EFFECT OF INCREASED ALBENDAZOLE COVERAGE ON CONTROL OF HUMAN AND PORCINE TAENIA SOLIUM CYSTICERCOSIS IN MBULU DISTRICT-TANZANIA

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ABSTRACT

Taeniosis and cysticercosis are infections caused by cestodes including *Taenia solium* (pork tapeworm). The cysticercosis in central nervous system accounts for 30% of acquired epilepsy in endemic developing countries. The school deworming program in Tanzania targeting intestinal and tissue worms does not seem to have an effect on reducing pork tapeworm in entire communities. One of the reasons may be that the adults may re infect the dewormed children. A quasi experimental intervention was conducted to evaluate the effect of increased albendazole coverage and rounds on controlling human and porcine cysticercosis among rural communities in the Mbulu district. The study involved community meetings with the heads of households before community deworming with 400 mg of albendazole. The Ag ELISA was used to determine human cysticercosis while pigs were examined by the lingual examination method. A total of 600 human participants were recruited, whereby 300 individuals were recruited before intervention and 300 after intervention. Furthermore, a total of 510 pigs were conveniently sampled, where 267 were sampled before intervention and 243 were sampled after intervention. The study has shown decrease in human cysticercosis by 6% in all study communities and a rise for porcine cysticercosis in control and one round intervention has been recorded. The younger age group had low infection 5% compared to the adults 11% in the population which may be attributed by school deworming program. It is therefore, recommended to increase anthelmintic coverage and rounds in communities' endemic with pork tapeworm to cover adults for some years consecutively for control of pork tapeworm and involve other sectors involved in life cycle of parasite for transmission interruption.

DECLARATION

I, Vedasto Bandi, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Vedasto John Bandi Date

The declaration is hereby confirmed by the followings:

Dr. Sr. John-Marry Vianney Date

Prof. Emmanuel Mpolya Date

Dr. Bernard Ngowi Date

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CERTIFICATION

The undersigned certify that, they have read and hereby recommend for approval by the Senate of the Nelson Mandela African Institution of Science and Technology a dissertation titled "*Effect of increased albendazole coverage on control of human and porcine Taenia solium cysticercosis in Mbulu district-Tanzania"* in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

Dr. Sr. John-Marry Vianney Date

Prof. Emmanuel Mpolya Date

Dr. Bernard Ngowi Date

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DEDICATION

This work is dedicated to my parents: Mr. John Gabriel Bandi (RIP, 2014) and Ms. Pascalina Aldo Mlawa (RIP, 1990) who laid the foundation of commitment to solve community problems.

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LIST OF ABBREVIATIONS AND SYMBOLS

Ab	Antibody
Ag	Antigen
ALB	Albendazole
Ca^{2+}	Calcium ion
CDC	Center for Diseases Control
CNS	Central nervous system
CREATES	the Center for Research, Agricultural Advancement, Teaching Excellence and Sustainability in Food and Nutrition Security
CT	Computed tomography
DALYs	Disability adjusted life years
DID	Difference in Difference method
ELISA	Enzyme-linked Immunosorbent Assay
ERR	Egg reduction rate
IgG	Immunoglobin G
KNCHREC	Kibong'oto Nelson Mandela CEDHA Health Research and Ethical Committee
MDA	Mass drug Administration
MRI	magnetic resonance imaging
NBS	National Bureau of Statistics
NCC	Neurocysticercosis
NICL	Niclosamide
NIMR	National Institute for Medical Research
NM-AIST	Nelson Mandela African Institution of Science and Technology
NTD	Neglected tropical diseases
OD	Optical density
PZQ	Praziquantel
WHO	World Health Organisation
SPSS	Statistical package for social sciences
SUA	Sokoine University of Agriculture
TMDA	Tanzania Medicines and Diagnostic Devices

CHAPTER ONE

INTRODUCTION

1.1 Background of the problem

Taeniosis and cysticercosis are infections with adult cestodes in human and their larval stages in tissues of human and pigs respectively the pork tapeworm (*Taenia solium)* is among them (Torgerson *et al*., 2015). *Taenia solium* cysticercosis mainly affects the health and livelihoods of subsistence farming communities in low-income countries. The transmission of pork tapeworm in endemic areas is due to poverty, free-ranging of pigs, poor sanitation, and consumption of raw or undercooked pork meat infected with cysticercosis (Mwape *et al*., 2013; Ngowi *et al*., 2004). The presence of *T. solium* larva in central nervous system is known as neurocysticercosis (NCC). Neurocysticercosis is estimated to cause 30% of all cases of acquired epilepsy in countries where the parasite is endemic (Torgerson *et al*., 2015). Globally, a total of 2.8 million disability-adjusted life-years (DALYs) were attributed to *T. solium* (Torgerson *et al*., 2015). The epilepsy burdens individuals and the economy due to; health expenses and social stigmatization. Another economic burden is from the value loss of infected pigs (Torgerson *et al*., 2015; Trevisan *et al*., 2017). Among the reasons that this disease has not been prioritized include a deficiency of records and localization of disease in marginalized populations (WHO, 2018).

Humans act as both the parasite's definitive and accidental dead-end intermediate hosts. Humans harbour the adult tapeworm in the small intestine, with each tapeworm segment releasing thousands of eggs into the environment (Ash *et al*., 2017; Gabriël *et al*., 2017; Garcia-Noval *et al* 1995). Underuse of pit latrines, free-ranging pigs, and poor sanitation facilitate the ingestion of tapeworm eggs by pigs and humans, leading to the formation of the cystic larval stage in both hosts (Ash *et al*., 2017). Cysts in the human central nervous system can result in NCC manifesting clinically as epilepsy, chronic headaches, dizziness, visual disorders and nausea (Okello *et al*., 2017). The benefits to health can be achieved with investments in the control of cysticercosis (Torgerson *et al*., 2015).

The diseases caused by pork tapeworms are not among the prioritized zoonotic diseases of Tanzania (CDC, 2017) and are not of priority in current ongoing neglected disease interventions. For this reason, little work has been done to control the diseases. Mbulu District in Tanzania is among the areas where pig husbandry is one of the sources of income. A health education intervention conducted in this District revealed a reduction in the

consumption of infected meat and the incidence of pig infection (Ngowi *et al.*, 2008). Five years later, a study was conducted in the same area and found a high prevalence among community members (Mwang'onde *et al*., 2012), suggesting that education intervention worked only for the short term. The eradication of taeniosis is based on interfering with the transmission from one host to another in a sizable geographical area (CDC, 1993). This can be done by a deworming regimen. The efforts of deworming in the country have been made targeting other parasitic infections; this includes a deworming program that provides albendazole and ivermectin once a year in lymphatic filariasis and onchocerciasis endemic areas (Malecela *et al*., 2009); praziquantel regimen is given in schistosomiasis endemic areas (Jones *et al.,* 2015; WHO, 2011). To date, a high prevalence of cysticercosis in the area has been observed (Mwang'onde *et al*., 2018). Thus, this study determined the effect of an intervention involving increased coverage of anthelmintic treatment intervention using albendazole for control of human and porcine cysticercosis in Mbulu District, Tanzania.

1.2 Statement of the problem

Taenia solium neurocysticercosis in human is responsible for 30% of acquired epilepsy in endemic areas including Tanzania. The human cysticercosis has an average seroprevalence of about 17% and it accounted for 212 deaths and 17 853 NCC incident cases for the year 2012 (Mwang'onde *et al.,* 2012; Mwanjali *et al.*, 2013; Mwita *et al.*, 2013; Trevisan *et al.*, 2017). The disease is responsible for morbidity and decreasing economy due to the value loss of infected pigs in endemic areas (Torgerson *et al*., 2015). The occurrence of the disease in a community with poor sanitation and free-rearing practice of pigs results in both human and porcine cysticercosis (Ngowi *et al*., 2004). The lack of appropriate interventions targeting the parasite in the community makes prevalence of the infection to remain high in the endemic areas in Tanzania (Mwang'onde *et al*., 2012, 2018; Mwanjali *et al*., 2013; Mwita *et al*., 2013).

The mass drug administration (MDA) currently targets schistosomiasis, filarial worms and soil- transmitted helminths under Neglected Tropical Diseases (NTD) program in collaboration with district councils (Jones & Sokolow, 2015; Malecela *et al.,* 2009). Moreover, studies that have been conducted after educational intervention (Ngowi *et al.,* 2008) in Mbulu have shown a high prevalence in the same area with a similar prevalence to Mbeya and Iringa ranging from 16-17% (Mwang'onde *et al*., 2012; Mwanjali *et al*., 2013; Mwita *et al*., 2013). Apart from the educational intervention by Ngowi *et al*. (2008), no intervention study has been conducted in Mbulu district. Moreover, the annual albendazole

dose through the MDA program among school children seems not to eliminate cysticercosis in the community, which may be due to re-infection and low community coverage (Jones & Sokolow, 2015; World Bank, 2018b). Thus, there is a need for evaluation of present deworming and better intervention strategies are employed.

1.3 Rationale of the study

The persistent morbidity and mortality related to cysticercosis in Tanzania may be a result of little coverage or a lack of proper anthelmintic treatment rounds through the MDA program (Ramiandrasoa *et al*., 2020) or non-continuous health education intervention (Carabin *et al*., 2018).

1.4 Research objectives

1.4.1 General objective

The study aimed to determine the effect of increasing albendazole coverage and rounds per year on control of *Taenia solium* cysticercosis in endemic communities of Mbulu district.

1.4.2 Specific objectives

(i) To determine albendazole coverage in previous Mass Drug Administration and Taeniasis risk factors at household and community levels in Mbulu District.

(ii) To determine prevalence of human and porcine cysticercosis in the Mbulu District.

(iii) To determine the effect of increasing albendazole coverage and rounds per year in eliminating cysticercosis.

(iv) Determine the trends of neurocysticercosis among patients with convulsive disorders.

1.5 Research questions

This study sought to provide information to researchers and policymakers on effect of increased coverage and rounds of albendazole per year in a community on control and elimination of cysticercosis in endemic localities. Below are the guiding questions for the study:

(i) What is the proportion of individuals who received albendazole in the previous MDA in the Mbulu district?

(ii) What are the current prevalence and community risks of human and porcine cysticercosis among rural communities in the Mbulu district?

(iii) What is the effect of increased albendazole coverage and rounds per year on control and elimination of cysticercosis among rural communities of Mbulu district?

(iv) What is the proportion of patients with convulsive disorders are confirmed with neurocysticercosis for four consecutive years in Mbulu district?

1.6 Significance of the study

This study gives the general trend of albendazole intervention when administered in the community while other factors are considered constant. The overall intention is to reduce morbidity, mortality, and economic burdens related to pork tapeworm in endemic communities. The effect of this reduction is not an immediate one but a long-term outcome for humans; however, pigs are a good measure of the immediate outcome of the infection trend. Furthermore, for long-term measures, the study suggests that infection reduction due to community treatment with albendazole in endemic communities will eventually reduce poverty caused by treatment costs, value loss of infected pigs, and social stigmatization of the epileptic individuals due to neurocysticercosis. This study has revealed that school deworming has a positive effect in lowering the prevalence of cysticercosis in lower age groups but not in higher age groups; thus resulting in re re-infection within communities from untreated to treated individuals and higher prevalence among untreated adult groups. The healthy facilities especially radiology departments in the district are good points for determining the effect of MDA intervention in endemic areas and report of cases from areas which are not surveyed in the country for intervention consideration. Furthermore, the study calls for combined efforts from all sectors involved in the life cycle of *T.solium* transmission interruption which are; veterinary sector (treatment and vaccination of pigs and inspection of meat prior to consumption), human health (scaling up of deworming to other age groups), environmental sector (by laws on sanitation), and local leaders (religious and political) to combine efforts to fight the *T.solium* cysticercosis under the One health approach which involves education as a powerful tool.

1.7 Delineation of the study

The study is a community-based covering humans and pigs in the Mbulu district of Manyara region, northern Tanzania. The Hydom Hospital radiology recorded data retrieved for

patients reported with convulsive disorders to get information on neurocysticercosis trends and endemic areas with reported cases for four consecutive years. The study suffered the low estimate of the actual infection status following the low sensitivity of Antigen ELISA test kits and lingual examination methods. Second the study intervention used 400 mg of albendazole while the WHO has recommended 400 mg for three days consecutive days in endemic communities; it was not employ it because the treatment guideline was not adopted in Tanzania, and authorities were cautious of any community treatment during COVID 19 the year 2020/21. Sample size for pigs were conveniently sampled, this was because of pig population fluctuations. The level of training of the radiologist on interpretation of Taenia solium neurocysticercosis may be questionable.

CHAPTER TWO

LITERATURE REVIEW

2.1 Biology of *Taenia solium* pork tapeworm

Taenia solium is cestodes with two hosts; human and pig. The adult worm lives in small intestine of human while the larval stage lives in tissues of human and pigs. The pork tapeworm (*Taenia solium)* has a life cycle involving two hosts, humans and pigs. Pigs and humans get infected with cysticercosis by ingesting pork tapeworm eggs (Yancey *et al*., 2005). Neurocysticercosis has a high prevalence in countries where pigs have contact with human fecal matter; however, cases have been identified even in non-endemic countries due to travel (Yancey *et al*., 2005). Humans are the only definitive hosts for the adult tapeworm, where taeniosis is acquired by eating raw or undercooked pork meat (Mwita *et al*., 2013; Sarti *et al.,* 1992; Schantz *et al*., 1993).

The adult worm structurally has a scolex, neck, and strobila. The cysticercus is resistant to temperature and a high concentration of salt. The oncospheres enter the human body with food contaminated with faeces containing eggs. Cysticerci have the vesicular wall and the scolex where the scolex has an armed rostellum and a rudimentary body (Willms, 2008). The tegument of the larva is covered with villi-like projections used to take up nutrients from the host. The tegumentary surface is important because the parasites are acoelomic with no digestive system (Willms, 2008).

