2)	46 (41.8)
	Female	145 (48.3)	41 (48.8)	40 (37.7)	64 (58.1)
	5–15	104 (34.7)	32 (30.7)	36 (36.6)	36 (36.6)
Age	16–25	51 (17.0)	11 (21.5)	14 (27.4)	26 (50.9)
	26–35	51 (17.0)	8 (15.7)	18 (35.3)	25 (49.0)
	36–45	43 (14.3)	14 (32.5)	15 (34.9)	13 (30.2)
	>45	51 (17.0)	19 (37.2)	22 (43.1)	10 (2.1)
	Primary	261 (87.0)	107 (41.5)	79 (30.6)	75 (29.1)

Table 1. *Cont.*

Variable		Total N (%)	Village		
			Harsha A (%)	Maghang Juu B (%)	Diyomat C (%)
Education	Secondary	12 (4.0)	2 (2.4)	9 (10.9)	1 (1.2)
	Tertiary	5 (1.7)	1 (20)	4 (80)	0 (0)
	None	22 (7.3)	0 (0)	14 (63.6)	8 (36.3)
Occupation	Students	96 (32.0)	30 (31.2)	34 (35.4)	32 (33.3)
	Farmer	204 (68.0)	54 (26.5)	72 (35.3)	78 (38.2)
Total		300 (100)	84 (28)	106 (35.3)	110 (36.7)

3.2. Prevalence of Cysticercosis

The overall prevalence of human *T. solium* cysticercosis was 7.67% (23/300), among which 12 (8.27%) were males and 11 (7.09%) were females. The prevalence was higher than 6 (11.76%) among those aged 26–35 years and ±45 years. There was no statistically significant difference in the prevalence by age group, sex, and occupation (Table 2). Among participants, 82 (27.3%) had received anthelmintics during the previous year, whereas 23 participants who tested positive by the antigen test, 5 who are 21.7% of those received anthelmintics. The likelihood of infection among anthelminthic users and non-users was low at 28% [0.72 (0.26–2.01)], but the protection was not statistically significant in all communities (Figure 4).

Table 2. Prevalence of cysticercosis by sex, age, education level, and village (*N* = 300).

Variable		Total (n)	Positive *p* (%)	Negative *N* (%)	OR (95% CI)	*p* Value
Sex	Male	145	12 (8.27)	133 (91.72)	1.18 (0.50–2.77)	0.702
	Female	155	11 (7.09)	144 (92.90)	Ref	
Age	5–15	104	5 (4.80)	99 (95.19)	Ref	
	16–25	51	2 (3.92)	49 (96.07)	0.81 (0.15–4.32	0.803
	26–35	51	6 (11.76)	45 (88.23)	2.64 (0.77–9.11)	0.124
	36–45	43	4 (9.30)	39 (90.69)	2.03 (0.52–7.96)	0.309
	46 and above	51	6 (11.76)	45 (88.23)	2.64 (0.77–9.11)	0.124
Education level	Primary	261	23 (8.8)	238 (91.1)	4.43 (0.2675.46)	0.303
	Secondary	12	0 (0)	12 (100)	1.8 (0.03–96.37)	0.772
	Tertiary	5	0 (0)	5 (100)	4.09 (0.07–230)	0.493
	None	22	0 (0)	22 (100)	Ref	
Village	Harsha	84	9 (10.71)	75 (89.28)	Ref	
	Diyomat	110	12 (10.90)	98 (89.09)	1.02 (0.41–2.55)	0.965
	Maghang Juu	106	2 (1.88)	104 (98.11)	0.16(0.03–0.76)	0.021
Occupation	Student	96	5 (5.20)	91 (94.79)	Ref	
	Farmer	204	18 (8.82)	186 (91.17)	1.76 (0.63–4.89)	0.278
	Total	300	23 (7.67)	277 (92.33)		