2.2 Parasite survival in Human host

The 'cuticle' of a tapeworm protects the worm from host intestinal activities. It has been reported that the anti-enzyme action of the cuticle does not prevent the parasite from absorbing nutrients from the host (Threadgold, 1962). However, parasites grown in immunized dogs showed reduced egg production and few numbers of proglottids (Zhang *et al.*, 2006). This approach may lead to the removal or weaken adult worms in the intestine without harm to the host (Fig. 1).

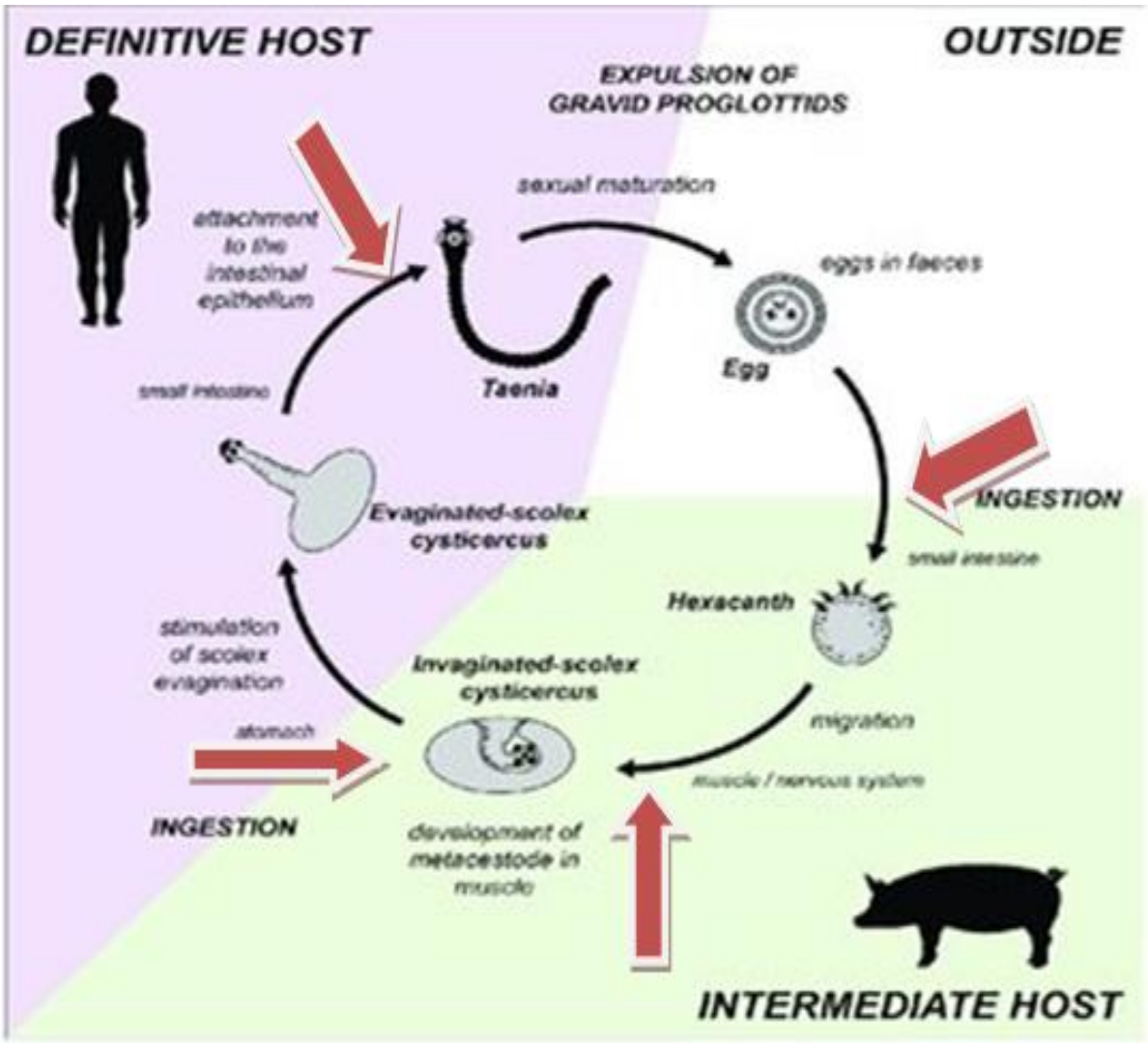

Figure 1: Life cycle of *Taenia solium*

The larval stage of the parasite (cysticercus cellulosae), on the other side, survives in the tissue through immune suppression, which is a common characteristic of taeniid infections (Williams & Jeffrey, 1979). The surfaces of larvae bind host IgG by using an Fc-like receptor which is considered an important evasion mechanism by masking the parasite to the host immune (Willms, 2008). It is suggested that the larval stage (cysticercus) may also have Fc-gamma-binding protein, similar to paramyosin from *Taenia crassiceps* cysticerci, which could explain the evasion of the immune response (Willms, 2008). A turbid vesicular fluid with scolex degenerating characterizes the cysticerci's colloidal stage. The granular stage with thickened cyst wall and mineralized the scolex shows the cysticercus is no longer viable; however, the degenerative process characterized by calcification of parasite remains (Fogang *et al*., 2015; Mahanty & Garcia, 2010).

2.3 *Taenia solium* infection in humans

The patients with adult worm become aware of infection by noting the passage of proglottids in their feces; nausea, abdominal pain, weakness and sleep disorders are more common and the motile proglottids usually cause discomfort (Li *et al*., 2015; Yancey *et al*., 2005); mature tapeworms may lead to several rare complications such as Meckel's diverticulitis appendicitis, intestinal obstruction, and colonic perforation (Li *et al*., 2015). Clinical manifestations of the disease are influenced by host characteristics and the infectious agent itself. Neurocysticercosis presents with various signs that vary in severity, but it is asymptomatic in many cases (Li *et al*., 2015). The most common alterations include epilepsy, intracranial hypertension, as well as neuropsychiatric symptoms, and focal neurological deficits or cognitive decline (Del Brutto, 2014).

The clinical situation depends upon parasite factors, which include amount, location, and stage at the central nervous system (CNS); host factors such as gender, age, and immunologic response; and finally, environmental factors (Del Brutto, 2014). The inflammatory reaction and the implied cellular and molecular events are responsible for seizures during the degenerating stage of NCC. Seizures triggered by the host brain inflammatory response are referred to as provoked or acute symptomatic seizures. On the other hand, seizures occurring in relation to "degenerating" stage of NCC are provoked, whereas those occurring with the "live" or the "inactive" phase are unprovoked (Singh *et al*., 2013). Cysticercosis of the eye causes visual impairment and sometimes result in blindness, whereas lesion of orbit leads to exophthalmoses (Singh *et al*., 2013). Muscular pseudo hypertrophy a rare presentation is also caused by heavy cysticercus infection of skeletal muscles (Singh *et al*., 2013). *Taenia solium* infection in pigs is due to larval stage; its impact to human is the value loss of infected pigs (Kayuni, 2021).

2.4 Epidemiology and risk factors of *Taenia solium* infections

Worldwide pork tapeworm infections prevail in poor subsistence farming communities in low and middle-income countries (Mwape *et al*., 2013; Rojas *et al.*, 2019; Shukla *et al.*, 2010). Taeniosis has been reported in Europe to range from 0.05-0.27% and ranges from 0-17.25% in Africa, Asia, and Latin America (Okello & Thomas, 2017). In Rwanda 38% (27/71) had viable cyst by Ag ELISA (Soto *et al*., 2021) detection, those who are likely to suffer neurocysticercosis in the future depending on number and parasite location. Neurocysticercosis causes up to 30% of all cases of acquired epilepsy in endemic localities (Mahanty & Garcia, 2010; Torgerson *et al.,* 2015; Torgerson & Macpherson, 2011), which

causes about 61 to 212 deaths annually in East African countries (Minani *et al.,* 2022; Trevisan *et al.*, 2017; Lozano *et al.,* 2012). In Tanzania it has been recorded 2-5% for Taeniasis, 16 % Ag ELISA for human cysticercosis. Porcine cysticercosis is 6-17% by lingua examination, 1-33% antigen ELISA and 0-18% slaughter slab meat inspection (Gabriël *et al.,* 2017; Shonyela *et al.,* 2017). The lack of pit latrines or open defecation, free ranging of pigs, absence of clean and safe water, lack of pork meat inspection and undercooked pork meat facilitates ingestions of tapeworm eggs and larva leading to taeniosis and cysticercosis (Bandi *et al.,* 2024; Guyatt & Fèvre, 2016; Mlowe *et al.,* 2024; Nyangi *et al.,* 2022; Okello & Thomas, 2017).

2.5 Diagnosis of taeniosis

The pork tapeworm (*Taenia solium*) burden estimation has not been established enough in endemic areas because the disease is marginalized in poor communities, this result in little political efforts to intervene the problem. The diagnostic challenges such as lack sensitive, specific and field friendly diagnostic too increases the problem in establishing diseases burden (Coster *et al*., 2018). The diagnostic challenges pose a problem for specific parasite intervention in endemic areas because the disease burden is not known. The diagnosis of the presence of adult tapeworm is confirmed by the released gravid proglottids in the feces (in short chains). The discharged chains of gravid segments are also diagnostic; there are 8-10 uterine branches (Willms, 2008). The presence of characteristic taeniid egg in stool suggests that there is either *T. solium* or *T. saginata* because they have a similar structure (Willms, 2008). The ova are 40 µm in diameter, surrounded by brown radial striations, and the embryos have six hooks. The ova of *Taenia* species are morphologically indistinguishable, however, the proglottids can be distinguished from those of *T. solium* by counting the number of uterine branches, where if greater or equal to14 branches suggests *T. saginata* or *T. asiatica* (Cappello *et al*., 1958). The microscopic investigation of fecal specimens is examined for intestinal taeniid eggs using the Kato-Katz thick smear technique (Jeon *et al*., 2013). Specific diagnosis of cysticercosis includes immunological tests, computed tomography (CT), magnetic resonance imaging (MRI), and ophthalmoscopy and ultrasound examination (Singh *et al*., 2013).

2.6 Diagnosis of *T. Solium cysticercosis*

Antibody tests for pork tapeworm are highly specific to those exposed to cysticercosis infection (Rodriguez *et al*., 2012). Serological antigen ELISA tests are available, which

recognize the cyst antigen in humans and pigs (ApDia, 2004), The Ag-ELISA ApDia test kit has been described as being sensitive to *T. solium* infections in humans with two or more viable cysts (Lightowlers *et al*., 2016; Rodriguez *et al*., 2012). The pigs' cysticercosis can be examined using visual lingual examination; this method has high specificity and low sensitivity (Kabululu *et al*., 2015).

2.7 Prevention and control of *Taenia solium*

The control of Taenia solium involves transmission interruption at any one point in the life cycle to prevent parasite stage to infect another new host. Use of toilet, improved pig management practice, inspection of pork meat, proper cooking of pork meat, treatment of taeniosis cases and treatment and vaccination of pig intervene transmission of *T. solium* (Bandi *et al.,* 2024; Coster *et al.,* 2018; Okello & Thomas, 2017). The prophylaxis and vaccine in pigs is currently in research work but not practiced in communities, but the result showed the high efficacy of combined TSOL18 and oxfendazole (Kabululu *et al.,* 2020).

2.8 Treatment of Taeniosis and Cysticercosis

Medications for the treatment of taeniosis include antiparasitic drugs such as; praziquantel (Biltricide) niclosamide and albendazole (Del Brutto, 2014; Yancey *et al*., 2005). The larval stage in the central nervous system needs special attention to treatment. The parenchymal neurocysticercosis (viable cysts) treatment depends on the number of cysts where antiparasitic drugs with steroids may be used. The degenerating cysts are usually neuro-imaged and treated with antiparasitic drugs with steroids; the subarachnoid cysts are also treated with antiparasitic drugs with steroids (PAHO, 2021; Yancey *et al.*, 2005). For spinal cysticercosis, intramedullary, or extra medullary, treatment is primarily surgical; however, the use of albendazole with steroids may restore the condition. Ophthalmic cysticercosis also needs surgical resection of cysts, but the calcified cysts are not treated with ant-parasitic drugs because they are dead (PAHO, 2021; Yancey *et al.,* 2005).

Based on characteristics of albendazole the sweet taste increases compliance because MDA treat many who are actually not sick, poor intestinal wall permeability makes it better for targeting the adult worm in intestine thus making adult sick and subsequent death of adult, thus intervening *T. solium* transmissions. The veterinary and medical reporting systems does not specify for taeniosis and cysticercosis (Mlowe *et al*., 2024). This further marginalizes the *T. solium* diseases. Despite all these diagnostic and reporting challenges, the disease burden has been established in some endemic areas. The mass drug administration (MDA) which is

the majority treatment without infection confirmation is adopted for various control programs. The selective case treatment and follow-up is another approach to MDA but it is constrained by taeniosis diagnostic challenge of availability of field friendly diagnostic tool (Coster *et al*., 2018).

The prophylaxis treatment is among the means of reducing the transmission of intestinal and tissue worms. The current prophylactic treatment using praziquantel and albendazole for schistosomiasis and soil-transmitted helminths is targeting school children only (World Bank, 2018a). The current treatment guideline for pork tapeworm diseases gives directives for treatment in humans Niclosamide and praziquantel are highly recommended for *T. solium* control in Mass drug administration because they don't cross blood brain barriers. Albendazole can cross brain barriers thus resulting in neurocysticercosis epileptic seizure as it kills the larval stage in brain (PAHO, 2021).