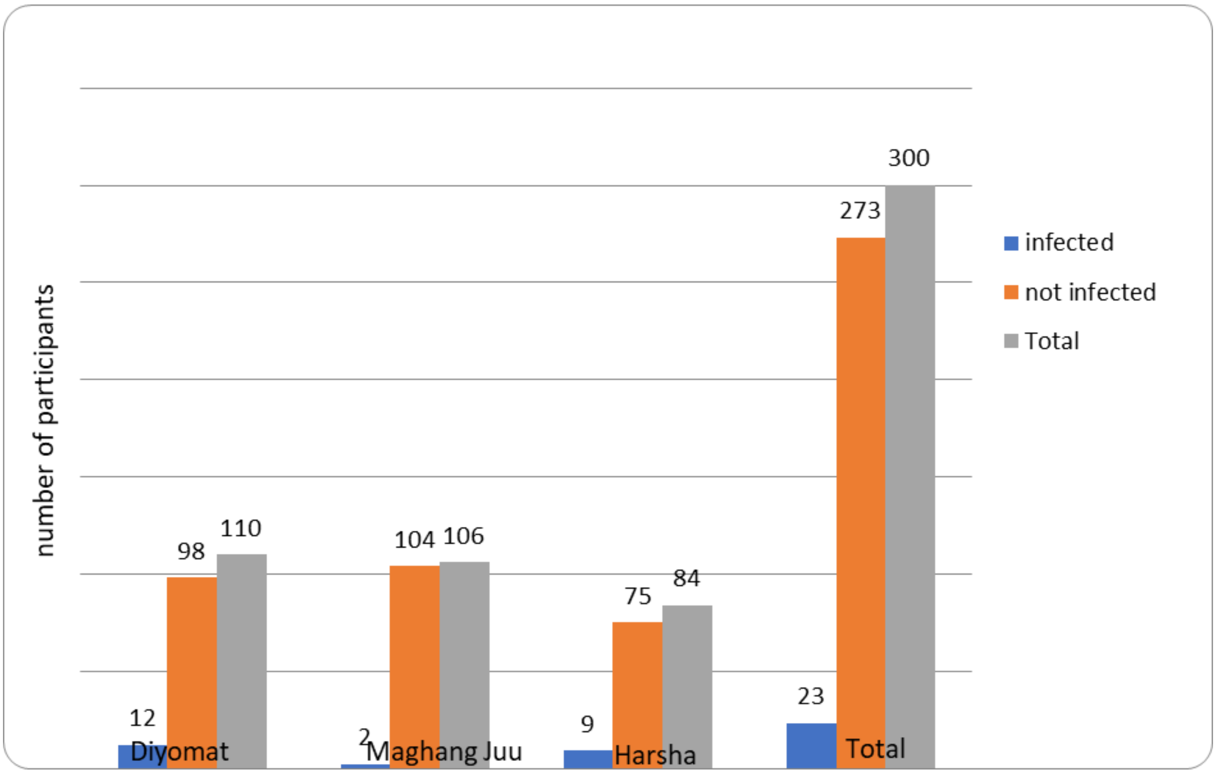

Figure 4. Infection statuses of study communities. Harsha and Diyomat were at high risk of *T. solium* infection for human cysticercosis.

3.3. Risk Factors

Eighty-nine households were visited during the survey. The availability of tap water was observed in two of the three villages. Maghang Juu had 14 water delivery points and people were receiving water throughout the year. The community in this village was connected with a low cysticercosis infection status. People living in Maghang Juu were the least infected and differed statistically with Harsha and Diyomat (Figure 3). Diyomat had five water delivery points with seasonal water availability mainly during the rainy seasons. Harsha had 11 water delivery points without water throughout the year; the community in this village was linked with a high prevalence of cysticercosis (Figure 3). Free-range pig rearing was observed in all three villages. About 46 (51.7%) of the visited households had no latrines/toilets. More than 50% of the households inspected had no access to a clean and safe water supply (tap water) (Table 3). Human feces were often observed near footpaths as the research team moved from one household to another.

Table 3. Prevalence and risk factors of cysticercosis by study village (N = 89).

Community	Household	Community Prevalence *p* (%)	Household and Community Risks for Cysticercosis					
			Tap Water T (%)	Pond Water *p* (%)	River Water R (%)	Latrine L (%)	Keeping Pig K (%)	Odds Ratio (95%CI)
Diyomat	34	12/110 (10.9)	29 (85.3)	3 (8.8)	2 (5.9)	24 (70.6)	26 (76.5)	Reference
Maghang Juu	22	2/106 (1.88)	12 (54.5)	0 (0)	10 (45.5)	11 (50.0)	17 (77.3)	3.8824 (0.7916–19.0407
Harsha	33	9/84 (10.71)	0 (0)	0 (0)	33 (100)	8 (24.3)	26 (78.8)	0.8889 (0.3209–2.4622)
Total	89	23/300 (7.67)	41/89 (46.1)	3/89 (3.3)	45/89 (50.6)	43/89 (48.3)	69/89 (77.5)	

Note: there is no significant difference in observed risk factors among the three communities; *p*-value of 0.0945 for Maghang Juu and 0.8207 for Harsha.

A total of 20 out of 107 households that gave blood samples had one to two positive participants from households, which is 18.69%. Three households had two infections; the remainder had one infection per household and two were close to each other (Diyomat and Harsha).

This high percentage of surveyed households supports the community risks in these communities.

4. Discussion

This study shows that human infection with *T. solium* cysticercosis in Mbulu District was high (7.67%). The prevalence was not statistically different between those who received and did not receive anthelmintics during the previous year. This may be a result of low anthelminthic coverage in the communities by targeting school children only and, thus, by continued transmission among elder age groups as indicated by the results of this study. The high prevalnce of cysticercosis established in this study implies environmental contamination with infective taeniid eggs from human feces and fecal–oral infections due to the lack of clean and safe water as reported in over half of the surveyed households. The absence of difference in the infection among those who received anthelmintics and those who did not may be explained by the continued adult worm carriers in the communities as more than half of the surveyed households did not have access to tap water and more than two-thirds of the community members did not receive anthelmintics, because they were not targeted despite being at risk of infection.