The use of anthelmintic drugs is common in veterinary medicine; and its use is now shifting to human as a treatment for deworming programs in endemic communities. It has been utilized by onchocerciasis and filariasis control programs where both combine the intestinal and tissue worms control strategies for increasing health benefits (CDC, 1993; Simonsen *et al*., 2010; WHO, 2005). The study done in Tanzania looked at albendazole efficacy with respect to reduction in fecal egg count and has suggested persistence of resistance after more than ten years of use in controlling intestinal worms of sheep and goats (Keyyu *et al*., 2002). Transferring this experience is important for studying the drugs used in the control of various worms and assessing their performance after prolonged use in the endemic communities as done in a study in Madagascar to see the efficacy in the reduction of taeniid eggs (Ramiandrasoa *et al*., 2020). The 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 (PAHO, 2021).

It has been shown that there is reduced efficacy in some areas after prolonged treatment where less than 40% of ovicidal activities have been noted for trematodes (Canevari *et al*., 2014). The egg reduction rate is a criterion used to assess the performance of a drug in treatment or transmission intervention (Keyyu *et al.,* 2002). The study in Lao People's Democratic Republic that was conducted to test for the efficacy of low dosage among infected school children, showed hookworm egg reduction rate (ERRs) of 86.7% (Soukhathammavong *et al*., 2012). It is important to study the egg reduction in human and

pig infection after albendazole treatment in the community intervention of *Taenia solium* diseases.

The drugs efficacy of praziquantel (PZQ), niclosamide NICL and albendazole (ALB) showed that PZQ 10 mg/kg, triple dose ALB 400 mg (400 mg per day for three consecutive days) and NICL 2 g resulted in better cure rates for *T. solium* taeniosis (99.5%, 96.4% and 84.3%, respectively) than PZQ 5 mg/kg or single dose ALB 400 mg (89.0% and 52.0%), respectively (Haby *et al.,* 2020). Which is currently adopted by WHO in mass drug administration? The side-effects due to the different drugs and doses showed mild, transient side-effects. Neurological side-effects following PZQ 5 mg/kg, including severe headaches in case of undiagnosed neurocysticercosis (Haby *et al.,* 2020).

2.9 Mechanism of action of anthelmintic

The anthelmintic drugs work by preventing cofactor, protein, and nucleic acid synthesis. They also inhibit membrane and microtubule and neuromuscular function along with energy metabolism, resulting in muscle paralysis (Holden-Dye & Walker, 2007). Other drugs affect the uptake of glucose and, consequently, energy stores (Holden-Dye & Walker, 2007). Adult tapeworm infection is confined to the intestinal tract, where they are weakened and eventually killed by drugs, and the best drug need not be absorbed by the host when taken by mouth for the increased time of activity with an intestinal parasite (Fig. 2).

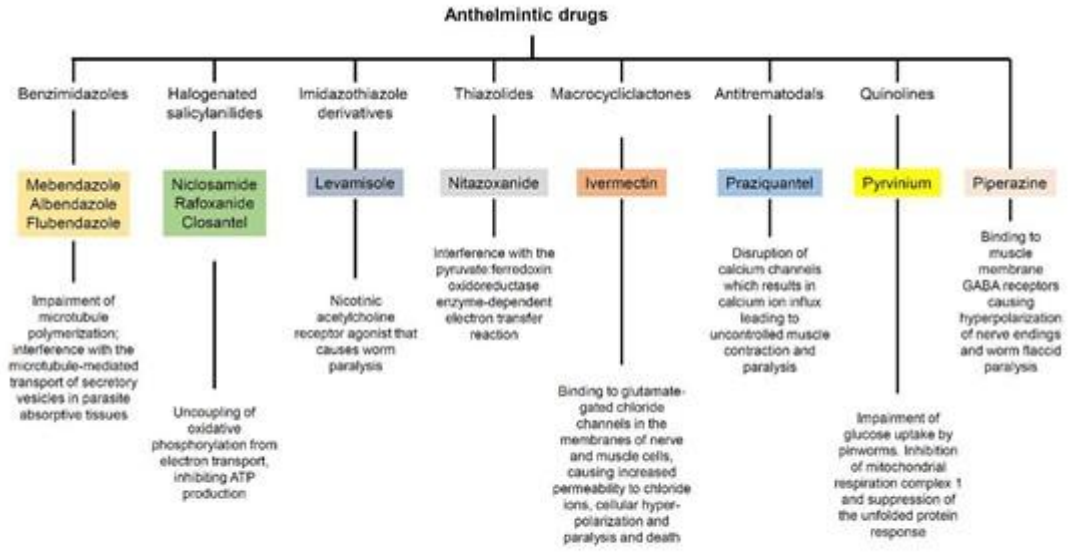

Figure 2 Mechanism of action of antiparasitic drugs. https://www.mdpi.com/ijms/ijms-21-04957/article_deploy/html/images/ijms-21-04957-g001.png. (Accessed 22 March 2024)

Figure 2: Mechanism of action of anthelmintic drugs

The main drugs that are used for cestodes infections are albendazole, niclosamide and praziquantel. Albendazole inhibits tubulin polymerization by binding to free beta-tubulin; it also constrains glucose uptake, which is important for energy production by tapeworms and, thereby has a paralytic effect on the worm (Holden-Dye & Walker, 2007). Praziquantel increases cell membrane permeability to Ca^{2+} resulting in tetanic contractions of the musculature of the worm followed by paralysis. Niclosamide uncouple oxidative phosphorylation. Albendazole is not readily absorbed from the intestinal tract as compared to praziquantel hence making it more useful for intestinal parasites (Garcia *et al*., 2014).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site

The Mbulu district has a total of 3800 km^2 with a total population of 377 865 as per the 2022 census, the district has urban and rural councils (Tanzania Beural of Statistics, 2013). This study site was a rural district council. The indigenous are involved in agriculture and animal husbandry, including pigs. The study area was purposively selected due to the previously reported high prevalence of human and porcine cysticercosis (Mwang'onde *et al.*, 2012, 2018). Three study villages were randomly selected for study from fifteen eligible wards; the other three wards were excluded as the residents are rarely involved in pig husbandry (Fig. 3).

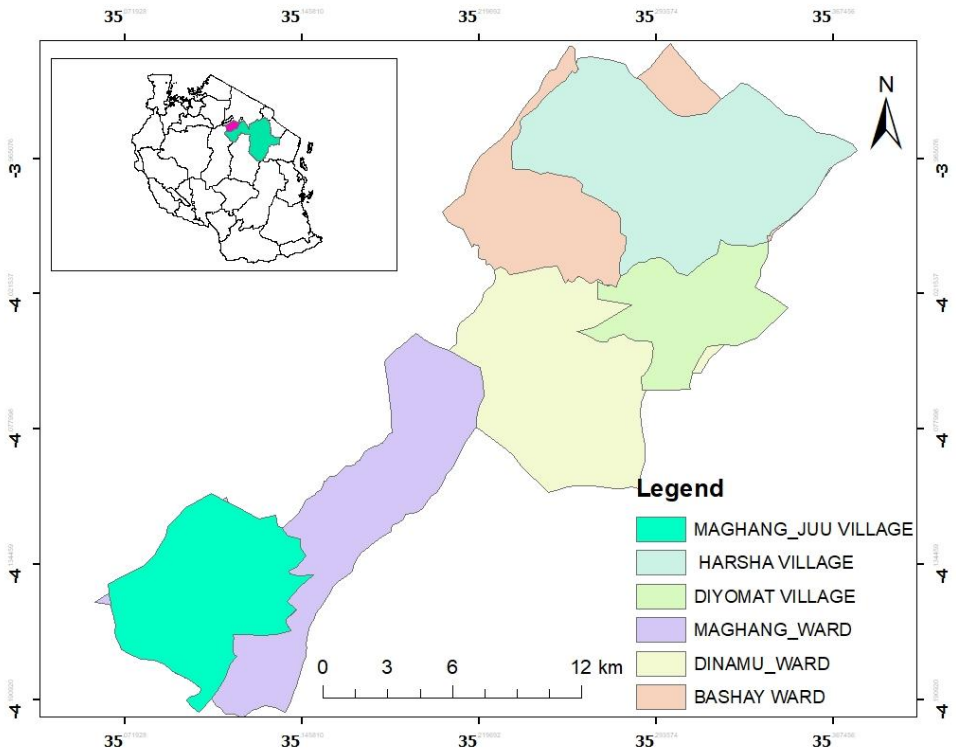

Figure 3: Mbulu district map showing study wards and villages (courtesy of Lucas Theodori)

3.2 Study design

The study was a quasi-experimental intervention trial conducted among three study communities (villages) in Mbulu district from March 2020 to march 2022 to assess the effect of entire community intervention on deworming as shown in Fig. 4. Multiple cross sectional studies were conducted in the study communities.

Figure 4: Schematic diagram on approach to *Taenia solium* control and elimination

3.3 Sample size

Sample size, n $=Z^2P(1-P)/C^2$

Z= 1.96, P= 16.3%, C= 0.0418

The Sample size was 300 for baseline and end line study for human study participants using16.3% previous study prevalence (Mwang'onde *et al.,* 2012). The pig population were conveniently sampled as pig population fluctuates.

3.4 Selection of study communities

The Mbulu district was selected based on previously reported high prevalence; the rural district council was purposely selected (Fig. 5).

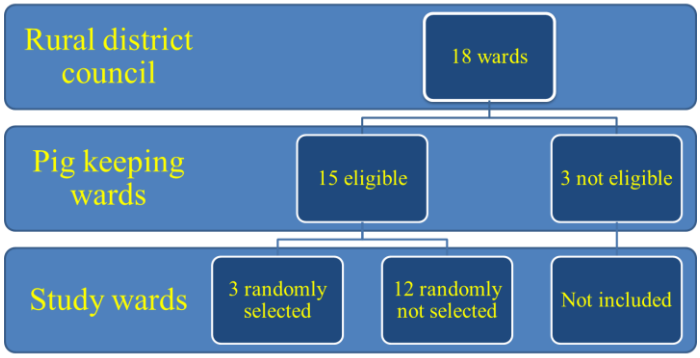

Figure 5: Selection of study communities

3.5 Sampling frame

The study team at community level with village leaders randomly selected one harmlet (sub village) for study, the harmlet leader and community health workers accompanied the study team throughout the data collection process. The Fig. 6 shows the sampling frame for data collection.

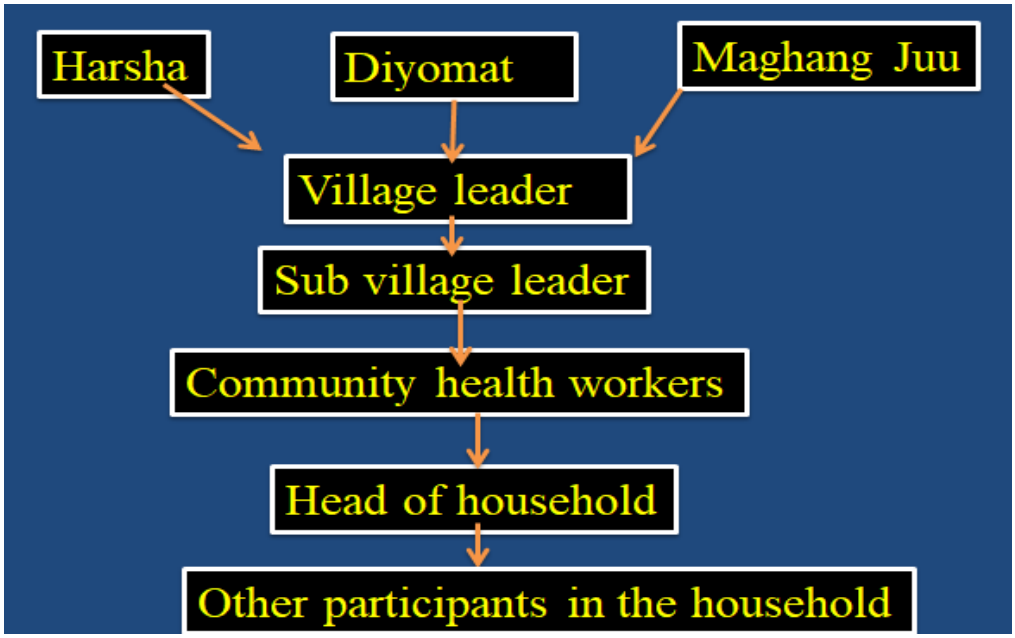

Figure 6: Sampling frame

3.6 Study setting, inclusion, and exclusion criteria

The study objectives one to three involved three Mbulu district (Rural) communities. In this setting, a cluster is represented by a village with a population of about 2200 persons. The selected villages from the district were those inhabitants who keep pigs as one of their economic activities.

Allocation of villages into intervention and control arms was done after baseline data collection, where the community with higher porcine cysticercosis prevalence was allocated

to two rounds of albendazole intervention, the least cysticercosis prevalence, no albendazole intervention by the study team only routine school deworming program. Household with a history keeping pigs were included in the study. Participants aged five years and above who have been village residents for three months were eligible for the study. Pigs aged two months and above grown in the respective community were included. Severely sick individuals, pregnant women, and children under five were excluded from the study.

3.7 Study objectives and methods

3.7.1 Determination of albendazole coverage in the previous MDA and risk factors at household and community level in Mbulu District

A cross sectional study was conducted in the study communities. The consented household leaders were asked about risk factors related to cysticercosis on source of water and participation in previous deworming programs. Other participants had few responses and on MDA and blood sample was requested. Observations and responses on the availability of pit latrines, water sources, and pigs keeping were recorded. The data were collected electronically using tablets installed with koBocollect software, kf.kobotoolbox.org. The information recorded among study participants was on education, occupation, and participation in deworming programs by swallowing anthelmintic in the last deworming program. The secondary (recorded) data on mass drug administration coverage from District medical officer were retrieved.

The risk factors were observed and recorded at household level and community level using observational checklist. The questionnaire responses are subject to recall bias on drug uptake. We used drug (albendazole) to show participants physically, they were finally requested for blood sample. Figure 5 shows the approach from village leader to other participants in the household. Furthermore, the recorded MDA coverage from the District medical officer was we retrieved.

3.7.2 Determination of the prevalence of human and porcine cysticercosis among rural communities in the Mbulu District

(i) Procedure for human cysticercosis detection

A cross sectional study was conducted in the three study communities. After household leader consent and participant consent and assent, five millilitres of blood was drawn from a median cubital vein by medical laboratory technician of Mbulu district council from each

recruited participant including the head of households who consented and 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 minutes (Cincinnati, 2018) and the supernatant was transferred into cryovials and stored in a -20^{O}C freezer until laboratory tests were done five months later. The laboratory work was done using cysticercosis Ag ELISA with Reference number 650505 for determination of viable metacestode of *Taenia* species of human serum sample as prescribed by the manufacturer (ApDia, 2004). The ELISA cut off value for antigen were calculated (cut off value = mean Optical density (OD) negative × 2). A positive reaction corresponded to the antigen index above or equal to 1.3 while antigen index value below or equal to 0.8 was negative. A grey zone between 0.8 and 1.3 was considered doubtful and was retested.

(ii) Procedure for Porcine cysticercosis detection

A cross sectional study was conducted in study communities. Pigs were conveniently sampled and a maximum of five pigs per household were diagnosed. With owners' consent, pigs were examined for the presence of cysticercosis by the lingual examination method. This was done by a veterinary officer of Mbulu rural district council. The whitish mass on the underside of the tongue set the decision on the presence of *T. solium* cysticercosis (Guyatt & Fèvre, 2016; Mutua *et al*., 2007; Ngowi *et al*., 2004).

3.7.3 The effect of increased albendazole coverage and rounds per year on the control of cysticercosis

The quasi-experimental intervention study was conducted in three villages (communities) in Mbulu rural district council, where all eligible individuals received 400 mg of albendazole. There were two intervention communities, which differed in intervention frequency. Albendazole was provided once per year in one community and twice a year in another. The control received routine annual school deworming. Dissimilarities of risk factors among communities at baseline were a challenge but we used the parallel trend assumption that other factors remained constant so as to assess the effect of albendazole community intervention. The community with higher porcine cysticercosis was allotted to two interventions (Harsha village); the next in infections (Maghang Juu) was allotted to one community intervention per year. The control had few pigs infected at baseline (Diyomat) and received routine school deworming which was for entire district (Fig. 7).

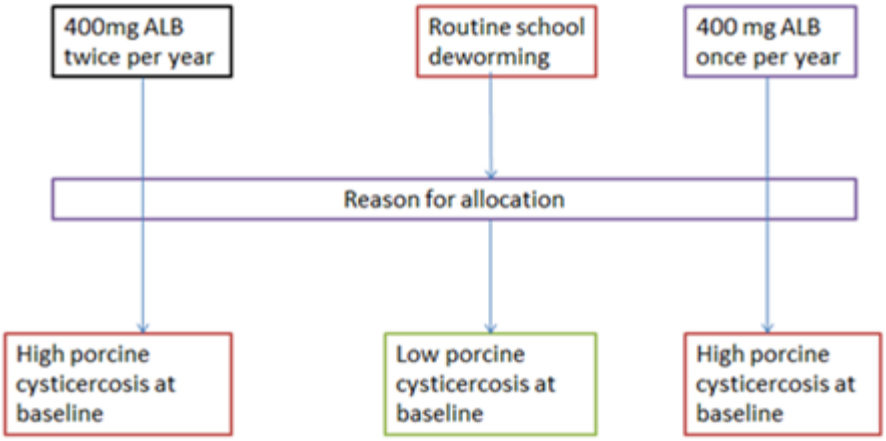

Figure 7: Allocation of communities to albendazole intervention

3.7.4 The trend of neurocysticercosis among patients with convulsions at Hydom Lutheran Hospital

A cross sectional study was conducted on March to April 2022 in the Manyara region. The patient's records from 2019 to 2022 with convulsions diagnosed at CT scan department for the cause of convulsions. All causes were recorded and proportion for *T. solium* neurocysticercosis as a cause of epileptic disorder or convulsions was retrieved for analysis.

3.8 Data collection periods

The baseline information was collected during the first visits for pigs and for human data, after twelve months for human cysticercosis and at intervals of six months for pigs: March, September, March and September for the years 2020 and 2021.

3.9 Recruitment of study participants for human cysticercosis determination

We recruited 600 participants from the three villages for human cysticercosis prevalence: Three hundred (300) at baseline and 300 at the end line. The treatment was for the entire village for those who met inclusion criteria; the study flow was as shown in Fig. 7. The intervention and control groups were selected based on baseline porcine cysticercosis prevalence. Before the albendazole intervention, the research team had a community meeting. The drug was administered by community members trained for the task. Each participant was recorded, and records are archived in the village office for future use.

Table 1: Participation in Mass drug administration in three villages

Village	number of sub villages	number of households	Total population	Eligible	Eligible and received drug		percentage coverage
					Male	female	
Maghang Juu June 2020	3	330	2026	1621	549 981	432	60.5%
Harsha June 2020	5	374	2364	1892	790 1433	643	75.7%
Harsha January 2021	5	374	2364	1892	741 1607	866	84.9%
Diyomat	5	320	2228	1782	∞	∞	∞

∞ denotes Diyomat village /a control site which was not treated

3.10 Data analysis

Data were analyzed using SPSS software, version 20. Continuous variables were summarized by the measure of central tendency and their respective dispersion. Categorical variables were summarized by proportions and frequencies and compared by chi-square test. The odds ratio and 95% confidence interval were used and a *p*-value of less than 5% was considered significant. The Difference in different methods was used to assess the effect of the intervention on human and porcine cysticercosis (Fredriksson & Oliveira, 2019). With two groups and two periods, and with a sample of data from the population of interest, the estimate of intervention effect is presented as follows:

$$DID = (\bar{y}_{s=Treatment,\ t=After} - \bar{y}_{s=Treatment,\ t=Before}) - (\bar{y}_{s=Control,\ t=After} - \bar{y}_{s=Control,\ t=Before})$$

Where Y is the outcome variable, the bar represents the average value (averaged over individuals, typically indexed by i), the group is indexed by s and t is time. With before and after data for treatment and control, the data is thus divided into the four groups and the above double difference is calculated.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Demographic characteristics

Three hundred participants were recruited from three different communities. The median age was 19, and the mode was 7, with a maximum of 89 and a minimum of 5 years (Fig. 8). Compared to other age groups, the lower age group was more prominent, reflecting the population composition in rural communities. The age group of 5 to 15 years was more represented than the other age groups giving mode lower than median and mean, thus positive skew observed with the tail pointing to the right of histogram. The older generation, with a large range of ages above 45, was underrepresented. The age groups were categorized with this range to capture primary school children (Table 2).

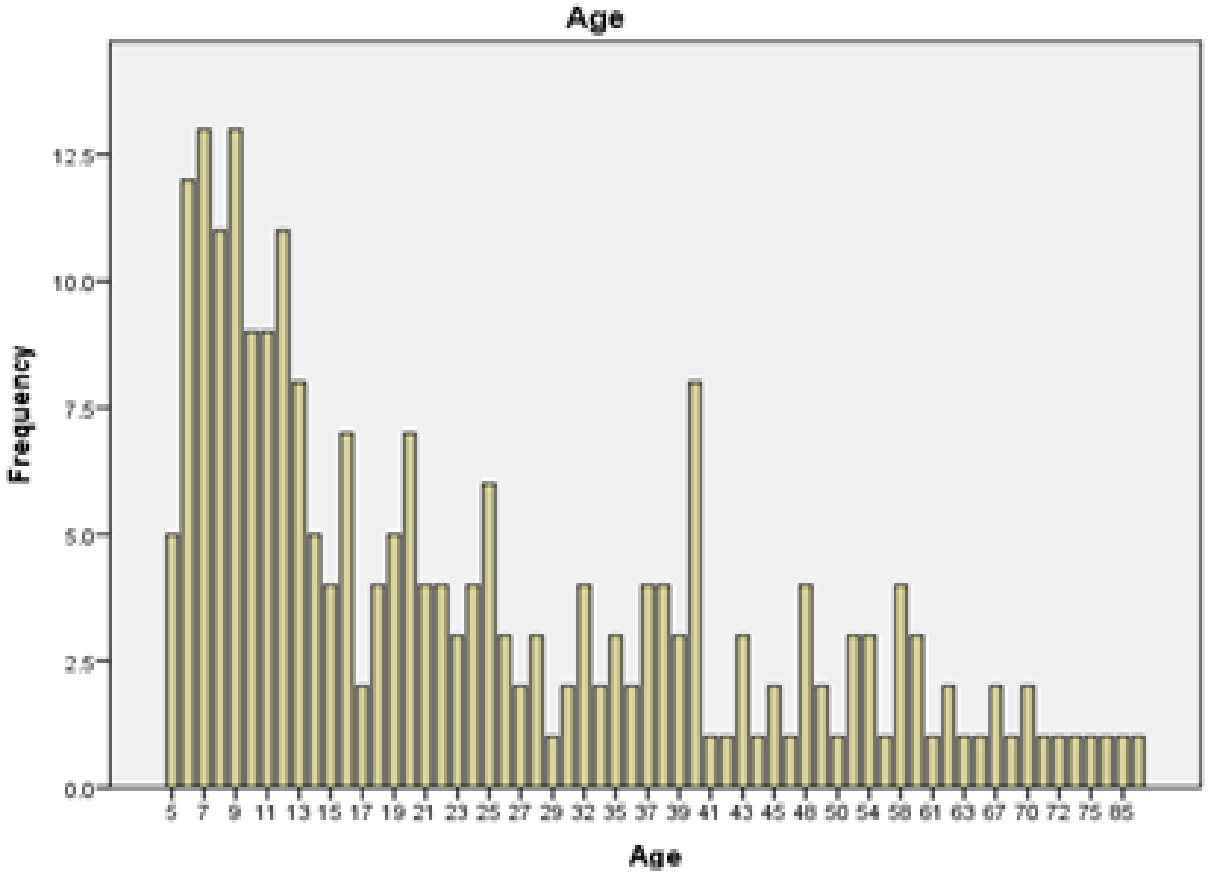

Figure 8: Demographic characteristics of study participants

Table 2: Demographic characteristics of participants

Variable	Harsha n (%)	Maghang Juu n (%)	Diyomatn (%)	Total n(%)
Gender				
Male	43 (51.1)	66 (62.2)	46 (41.8)	155 (51.7)
Female	41 (48.8)	40 (37.7)	64 (58.1)	145 (48.3)
Age				
5-15	32 (30.7)	36 (36.6)	36 (36.6)	104 (34.7)
16-25	11 (21.5)	14 (27.4)	26 (50.9)	51 (17.0)
26-35	8 (15.7)	18 (35.3)	25 (49.0)	51(17.0)
36-45	14 (32.5)	15 (34.9)	13 (30.2)	43 (14.3)
>45	19 (37.2)	22 (43.1)	10 (2.1)	51 (17.0)
Education level				
Primary	107 (41.5)	79 (30.6)	75 (29.1)	261 (87.0)
Secondary	2 (2.4)	9 (10.9)	1 (1.2)	12 (4.0)
Tertiary	1 (20)	4 (80)	0 (0)	5 (1.7)
none	0 (0)	14 (63.6)	8 (36.3)	22 (7.3)
Occupation				
Students	30 (31.2)	34 (35.4)	32 (33.3)	96 (32.0)
Farmer	54 (26.5)	72 (35.3)	78 (38.2)	204 (68.0)
Total	**84 (28)**	**106 (35.3)**	**110 (36.7)**	**300 (100)**

4.1.2 Prevalence, albendazole coverage and Taeniasis risk factors at household and community levels in Mbulu District

Eighty nine households from the three communities were visited during survey. Availability of tap water was observed in two villages, with one village (Maghang Juu) getting water throughout the year with 14 water delivery points, located at one hamlet. The second village (Diyomat) had five delivery points with seasonal water, mainly during rainy seasons, due to irrigation demands of dry season. The third village had eleven delivery points but no flowing water throughout the year. Each household risks to infection was high because of free pig rearing practice. The absence of toilets was another risk to infections in half of households visited as well as the absence of safe and clean water (Table 4). Twenty households among 107 households which gave blood samples had one to two positive participants from household which is 18.69%. Three households had two infections; the remaining had one infection per household; two household were from Diyomat village and one from Harsha.

Table 3: Risk factors and cysticercosis prevalence at community level in three study communities

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)**	

Absence of clean and safe water predicts increased human cysticercosis in community while absence and under use of toilet prevails in all communities leading to high porcine cysticercosis

(i) Human Taeniasis

There was no significant difference in infection status by age groups, sex and occupation (Table 3). About 82 (27.3%) of the sampled population received anthelmintic; among those, 5 (21.7%) residents out of 23 were infected. The lowest age group comprised primary school children who received anthelmintic as supported by the data retrieved from district MDA program in previous years with the coverage of above 93% for school children in the district (Fig. 9). The likelihood of infection among anthelmintic users and non-users seemed to be low among anthelmintic users by 28% [0.72 (0.26-2.01)], but the protection was not statistically significant.