The prevalence of human cysticercosis in this study is lower than that reported previously [31]. This may be a result of different diagnostic assays used with different sensitivity and specificity. The current study used antigen ELISA which detected the active parasite, whereas the previous study used the IgG Western blot Assay [31], which detected exposure to the parasite infection. Furthermore, individuals who tested negative for this test could have tested positive for the antibody tests as observed in studies elsewhere in Tanzania, Zambia, and Venezuela [10,11,19].

The radiology departments as part of diagnosis play an important role in case identification in hospitals for patients presenting with convulsions, which is proved in Uganda as a case of a 73-year-old woman who presented with high blood pressure [34]. The scarce resources presented in the hospital reflect what is taking place in low- and middle-income countries for the shift in regimen for this case treatment. The regular training of radiologists on the interpretation of cystic lesions caused by *T. solium* larvae is very important for case identification as presented in the Uganda case. The cost of Computed Tomography scans and Magnetic Resonance Imaging, although gold standards, cannot be employed as a routine test for *T. solium* neurocysticercosis; the available serological tests suffer from low sensitivity and specificity and are not cost-effective [35]. These diagnostic challenges marginalize this neglected disease from routine diagnostics and treatment due to the scarcity of treatment presented for the discussed case [34].

The slaughterhouse carcass condemnation is highly practiced in developed countries [36]. The bylaws are strongly enforced in developed countries; while in developing countries, an alternative to minimize total loss is opted for, and not under supervision, which falls to the human consumer buying the carcasses at the cheapest price, thus continuing zoonotic disease transmissions.

There was a variation in the prevalence of human cysticercosis across villages. The prevalence was higher at Harsha village, and this could be associated with the absence of clean and safe water, the underuse of pit latrines, and the presence of free-ranging pigs. The relatively high prevalence among people of Diyomat may be explained among other reasons by the shared water source for irrigation and, thus, the lack of water supply throughout the year. The low prevalence in Maghang Juu was most likely associated with the availability and use of safe and clean water throughout the year. The community risk factors are related to the number of people housed with infection, which is two communities with more infections (Harsha and Diyomat than the one with the availability of a clean and safe water supply (Maghang Juu). This is also supported by other studies on the clustering of infections for targeted control [37]. These risk factors are in line with similar endemic communities reported in other studies [38,39].

From these findings, mass drug administration in primary school children seems to have little effect on the prevalence of cysticercosis, most likely due to low community coverage; the targeted school children represent about 20% of the total population [40]. Previous studies have shown that porcine cysticercosis was high in households that were not using latrines and among those practicing the free-rearing of pigs [21,22,41]. Similarly, in Mozambique, free-ranging has been reported as an important risk factor [23]. The transmission is high because of the free rearing of pigs combined with a lack of pit latrines among households, and open defecation practices together scale up taeniosis and cysticercosis transmissions in these communities. Individuals of higher age were at high risk because they were not involved in the national school deworming program. The community with an uneven supply and use of clean and safe water had a high prevalence of human cysticercosis, which was the case in Harsha village, implying an increased risk of human cysticercosis infection in communities with similar risk factors. This study used an antigen test, thus missing those infected but recovered from infection and depending on the number of viable cysts [42]. A previous study in the same area has shown that 76% of seropositive cases had neurocysticercosis-suggestive lesions upon Computed Tomography (CT) scan, with the limitation of this study in confirming the positive result. It may be estimated that 18 persons were likely to have lesions if the CT scan test was performed [31]. Convenient sampling has some limitations as the study participants might have some hidden motives, thus not being representative of the study communities.

5. Conclusions

This study established a high prevalence of human cysticercosis among higher-age groups compared to lower-age groups. This reveals that school deworming has a positive effect in lowering the prevalence of cysticercosis in lower-age groups. It is recommended that the deworming program should be scaled up to higher age groups.

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Institutional Review Board Statement: This study was approved by the Medical Research Coordinating Committee of the National Institute of Medical Research in Tanzania (Reference No. NIMR/HQ/R.8c/Vol.1/1612) of 16 December 2019. Written informed consent was obtained from all subjects $\geq$18 years, and consent was obtained from parents or guardians of the respective individuals <18 years old following the subject's assent.

Informed Consent Statement: All authors approved the manuscript for publication.

Data Availability Statement: All data are available in the main document.

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Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Abbreviations

ELISA	Enzyme-linked Immunosorbent Assay
NCC	Neurocysticercosis
NIMR	National Institute for Medical Research
OD	Optical density
SPSS	Statistical Package for Social Sciences
WHO	World Health Organisation

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