Table 4: Prevalence of human *T. solium cysticercosis*

Variable	Total	Positive n (%)	Negative n (%)	OR (95% CI)	P value
Sex					
Male	145	12 (8.27)	133 (91.72)	Ref	
Female	155	11 (7.09)	144 (92.90)	1.18 (0.50-2.77)	0.702
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 (0.26-75.46)	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 (92.3)		

Note: Socio-demographic factors showing an existing trend of cysticercosis infection in Mbulu community

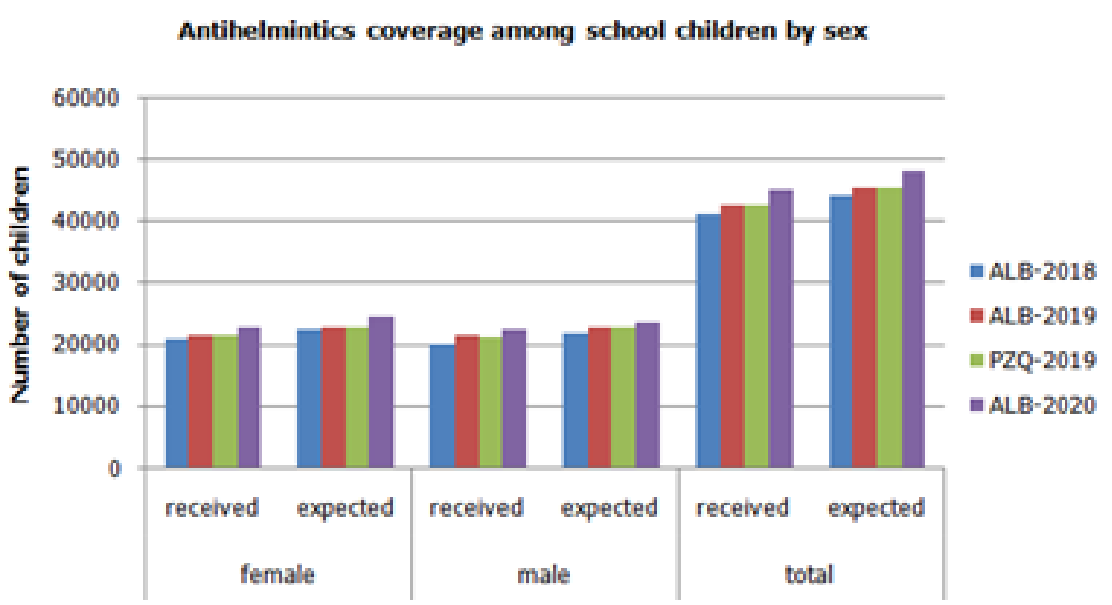

Figure 9: Mass Drug Administration Coverage for school children (recorded data)

(ii) Porcine cysticercosis

Five hundred and ten (510) pigs were conveniently sampled; of these 267 (52.4%) were sampled during the rainy (March) and dry (September) seasons of the year 2020 while 243 (47.6%) were sampled in the year 2021 for rainy and dry season. Of the 510, 237 (46.5%) were male pigs. Out of 510 pigs, 43 (8.4%) pigs were infected with pork tapeworm larva, while 21 (48.8%) were males and 22 (51.2%) females. There was no statistically significant difference in infection between male and female pigs (p= 0.7451); this may be attributed by early time of life infections as most piglets are neither tethered nor penned. The infection for two consecutive years 2020 and 2021 was 24 (9%) and 19(7.8%), respectively (Table 5). A significant seasonal difference in infection was observed for the year 2020 where the pigs were more than two times infected due to the running water of rainy season compared to the dry season (OR 2.27 (95% CI of 1.16-7.22) (Table 6).

Table 5: Porcine cysticercosis variations among three villages in Mbulu district for two consecutive years

Year	Village	Total	positive	Prevalence	Fisher's exact test
2020	Diyomat	101	5	4.95 (2.13-11.07)	Reference
	Maghang Juu	62	4	6.45 (2.54-15.45)	0.7319
	Harsha	104	15	14.42 (8.94-22.44)	0.0323
	Overall communities	267	24	8.99 (6.11-13.03)	0.2781
2021	Diyomat	75	5	6.67 (2.88-14.68)	Reference
	Maghang Juu	101	7	6.93 (3.4-13.62)	1.0000
	Harsha	67	7	10.45 (5.15-20.03)	0.5488
	Overall communities	243	19	7.82 (5.06-11.89)	1.0000

There was no significant difference in prevalence for the years 2020 and 2021. The chi-square statistic = 0.2255 and the p= 0.6348

Table 6: The seasonal prevalence of porcine cysticercosis in Mbulu district, Tanzania

Year	Month (Season)	Positive n (%)	Negative n (%)	Total	odds ratio((95CI)	z statistic (P value)
2020	March (rainy)	17 (13.3)	111 (86.7)	128	2.27 (1.16-7.22)	2.270 (0.0232)
	September (dry)	7 (5.0)	132 (94.9)	139		
	Sub-Total	24 (9.0)	243 (91.0)	267		
2021	March (rainy)	7 (8.1)	79 (91.8)	86	1.07 (0.40-2.82)	0.138 (0.8904)
	September (dry)	12 (7.6)	145 (92.3)	157		
	Sub-Total	19 (7.8)	224 (100)	243		
	Total	**43 (8.4)**	**467 (91.6)**	**510**		

The pig-keeping styles recorded in the study area for the year 2020 include; 141 (52.8%) with no tethering, 64 (24%) penned and 62 (23.2%) tethered. Human faeces were often observed on footpaths as the research team moved from one household to another. The pig lingual examiners reported to have smelt human faeces in several pigs inspected. The difference in pig infection outcomes in the study villages was not statistically significant regardless of the pig-keeping style (Table 7).

In this study, 94 households were visited for the year 2020, with members ranging from two to ten. Of these household heads, 78 (83%) reported drinking water without boiling; and only 16 (17%) households reported using boiled water. Fifty-nine (62.7%) household heads reported having heard taeniosis and cysticercosis in vernacular called ‘gilgiri’ as observed in faeces for taeniosis and ‘fini’ for cysticercosis as observed in pork during preparation.

Table 7: Prevalence and risk factors of porcine cysticercosis

Variable	n	Infected n (%)	Non-Infected n (%)	OR (95% CI)	n	Infected n (%)	Non-Infected n (%)	OR (95% CI)
		Rainy season				**Dry season**		
Population (n)	128				139			
Village								
Harsha	50	12 (24.0)	38 (76.0)	Ref	54	3 (5.56)	51 (94.44)	Ref
Diyomat	52	1 (1.92)	51 (98.08)	0.06 (0.01-0.49)	49	4 (8.16)	45 (91.84)	1.51(0.32-7.12)
Maghang Juu	26	4 (15.38)	22 (84.62)	0.58 (0.17-2.01)	36	0 (0.00)	36 (100.0)	~
Rearing style								Ref
caged	32	3 (9.38)	29 (90.63)	0.81 (0.19-3.49)	32	0 (0.00)	32 (100.0)	0.19 (0.03-1.15)
free	43	8 (18.60)	35 (81.40)	1.79 (0.57-5.63)	98	5 (5.10)	93 (94.90)	~
mixed	53	6 (11.32)	47 (88.68)	Ref	9	2 (22.22)	7 (77.78)	
Total	**128**	**17 (13.28)**	**111 (86.72)**		**139**	**7 (5.04)**	**132 (94.96)**	

Note: Increased cysticercosis infections during rainy season compared to dry season [odds ratio 2.88 (95% CI of 1.16-7.22)]. ~ This is omitted because do not have enough numbers

4.1.3 Effect of increasing albendazole coverage and rounds per year in eliminating cysticercosis

(i) Effect of intervention on human cysticercosis

The effect of intervention showed decrease in human cysticercosis in both arms. For two rounds albendazole intervention it decreased by 7.3%. While for one round albendazole intervention decreased by 0.94%. The control arm showed a decrease by 9.96% as shown in Table 8.

Table 8: Effect of interventions on infection of human cysticercosis among three communities

	Pre intervention prevalence		**Post intervention prevalence**		**Difference between Pre and post intervention (%)**	**DID (%)**
Village	N	n (%)	N	n(%)		
Diyomat	110	12 (10.90)	106	1 (0.94)	-9.96	Reference
Maghang Juu	106	2 (1.88)	106	1 (0.94)	-0.94	9.02
Harsha	84	9 (10.71)	88	3 (3.4)	-7.31	2.65
Overall	300	23 (7.67)	300	5 (1.67)	-6.00	3.96

Note; DID denote Difference in difference estimation of effect

(ii) Effect of intervention on porcine cysticercosis

A total of 510 pigs were conveniently sampled were 267 were sampled during pre-intervention and 243 were sampled during post intervention. There was a decrease in two round albendazole interventions while in one round intervention per year there was a rise by 0.5%. The control showed a rise by 1.8% as shown in Table 9.

Table 9: Effect of interventions on infection of porcine cysticercosis among three communities

Intervention unit	Pre intervention (%)		Post intervention (%)		Difference between Pre and post intervention (%)	(DID) (%)
Control(Diyomat)	101	5 (4.9)	75	5 (6.7)	1.8	Reference
intervention one (Maghang Juu)	62	4 (6.4)	101	7 (6.9)	0.5	-1.3
Intervention two (Harsha)	104	15 (14.4)	67	7 (10.4)	- 4.0	.-5.8
Overall communities	267	24 (9.0)	243	19 (7.8)	-1.2	-3.0

Note there is a decrease in prevalence after community anthelmintic intervention. DID denote Difference in difference estimation of effect. The pre intervention villages' prevalence was criterion for allocation to two rounds or one round community treatment

4.1.4 Trend of neurocysticercosis cases

A total of 78 patients data with convulsive disorders were retrieved from records in radiology department at Hydom hospital in Mbulu district -Manyara region from 2019 to 2022 the results were up to the first quarter of the year 2022. The pork tapeworm cysticercosis had about 31% cases of all with convulsive disorders. The patients came from Mbulu district and nearby districts; the positive cases were reported from seven districts (Table 10); the male and female patients were equally infected *p* value 0.7950. The trend of neurocysticercosis cases recorded at radiology department was almost the same for four consecutive years at an average of 30% of all with convulsive disorders (Table 11).

Table 10: Neurocysticercosis cases at Hydom Hospital by residence of the patients

Residence	Total N	Neurocysticercosis	
		negative n(%)	positive n (%)
Mbulu	25	17 (68)	8 (32)
Mkalama	14	10 (77.4)	4 (28.6)
Meatu	1	19 (100)	0 (0)
Hanang	16	13 (71.3)	3 (18.7)
Babati	13	8 (61.6)	5 (38.4)
Kiteto	1	1 (100)	0 (0)
Karatu	6	3 (50)	3 (50)
Kilosa	1	0 (0)	1 (100)
Kateshi	1	1 (100)	0 (0)
Total	78	54 (69.2)	24 (30.8)

The neurocysticercosis cases at Hydom Lutheran Hospital

Table 11: The trend of neurocysticercosis among patients with convulsive disorders

		N	NCC		Chi square test p -value
			negative n(%)	positive n(%)	
year	2019	25	17 (68)	8 (32.0)	
	2020	13	9 (69.3)	4 (30.7)	
	2021	28	20 (77.5)	8 (28.5)	
	2022	12	8 (66.7)	4 (33.3)	0.990
Total		**78**	**54 (69.2)**	**24 (30.8)**	

Note for four consecutive years the proportion of neurocysticercosis cases remained constant at Hydom Lutheran Hospital

4.2 Discussion

The study results showed persistent porcine cysticercosis for two consecutive years and observed seasonal variations in porcine cysticercosis prevalence for the year 2020. Porcine cysticercosis prevalence did not vary significantly based on the pig-keeping style. The observed difference between the rainy and dry seasons of the year 2020 may be explained by the long rainy season observed compared to the year 2021 where the rain was moderate (TMA, 2022). The persistent prevalence of porcine cysticercosis is an indicator of fecal contamination of soil and water with infective pork tapeworm eggs from human faeces as faeces were observed along the footpath as the team moved from one household to another; the smell of faeces in the mouth of pigs during the lingual examination was also detected. This study recorded four different points to have a trend of infection in the community; the varied trends may be either a result of school deworming interventions conducted annually; or, maybe a result of discouraged pig farmers to keep pigs due to pig loss experienced from previous year infected pigs resulting in the household with a tapeworm carrier unknowingly avoiding to keep pigs as a consequence of a loss experienced.

The results showed no statistical significance in pig management practices; this may be due to the free-roaming of young pigs thus being infected at the first two months of life as they were observed neither tethered no penned, and it was not for the reason of preventing pigs from infection but from disturbances caused by pigs to growing crops. This may also be attributed to the community treatment with albendazole in households conducted by the research team. The results from this study are similar to the results from other studies conducted in Kenya, Mozambique, and Zambia where the prevalence of lingual examination ranged from 6-15 % (Mutua *et al*., 2007; Pondja *et al*., 2010; Sikasunge *et al*., 2007). The pork tapeworm risks of free-roaming and tethering sometimes were observed; this is similar

to other studies conducted in Tanzania, Mozambique, and Zambia (Kabululu *et al*., 2015; Pondja *et al*., 2010; Sikasunge *et al*., 2007).

The high prevalence of porcine cysticercosis suggests presence of tapeworm carriers in communities, while drinking unsafe water in endemic communities presents risks to human cysticercosis in these communities. Pig vaccination and treatment for pork tapeworm in pigs are not in operation in Mbulu district because the treatment (oxfendazole) and vaccine (TSOLI8) are currently not in Tanzania market although, both have shown positive results (Kabululu *et al.,* 2020). The deworming program is for humans only. The school deworming program may have contributed to the observed decrease in porcine cysticercosis compared to the prevalence (17.4%) reported twenty years back in the same study area using the same diagnostic method - lingual examination (Ngowi *et al*., 2004). After health education in the same area fifteen years ago, the porcine cysticercosis incidence showed a decrease of 13% (95% CI: 12-14) per 100 pig-years, a halfway drop from the baseline (Ngowi *et al*., 2008).

This study suffered short time of intervention, we did not employ carcass examination of slaughtered pigs in communities, and antigen and antibody diagnostic methods were not employed thus underestimating the prevalence. The study has shown that porcine cysticercosis prevalence fluctuates. The decrease in the subsequent year with little rain needs further research as there was community deworming apart from school deworming as conducted for entire human population in the study sites. Thus it is not conclusive that the decrease was attributed to low rain or community deworming programs in human. The observed porcine cysticercosis prevalence and a large proportion of households drinking unsafe water imply a high prevalence of taeniosis and human cysticercosis in these communities**.**

This study shows that human infection with *T. solium* cysticercosis in Mbulu District was high (7.67%). The prevalence was not statistically different among those who received anthelminthic and those who did not receive anthelminthic during the previous year. This may be a result of low anthelminthic coverage in the communities by targeting school children only, leading to continued transmission among elder age groups as indicated by the results of this study. The high prevalence of cysticercosis established in this study has the implication of environmental contamination with infective taeniid eggs from human faeces and faecal-oral infections due to lack of clean and safe water as over half of the surveyed households didn't have pit latrines. The absence of difference in the infection among those who received anthelmintic and those who didn't receive may be explained by the continued

carriers in the communities contaminating environment including water as more than half of the surveyed households didn't have access to tape water and more than two-thirds of the community members didn't receive anthelminthic because they were not targeted despite being at risk of infection.

The prevalence of human *T. solium* cysticercosis in this study was lower than that reported previously (Mwang'onde *et al*., 2018). This may be a result of different diagnostic assays used with different sensitivity and specificity. This study used antigen ELISA which detects the active parasite while the previous study used IgG Western blot Assay (Mwang'onde *et al*., 2018) which detects 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 (Mwanjali *et al*., 2013; Mwape *et al*., 2013; Rojas *et al*., 2019). Thus, integrating pig vaccination and deworming, health education, and school or community deworming may be the future solution to porcine cysticercosis.

The Computed Tomography (CT)scan and Magnetic Resonance Imaging (MRI) play important role in case identification in hospitals for patients presenting convulsions. It is reported in Uganda as a case of high blood pressure patient aged 73 years (Segala *et al*., 2022). The scarce resources presented in the hospital reflect what is happening in low and middle income as a reason for shifting regimen in this case treatment. The regular training of radiologists on interpretation of cystic lesions caused by *T. solium* larvae is very important for case identification as presented in Uganda case. The slaughterhouse carcass condemnation is highly practiced in developed countries (García-Díez *et al.,* 2023). The bylaws are strongly enforced in developed countries; While In developing countries alternative is to minimize total loss is opted, and not under supervision which actually fall to human consumer buying at cheapest price the carcases, thus continued zoonotic diseases transmissions.

There was a variation in the prevalence of human cysticercosis across villages. The prevalence was higher at Harsha village, and this could be a result of the absence of clean and safe water, underuse of pit latrines, and practice of free rearing of pigs. The shared water source for irrigation may explain the relatively high prevalence among people of Diyomat. The low prevalence at Maghang Juu was most likely associated with the availability and use of safe and clean water throughout the year. These risk factors were aligned with similar endemic communities reported in other studies (Alexander *et al*., 2012; Carabin *et al*., 2018).

From these findings, mass drug administration in primary school children seems to have little effect on the prevalence of *T.solium* cysticercosis, most likely due to low coverage of school children which is about 20% of the total population (World Bank, 2018b). Previous studies have shown that porcine cysticercosis was high in households that were using latrines and among those practicing free-ranging pig (Kabululu *et al*., 2020; Ngowi *et al.*, 2004; Shonyela *et al*., 2017). Similarly, free-ranging has been reported as an important risk factor in Mozambique (Pondja *et al*., 2010). Adults were at high risk because they were not involved in the National school deworming program. The community with uneven supply and use of clean and safe water had a high prevalence of human cysticercosis which was the case of Harsha and Diyomat communities, implying an increased risk of human cysticercosis infection in communities with similar risk factors.

The study established a high prevalence of human cysticercosis among adults 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 adult groups. The study reveals reduction in human cysticercosis prevalence; the reduction is higher in communities with high pre intervention human cysticercosis prevalence. Porcine cysticercosis prevalence showed a decrease in the two rounds intervention arm and a rise in one round intervention arm but remained constant in the control. The varied community risks account for the observed discrepancies *in T. solium* cysticercosis reduction.

The albendazole intervention as accompanied by education package prior to intervention might have contribution on reducing prevalence at community level. This is supported by community education intervention study which showed reduction in porcine cysticercosis incidence (Ngowi *et al*., 2008) and reduction in taeniosis after anthelmintic treatment (Ramiandrasoa *et al*., 2020). Education intervention on disease during preventive chemotherapy campaign is important since not all will take drug because it is voluntary.

The reduction of human *T. solium* cysticercosis in this study is due to anthelmintic treatment in the communities and sanitation practices observed during Covid 19. This is in line with the study done in Madagascar which showed a reduction in taeniosis prevalence (Ramiandrasoa *et al*., 2020), this has indirect effect on reduction of *T. solium* cysticercosis in the community because treating human subjects with anthelmintic reduces taeniosis and subsequently cysticercosis (Holden-Dye & Walker, 2007; Ramiandrasoa *et al*., 2020).

Among the limitations of this study is the short study duration; furthermore, during this intervention there were national wide campaign on hand wash and sanitation as intervention against Covid19 which had positive impact on human cysticercosis. The antigen ELISA test didn't give the exactly exposed population to infection but those with live *T. solium* larvae. The intervention has implication of positive effect if sustained for long time in communities at high risks and endemic in developing countries.

The radiology departments as part of diagnosis play important role in case identification in hospitals for patients presenting convulsions, this is proved in Uganda as a case of 73 year old woman who presented with high blood pressure (Segala *et al.,* 2022). The scarce resources presented in the hospital reflect what is happening in low and middle income for shifting of regimen for this case treatment. The regular training of radiologists on interpretation of cystic lesions caused by *T. solium* larvae is very important for case identification as presented in Uganda case. The cost of Computed Tomography scan and Magnetic Resonance Imaging although gold standard cannot be employed as routine test for *T. solium* neurocysticercosis; the available serological tests suffer low sensitivity and specificity hence not cost effective (Hossain *et al.,* 2023). These diagnostic challenges marginalise more this neglected disease from routine diagnostic and treatment as the scarcity of treatment presented for the discussed case (Segala *et al.,* 2022). Thus, the district hospitals are important point to identify the endemic areas for targeted interventions on cysticercosis/taeniosis; the districts without cases do not mean they are not endemic; this is because patients visited health facility at their proximity.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

High prevalence of human and porcine *T. solium* cysticercosis was found among rural communities in Mbulu district. The school deworming has positive effect on younger age group. The community intervention using albendazole has shown reduction in prevalence when other factors considered constant. The *T. solium* neurocysticercosis among patients with convulsions is constant for four consecutive years in Mbulu district regardless albendazole intervention in three communities; the radiology department data in district hospitals with CT scan may be used for identifying the endemic areas for conducting survey to establish disease burden and subsequent tapeworm control actions.

5.2 Recommendations

(i) A higher prevalence was observed during the rainy season (March) calling for timed intervention using anthelmintic during this season.

(ii) Higher age groups are more infected than younger age groups. It is proposed to increase anthelmintic coverage and rounds in communities' endemic with pork tapeworm to cover the adults.

(iii) It is important to have health facility staff training on *T. solium* neurocysticercosis case identification and management.

(iv) One health approach involving different sectors should be employed to cover other factors considered constant throughout this intervention study; education, clean and safe water provision, improvement of pig management through by laws, hygiene and sanitation and treatment and vaccination of pigs.

(v) National representative research/survey needed on this parasite so as to have clear burden in areas with cases identified but originating from other districts in the country for establishing burden and intervention strategies.

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APPENDICES

Appendix 1: Informed consent

Consent forms: English versions

THE NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY

(NM-AIST)

SHOOL OF LIFE SCIENCE AND BIOENGENEERING

(Global Health and Biomedical Sciences)

P.O.Box 447, Tengeru

ARUSHA, Tanzania

Research title: THE EFFECT OF INCREASING ALBENDAZOLE COVERAGE AND ROUNDS ON ELIMINATION OF CYSTICERCOSIS IN HUMAN AND PORCINE IN MBULU DISTRICT, TANZANIA

SECTIN A: Descriptions to participant

My name is Vedasto John Bandi. I am working with the team of researchers from Nelson Mandela African Institution of Science and Technology (NM-AIST) of Arusha, Tengeru area, doing a research on diseases caused by tapeworm.

We are requesting to investigate your family and some of your pigs and use the data and findings to solve this society problem. The information obtained from this research will contribute on proposing the best intervention for eliminating the diseases in endemic localities.

Your information will be treated as confidential. Please, know that your participation is voluntary and you have right to refuse or withdraw from the study without being affected. No cost is involved for you to participate in this study.

Description and objective of study

Human harbour adult tapeworm in the intestine releasing thousands of eggs , pork tapeworm lava are infections in tissue(musle and brain) of human and pigs the disease known as cysticercosis, in the cental nervous system is called neurocysticercosis causing severe headach and epilepsy. pigs usually dont show any change but the quality of meat is lowered and lead to financial losses. the disease is in communities practising free ranging style of pigs. **In this research we want to know the disease (cysticercosis) burden in this community**. if you join this study we will diagnose for porktapeworm lava. you and or your children will be requested for blood sample and you will be asked some questions. If any of you will be infected you will be treated and advised.

Study procedure

if you agree to be recruited in this study, and your children meet inclusion criteria for the study you will be asked some questions and we will draw blood sample and laboratory investigations will be done after two weeks for cysticercosis infection. we will need to know your understanding of the disease transmissions and preventions and household risk factors for disease transmissions. we will write your name for reason of followup if you are to be treated, your study number will be your identity. if you will be infected you will be treated and adviced without any cost to pay. we will diagnose your pigs for pork tapeworm lava(cysticercosis).

Benefits

You will benefit from this study from free treatment in case you are infected, this study will benefit you individually and community at large because wehas an approach of intervention in the commnity.neither you or your children will not be paid for participating in the study.

Risks

Taking blood sample involve punching your skin, this causes some pain, swelling and continued bleeding for few minutes. Health professional will perform this task and will handle all side effects wich may arise.

Confidentiality

Information which you will provide will be confidential no one will know the source of response. your name will not be used in any report of this study. You can get you records and information any time. you or your children are free to ask questions any time.

Voluntary participation

It is a voluntary paticipation. you or your child has right to withdraw from the study at anytime, even if you have signed this consent form. This will not affect the services which you or your child have been offerred, neither your household or entire community will not be affected.

Ethical commitees

This study is approved and has ethical clearances from the Northern zone ethical committee with ethical clearance number KNCHREC0019 and National Institute for Medical Research (NIMR/HQ/R8a/Vol.IX3301. Also Tanzania Medicines and Medical Devices Authority (TMDA) approved the study with reference number TMDA0019/CTR/0017/02.

SECTION B1: consent form

Consent (aged 18 and above):

I confirm to have been explained about this study and I have been given a copy of consent and explanations of this study. I have read and understood risks of participating in this study. I had eough time to investigate informations on this study, to ask questions and got appropriate and satisfactory answers.I know that, information wich I will provide will be used appropriately and confidential; and i will not be named anywhere in any report and publication of this study.

I, ... voluntarily agree to participate in this study for responding to questions and blood sample for cysticercosis test.

YES ☐ NO ☐ (Compulsory)

Jina la mshiriki mtu mzima:	Sahihi au dole gumba la mshiriki mtu mzima:
Jina la shahidi:	Sahihi ya shahidi kama (hajui kusoma na kuandika):
Jina la matafiti:	Sahihi ya mtafiti:
Mahali:	Tarehe:

SEHEMU B2: Assent form for participants aged 5-17

I confirm to have been explained about this study and I have been given a copy of consent and explanations of this study. I have read and understood risks of participating in this study. I had eough time to investigate informations on this study, to ask questions and got appropriate and satisfactory answers.I know that, information wich I will provide will be used appropriately and confidential; and i will not be named anywhere in any report and publication of this study.

I, ... voluntarily agree my children to participate in this study for responding to questions and blood sample for cysticercosis test.

YES ☐ NO ☐ (Compulsory)

In addition , I agree that for my consent, the oral assent of my children will be requested before participation in this study.

Children assent: YES ☐ NO ☐ (Compulsory)

Name of Children :	Date of birth:
Name of parent/Guardian:	signature parent/guardian:
Name of researcher:	signature of researcher:
Place:	Date:

SECTION C: Institutions and persons to communicate if you have more questions about this study

if you have questions about your participation in this study or you think you have been ill treated or the results of this study you can communicate to the following:

National Ethics Commitee, 3 Barack Obama Drive, S.L.P 9653, 11101 Dar es Salaam, Tanzania Simu: + 255-22-2121400, Faksi: + 255-22-2121360, Barua pepe; Hq@nimr.or.tz | Info@nimr.or.tz

OR

Mr. Vedasto John Bandi (PhD student), Nelson Mandela African Institution of Science and Technology. S.L.P 447, Tengeru Arusha Tanzania. mobile +255754742751, email bandiv@nm-aist.ac.tz.

SEHEMU YA B3: fomu ya ridhaa

Ridhaa ya mmiliki wa nguruwe:

I confirm to have been explained about this study and I have been given a copy of consent and explanations of this study. I have read and understood risks of participating in this study. I had eough time to investigate informations on this study, to ask questions and got appropriate and satisfactory answers.

I know that iformation will help the control of pork tapeworm.

I,..... voluntarily agree my pigs to be diagnosed in this study.

Ndio ☐ Hapana ☐ (LAZIMA)

Jina la mmiliki wa nguruwe:	Sahihi au dole gumba la mmiliki:
Jina la shahidi:	Sahihi ya shahidi kama (hajui kusoma na kuandika):
Jina la matafiti:	Sahihi ya mtafiti:
Mahali:	Tarehe:

Appendix 2: Consent forms: Swahili versions

FOMU YA RIDHAA YA USHIRIKI KATIKA UTAFITI

Namba ya mshiriki…….

THE NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY (NM-AIST)

SCHOOL OF LIFE SCIENCE AND BIOENGENEERING

(Global Health and Biomedical Sciences)

P.O. Box 447, Tengeru

ARUSHA, Tanzania

Jina la mradi: MATOKEO YA KUONGEZA ALUBENDAZOLE KATIKA KUTOKOMEZA MNYOO TEGU/FINI KWA BINADAMU NA KWA NGURUWE KATIKA WILAYA YA MBULU, TANZANIA

Sehemu A: Maelezo kwa mshiriki

Hello, Jina langu ni Vedasto John Bandi nafanya kazi na timu ya watafiti kutoka Chuo cha Nelson Mandela kilichopo Arusha , Tengeru, tunafanya utafiti wa magonjwa yanayo sababishwa na mnyoo tegu wa nguruwe (Fini).

Tunaomba ridhaa yako ya utafiti huu ya kuwahoji na pia kuchukua vipimo vya damu

Wewe na wanakaya wako mnaalikwa kujiunga na utafiti unaohusika na ugonjwa unaosababishwa na tegu ya nguruwe. Tuna lengo la kuchunguza epidemiolojia na namna ya kudhibiti ugonjwa wa tegu ya nguruwe(Fini).Tegu ya nguruwe ambayo inaweza kuishi katika

matumbo ya binadamu na viluilui vyake ambavyo vinaweza kuishi katika ubongo wa mtu yeyote.

Kusudi na maelezo ya utafiti

Watu wanaweza kuwa na tegu wazima wa nguruwe kwenye utumbo, wakati viluilui vya tegu wa nguruwe wanaweza kupatikana hasa katika misuli na ubongo wa binadamu na nguruwe. Ugonjwa huo huitwa 'cysticercosis' katika kesi hii inaweza kusababisha kifafa na maumivu ya kichwa. Nguruwe kawaida hawana dalili kali za ugonjwa huo, lakini nyama yao inakuwa si salama kwa matumizi. Mara nyingi tunaona ugonjwa huu katika vijiji ambapo nguruwe wanazururа ovyo. Katika utafiti huu, tunataka kutathmini ugonjwa wa fini. Ikiwa wewe / mtoto wako akijiunga na utafiti huu, tutampima wewe / mtoto wako kwa kipimo cha tegu wa nguruwe na viluilui vyake yake. Wewe / mtoto wako ataombwa sampuli ya damu ambayo ni muhimu kuthibitisha majibu yetu. Pia tutakuuliza / mtoto wako kujibu maswali fulani. Ikiwa wewe / mtoto wako ana / ana shida (maambukizi ya TSCT), wewe / mtoto wako atapata matibabu na ushauri.

Jinsi utafiti utafanyika

Ikiwa wewe / mtoto wako atakubali kushiriki katika utafiti huu, na kama wewe / mtoto wako ana vigezo vya kushiriki katika utafiti huu, tutakuuliza / mtoto wako kutoa damu ili kupimwa kama ana ugonjwa wa tegu wa nguruwe (Fini). Sampuli za damu zitapimwa kuthibitisha matokeo yake. Tunataka kujua ni nini wewe / mtoto wako anajua juu ya ugonjwa huu na hali ya kaya yako ambayo inasababisha kuenea kwa ugonjwa huo.

Tutaandika jina la mtoto wako, lakini litatumika tu ikiwa unahitaji matibabu au kufuatiliwa. Ikiwa wewe / mtoto wako ni / umeambukizwa na tegu ya nguruwe au viluilui vyake, mtoto wako au wewe atapata matibabu ya bure na ufuatiliaji bure wa matibabu katika kituo cha afya au hospitali.

Tutachunguza na nguruwe wako kwa kuangalia ulimi kama kuna fini(cysticercosis)

Faida

Wewe au mtoto wako mtafaidika kutokana na utafiti, kama wewe au mtoto wako atafanyiwa uchunguzi na kuonekana ana maambukizi ya ugonjwa huu atapata matibabu dhidi ugonjwa huu bila malipo. Utafiti huu pia unatarajiwa kufaidisha jamii kwa kuwa utapunguza uwezekano wa maambukizi ya ugonjwa huu katika jamii, na pia kupunguza uwezekano wa watu wengine kuambukizwa au wewe au mtoto wako kuambukizwa tena pia utapunguza

nguruwe wako kupata fini/cysticercosis. Wewe au mtoto wako hatapata malipo ya kushiriki katika utafiti huu.

Hatari na matatizo

Kutoa Sampuli ya damu inaweza kusababisha usumbufu, kutokwa na damu au mchubuko mahali ambapo sindano imetoboa kwenye kidole (Kwa 1%). Kiasi kidogo cha damu kinaweza kuganda pale ambapo sindano imetoboa kwenye mwili wako na pia panaweza kuvimba. Mara chache kupoteza fahamu au kupata maambukizi ya magonjwa. Wataalamu wa afya wenye sifa zinazotakiwa watafanya kazi ya kutoa sampuli za Damu, hatua zitachukuliwa ili kuzuia matatizo yoyote na usumbufu unaoweza kutokea. Kwa ujumla, hakuna hatari kubwa ya afya yako inayohusishwa na kutoa damu kama sehemu ya utafiti huu. Wakati mwingine mchubuko unaweza kutokea kwa mara chache maambukizi ya magonjwa yanaweza kutokea mahali ambapo sindano imetoboa na pia panaweza kuendelea kutoa damu. Ikitokea hivyo njoo hospitali mara moja.

Usiri na Faragha

Taarifa ambayo wewe au mtoto wako atatoa katika utafiti huu itahifadhiwa kwa usiri mkubwa. Mipango itafanywa ili kuhakikisha usiri na faragha inazingatiwa. Jina lako / jina la mtoto wako halitatumiwa katika ripoti yoyote kuhusiana na utafiti huu. Unaweza kupata taarifa na rekodi zako wakati wowote. Wewe au mtoto wako mko huru kuuliza swali lolote wakati wowote.

Ushiriki wa hiari

Kushiriki kwa mtoto wako au wewe katika utafiti huu ni kwa hiari. Pia wewe au mtoto wako yuko huru kujitoa katika utafiti huu wakati wowote wakati wa utafiti, hata baada ya wewe / mtoto wako / akiwa amesaini Fomu hii ya ridhaa ya kushiriki. Hii haitaathiri huduma ambazo wewe au mtoto wako, mmekuwa mkizipata wala wanakaya wako wengine au jamii yako haitaathirika kwa namna yoyote.

Kamati ya Maadili

Utafiti huo umekubalika na kupewa kibali na Kamati ya Mapitio ya Maadili ya Utafiti Tanzania (Dar es Salaam) na Kamati ya mapitio ya maadili ya utafiti kanda ya Kaskazini (KNCHREC).

SEHEMU YA B1: fomu ya ridhaa

Ridhaa ya washiriki (umri wa miaka 18 na zaidi):

Ninathibitisha kuwa nimeezwa juu ya utafiti na kwamba nimepata nakala ya karatasi ya ridhaa ya washiriki na maelezo kuhusu utafiti huu. Nimesoma na kuelewa habari za utafiti huu. Nimepewa taarifa za kutosha kuhusu muda wa utafiti na madhara yoyote yanayoweza kutokea. Kwa kuongeza, nimepata muda wa kutosha kuchunguza taarifa za utafiti huu na kuuliza maswali, ambayo nimepata majibu yenye kuridhisha. Ninafahamu kwamba taarifa nitakazotoa itatendewa haki kwa kutunzwa kwa usiri mkubwa na mimi sitatambuliwa binafsi katika ripoti yoyote ya utafiti huu au nyaraka za machapisho yake.

Mimi..... kwa hiari yangu naridhia kushiriki katika utafiti huu na kukubali kushiriki katika utafiti huu, ikiwa ni pamoja nakutoa sampuli ya damu kushiriki katika uchuguzi na kujibu maswali.

Ndio ☐ Hapana ☐ (LAZIMA)

Jina la mshiriki mtu mzima:	Sahihi au dole gumba la mshiriki mtu mzima:
Jina la shahidi:	Sahihi ya shahidi kama (hajui kusoma na kuandika):
Jina la matafiti:	Sahihi ya mtafiti:
Mahali:	Tarehe:

SEHEMU B2: Idhini kwa washiriki wenye umri kati ya miaka 5-17

Ninathibitisha kuwa nimeelezwa juu ya utafiti na kwamba nimepata nakala ya karatasi maelezo kwa washiriki na ya ridhaa ya kushiriki katika utafiti huu. Nimesoma na kuelewa taarifa hizi. Nimepewa maelezo za kutosha kuhusu hali, muda wa utafiti na madhara yoyote yanayoweza kutokea. Kwa kuongeza, nimepata muda wa kutosha kuchunguza maelezo haya na kuuliza maswali, ambayo nimepata majibu yenye kuridhisha. Ninakubali kwa hiari yangu kuwa mtoto wangu ashiriki katika utafiti huu na kukubaliana kushirikiana na shughuli zilizoombatana na utafiti huu, ikiwa ni pamoja na kutoa sampuli ya damu, kushiriki katika vipimo na kujibu maswali.

NDIYO ☐ HAPANA ☐ (LAZIMA)

Kwa nyongeza nakubali kwa kibali changu, kibali cha mdomo cha mtoto wangu kitaombwa kabla ya kushiriki katika utafiti huu.

Ukiri wa mdomo wa mtoto: NDIO ☐ HAPANA ☐ (LAZIMA)

Jina la mtoto :	Tarehe ya kuzaliwa mtoto:
Jina la Mzazi/Mlezi:	Sahihi ya Mzazi/Mlezzi:
Jina la mtafiti:	Sahihi ya Mtafiti:
Mahali:	Tarehe:

SEHEMU C: Watu wa Kuwasiliana nao ikiwa una maswali zaidi kuhusu ushiriki wako katika utafiti huu

Ikiwa una maswali yoyote kuhusu ushiriki wako katika utafiti huu au unafikiri umeumizwa kwa kushiriki kwako katika utafiti huu au kwa matokeo ya utafiti huu unaweza kuwasiliana na wafuatao

Kamati ya Maadili ya Utafiti ya Taifa 3 Barack Obama Drive, S.L.P 9653, 11101 Dar es Salaam, Tanzania Simu: + 255-22-2121400, Faksi: + 255-22-2121360, Barua pepe; Hq@nimr.or.tz | Info@nimr.or.tz

AU

Mr. Vedasto John Bandi (Mwanafunzi wa shahada ya uzamivu), Chuo kikuu cha Nelson Mandela. S.L.P 447, Tengeru Arusha Tanzania. Simu ya mkononi +255754742751, Barua pepe bandiv@nm-aist.ac.tz.

SEHEMU YA B3: fomu ya ridhaa

Ridhaa ya mmiliki wa nguruwe:

Ninathibitisha kuwa nimeezwa juu ya utafiti na kwamba nimepata nakala ya karatasi ya ridhaa ya mmiliki wa nguruwe na maelezo kuhusu utafiti huu. Nimesoma na kuelewa habari za utafiti huu. Nimepewa taarifa za kutosha kuhusu muda wa utafiti na madhara yoyote yanayoweza kutokea. Kwa kuongeza, nimepata muda wa kutosha kuchunguza taarifa za utafiti huu na kuuliza maswali, ambayo nimepata majibu yenye kuridhisha. Ninafahamu kwamba taarifa zitakazopatikana zitasaidia kuongeza udhibiti wa minyoo tegu/fini katika jamii yetu..

Mimi..... kwa hiari yangu naridhia nguruwe wangu wachunguzwe katika utafiti huu.

Ndio ☐ Hapana ☐ (LAZIMA)

Jina la mmiliki wa nguruwe:	Sahihi au dole gumba la mmiliki:
Jina la shahidi:	Sahihi ya shahidi kama (hajui kusoma na kuandika):
Jina la matafiti:	Sahihi ya mtafiti:
Mahali:	Tarehe:

Appendix 3: Questionnaire

Data collection form English version

Head of Household data collection form 01

INTRODUCTION

Thank you for agreeing to participate. In this survey, I will ask you questions about you and your household, knowledge on the parasite, a tapeworm. The questions in this survey usually take less than 30 minutes. All of the answers you give will be confidential and will not be shared with anyone other than members of our research team that will analyze the information collected from all households together. You don't have to be in the survey, but we hope you will agree to answer all the questions since your views are important.

Name of interviewer: ……

Date: ……

1	Location	Cluster no	
		Ward	
		Village	
		Household no	
		GPS	
2	Are you the head of the household?		Yes
			No
	If No, can I speak with the head of the household?		Yes
			Not Available
	If not available, could you / somebody over 18 years speak on his/her behalf?		Yes
			No
3	If NOT head of household: What is your relation to the head of the household?	Father	
		Mother	
		Uncle	
		Grandparent	
		Others, specify …….	
4	How many years have your family lived in this particular household?		
5	How many people live in this house for about a week to three months?		
6	Can you tell the number of a household head or your phone number?		Yes
			No

		DK	
7	If yes, What is the phone number?		
8	Have you heard of taeniosis/neurocysticercosis?	Yes	
		No	
		DK	
9	What are the symptoms of taeniosis/neurocysticercosis?	Abdominal discomfort	
		Loss of appetite	
		nausea	
		Epilepsy	
		Chronic headaches	
		Dizziness	
		Visual disorders	
10	What causes taeniosis/neurocysticercosis?	Eating infected pork meat	
		Drinking unboiled water	
		Eating without washing hands	
		Others, Specify ……	
11	What can you do to prevent taeniosis/neurocysticercosis?	Eating properly cooked pork meat	
		Eating inspected pork meat	
		Drinking boiled water	
		Keeping pigs indoor(cage)	
		Others specify	
12	Have you heard any intervention using drugs to control worms in this community?	Yes	
		No	
		DK	
13	Where have you heard of this mass drug administration for controlling worms?	Radio	
		Announcement of village leaders	
		once they came to give me drugs	
		others, Specify ……..	
14	Have you ever swallowed tablets for the	Yes	

	prevention and treatment of worms/tapeworms during Mass drug administration campaigns?	No
		DK
15	How many times have you taken the drug during such a campaign?	
16	When was your last time to take the drug during the mentioned drug campaign? (Mention month and year).	
17	Why are you not taking these drugs?	Never heard of it
		No one came to give me
		I am not sick
		I got problems when I swallowed
		Others, Specify …….

Observations on households risk factors

18	Observations on households risk factors	Water source	Tap water	
			River	
			Pond	
		Toilet/pit latrines present	Yes	
			No	
		If present, used	Yes	
			No	
		Criteria for use of toilets	Presence of clear route	
			Recent water	
			Fresh stool	
		Pig keeping	Yes	
			No	
		If Yes, Pig caged	Yes	
			No	

Participants data collection form 02

INTRODUCTION

In this survey, I will ask you questions about you, knowledge on parasite, tapeworm. The questions in this survey usually take less than 30 minutes. All of the answers you give will

be confidential and will not be shared with anyone other than members of our research team that will analyze the information collected from all households together.

Name of interviewer: ……

Date: ……

1	Location	Cluster no		
		Ward		
		Village		
		Household no		
		GPS		
		Date		
2	Participant information	ID number		
		Phone if any		
		Name		
		Age		
		Sex	Male	
			Female	
		Occupation	Student	
			Agriculture	
			Business	
			Civil servant	
3	Knowledge about taeniosis/cysticercosis	Can pork contain worms that can infect you?	yes	
			No	
			Don't know	
		Do you know that human infected with an adult worm (Tapeworm) usually releases eggs/worms in feces?	Yes	
			No	
4	Previous year Albendazole treatment/ Coverage of MDA	Did you take worm drugs (albendazole) a sweet chewable drug like this last year?	Yes	
			No	
			Don't know	
		How many times have you taken the drug under Mass drug administration?	Never	
			Once	
			Twice	
			Three times	
			Many times	
5	Why are you not often (if more than twice) taking these drugs?		Never heard of it	
			No one came to give me	
			I am not sick I got problems when I swallowed	

			Others, Specify …….
6	Can you provide us with a blood sample for diagnosing the worm?	Yes	
		No	
		If the sample is taken sample number	

Data collection form 03 for pigs

INTRODUCTION

In this survey, I will diagnose your pigs on parasite, tapeworm. In your pig farm maximum of five pigs of a different age will be diagnosed. The results will be confidential and will not be shared with anyone other than members of our research team that will analyze the information collected from all pig farms together.

Name of interviewer: ……

Date: ……

1	Location	Cluster no		
		Ward		
		Village		
		Household no		
		GPS		
		The phone of the head of household		
		Age of pig(months)		
		Sex	Male	
			Female	
2	Pig keeping style	Free rearing		
		caged		
		mixed		
3	Cysticercosis test/lingual examination results	Yes		
		No		

Patients Data collection form 04

INTRODUCTION

In this survey, I will ask you to provide information of patients with convulsive disorders presented to your facility for CT scan diagnosis for the years 2019, 2020, 2021 and 2022. The information required is the confirmed diagnoses was neurocysticercosis or other causes and specify those other causes of mental disorder.

Name of research assistant: ……

Date: ……

1	Location	Facility		
		Region		
		District		
		Patient no		
		From (District/ward/village)		
		Phone if any		
		Age		
		Sex	Male	
			Female	
		Date diagnosed	Day	
			Month	
			Year	
3	CT scan results on neurocysticercosis	Yes		
		No		
		If no, specify other cause of the neural disorder		

Data collection form 05

INTRODUCTION

In this survey, I will ask you to provide information on Mass drug administration coverage targeting worms for the previous years to present. The information is important for assessing the impact of this intervention.

Name of researcher: ……

Date: ……

Mass drug administration coverage (Albendazole)

Year	Population	Eligible	Received
2019			
2018			
2017			
2010			
2009			

Swahili version of data collection form

Form 01 ya taharifa za kaya

Utangulizi

Katika utafiti huu tutakuuliza maswali kuhusu nyumba yako, na uelewa kuhusu mnyoo tegu. Maswali katika utafiti huu hayatozidi dakika thelathini. Majibu yako yatakuwa siri hatoshirikishwa yeyote nje ya kundi letu tutakaochambua na kupambanua taharifa kutoka kila kaya kwa pamoja. Haulazimiki kuwa mshiriki, lakini majibu yako ni muhimu sana kwa utafiti wetu.

Jina la mtafiti: ……

Tarehe: ……

1	Mahali	Kundi no	
		Kata	
		Kijiji	
		Nyumba nambari	
		GPS	
2	Wewe nimkuu wa kaya? Au ,naweza ongea na mkuu wa kaya? Kama hayupo, unaweza jibu maswali kwa niaba yake? Au, kuna yeyote mkubwa wa umri wa miaka kumi na nane au Zaidi niongee naye?		
3	Unahusianaje na mkuu wa kaya?	Baba	
		Mama	
		Mjomba	
		vinginevyo, ainisha	
4	Familia yenu imeishi hapa kwa miaka mingapi?		
5	Ni watu wangapi huishi katika familia hii muda wote?		
6	Unaweza nitajia namba yako ya simu?		
7	Namba yakoya simu ni namba ngapi?		
8	Umewahi sikia kuhusu mnyoo tegu?		
9	Dalili za kuwa na mnyoo tegu ni zipi?		
10	Nini hasa husababisha kupatwa na mnyoo tegu?		
11	Unawezaje kujikinga na mnyoo tegu?		
12	Umewahi kusikia mkakati wa kuzuia minyoo kwa kutumia dawa katika kijiji?		
13	Umesikia wapi mkakati wa kugawa dawa kwa jamii nzima?		
14	Umewahi kunywa dawa ya kuzuia na kutibu minyoo katika?		
15	Ni mara ngapi umekula dawa hizo katika		

	kampeni?	
16	Mara ya mwisho ulikunywa lini? (taja mwezi na mwaka	Mwezi
		Mwaka
17	Kwa nini huwa hunywi hizi dawa?	

Washiriki katika utafiti form 02

Utangulizi

Katika utafiti huu nitakuuliza maswali kuhusu, uelewa wa mnyoo tegu. Maswali hayatozidi nusu saa. Majibu yako yote yatakuwa siri na hatopewa mtu yeyote nje ya kundi letu watafiti tutakao tafsiri taharifa kutoka katika familia zote kwa pamoja.

Jina la mtafiti: ……

Tarehe: ……

1	Mahali	Kundi nambari		
		kata		
		kijiji		
		Nyumba nambari		
		GPS		
2	Taharifa za mshiriki	nambari ya mshiriki		
		Jina		
		Nambari ya simu		
		umri		
		Jinsia	kiume	
			kike	
		Kazi	mwanafunzi	
			mkulima	
			mfanyabiashara	
			Mtumishi wa umma	
3	Uelewa kuhusu mnyoo tegu	Nyama ya nguruwe inaweza kuwa na mnyoo unaoweza kukupata?	ndiyo	
			hapana	
		Unajua kuwa mtu mwenye mnyoo tegu hutoa mayai na mnyoo katika kinyesi?	Ndiyo	
			Hapana	
4	Ushiriki katika awamu za ugawaji dawa za minyoo	Ulikunywa dawa ya minyoo (albendazole) ya kutafuna tamu tamu?	Ndiyo	
			Hapana	
		Ni mara ngapi umekunywa dawa katika kampeni za dawa ya minyoo?	Sijawahi kabisa	
			Mara moja	
			Mara mbili	
			Mara tatu	
			Mara nyingi	
5	Kwa nini huwa hunywi hizi dawa?			

6	Unaweza tupatia damu kwa ajili ya kuchunguza huyo mnyoo?	Ndiyo	
		hapana	
		Nambari ya sampuli	

Appendix 4: Research ethical clearance certificates

TANZANIA MEDICINES AND MEDICAL DEVICES AUTHORITY

Tel: +255 26 2961989, 2961990
+255 22 2450512/2450751/2450959
Toll free: 0800 110 084
Email: info@tmda.go.tz
Website: www.tmda.go.tz
All letters should be addressed to the Director General
In reply please quote our Ref No:

TMDA
Tanzania Medicines & Medical Devices Authority

TMDA- Head Office
P668F House, 10th Floor,
Makole Road,
P.O. Box 1253,
Dodoma, Tanzania

Ref. No.TMDA0019/CTR/0017/02 20th March, 2020

Vedasto John Bandi,
Principal Investigator,
The Nelson Mandela African Institute of Science and Technology,
P. O. Box 447,
ARUSHA.

RE: APPROVAL TO CONDUCT A STUDY ENTITLED "THE IMPACT OF INCREASING ALBENDAZOLE REGIMEN ON ELIMINATION OF TAENIA SOLIUM CYSTICERCOSIS IN HUMAN AND PORCINE IN MBULU DISTRICT, MANYARA REGION, TANZANIA".

1. Approval is hereby granted for you to conduct the above study.
2. The approved study site is **Mbulu District** in Manyara Region.
3. The approval is subject to the following conditions;
   a. Complying with all provisions of the Tanzania Medicines and Medical Devices Authority Act, Cap 219 and Tanzania Medicines and Medical Devices (Clinical Trials Control) Regulations, 2013.
   b. Complying with the approved Protocol No. **KNCHREC OO19, of 12th July, 2019.**
   c. If for any reason the trial is prematurely terminated or suspended, a detailed written explanation must be submitted to TMDA not later than 15 days after the date of the discontinuance.
   d. The Authority may withdraw the approval already given if it is dissatisfied with the conduct of the study or there are breaches of any conditions prescribed in this letter.
   e. Six monthly progress and final reports should be submitted to TMDA, including interim analyses done by the Data Safety Monitoring Board (DSMB) or related Committee. The progress reports should be submitted within three weeks after the end of the period being reported and the final report within 60 days of conclusion of the trial.
   f. All relevant information, documents and records pertaining to the trial should be retained at the clinical trial site for a period of not less than 20 years after completion of a trial and made available upon request by TMDA.

g. Any amendment of the protocol, product or Investigators Brochure should be reported to TMDA and approval obtained before its implementation.

h. All serious adverse events should be reported in writing within 14 days and for fatal ones within 24 hours of their occurrence in any of the study sites.

i. Permits for Importation of Investigational Medicinal Product(s) should be obtained before importation. The product(s) should be inspected and approved at the port of entry.

j. The approved study should be registered in the National Registry for Clinical Trial available online at www.tnctr.or.tz.

k. Copies of publication(s) of any part of the study should be submitted.

4. The validity of this permit expires on **19th March, 2021.**

5. Looking forward to your continued cooperation.

Akida M. Khea.
ACTING DIRECTOR GENERAL

AMK/ab/sjh/ou

THE UNITED REPUBLIC OF TANZANIA

National Institute for Medical Research
3 Barack Obama Drive
P.O. Box 9653
11101 Dar es Salaam
Tel: 255 22 2121400
Fax: 255 22 2121360
E-mail: nimrethics@gmail.com

Ministry of Health, Community
Development, Gender, Elderly & Children
University of Dodoma, College of
Business Studies and Law
Building No. 11
P.O. Box 743
40478 Dodoma

NIMR/HQ/R.8a/Vol. IX/3301

16th December 2019

Mr Vedasto John Bandi
The Nelson Mandela African Institution
of Science and Technology (NM-AIST)
School of Life Science and Bioengineering
Global health and biomedical sciences)
P.O. Box 447
Arusha
Tanzania

RE: ETHICAL CLEARANCE CERTIFICATE FOR CONDUCTING MEDICAL RESEARCH IN TANZANIA

This is to certify that the research entitled: "The impact of increasing albendazole regimen on elimination of *Taenia solium cysticercosis* in human and porcine in Mbulu district, Tanzania." (Bandi VJ. et al), has been granted ethical clearance to be conducted in Tanzania.

The Principal Investigator of the study must ensure that the following conditions are fulfilled:

1. Progress report is submitted to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research, Regional and District Medical Officers after every six months.
2. Permission to publish the results is obtained from National Institute for Medical Research.
3. Copies of final publications are made available to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research.
4. Any researcher, who contravenes or fails to comply with these conditions, shall be guilty of an offence and shall be liable on conviction to a fine as per NIMR Act No. 23 of 1979, PART III Section 10(2).
5. Sites: Manyara region.

Approval is valid for one year: 16th December 2019 to 15th December 2020.

Name: Prof. Yunus Daud Mgaya

Signature
CHAIRPERSON
MEDICAL RESEARCH
COORDINATING COMMITTEE

Name: Prof. Muhammad Bakari Kambi

Signature
CHIEF MEDICAL OFFICER
MINISTRY OF HEALTH, COMMUNITY DEVELOPMENT, GENDER, ELDERLY & CHILDREN

CC: Director, Health Services-TAMISEMI, Dodoma
RMO of Manyara region.
DMO/DED of Mbulu district.

Kibong'oto Infectious Diseases Hospital- Nelson Mandela African Institution of Science and Technology- Centre for Educational Development in Health, Arusha (KIDH-NM-AIST-CEDHA) -KNCHREC

RESEARCH ETHICAL CLEARANCE CERTIFICATE

Research Proposal No: KNCHREC0019 **12th July 2019**

Study Title: The Impact Increasing Albendazole Regimen on Elimination of TaeniaSolium Cysticercosis in Human and Porcine in Mbulu District Tanzania

Study Area: MBULU DISTRICT

PI Name: VEDASTUS JOHN BANDI

Co-Investigator:

Institutions: **NM-AIST** School of Life Science and Bio-Engineering (LiSBE) of the Nelson Mandela African Institution of Science and Technology

The Proposal has been approved by KNCHREC on 14th March 2019

1. Subject to this approval you will be required to Register your Protocol with the TFDA upon NIMR receiving NIMR Certificate
2. Subject to this approval you will be required to submit your progress report to the KNCHREC, National Institute for Medical Research, TFDA, and Ministry of Health Community Development Gender Elderly and Children
3. Publication of your findings is subject to presentation to the KNCREC and NIMR Approval.
4. Copies of final publication should be made available to KNCHREC, National Institute of Research and Ministry of Health Community Development Gender Elderly and Children and TFDA

Duration of Study Renewal: Subject to Renewal within ONE YEAR

Span From: 12th July 2019 to 11TH July 2020.

.....

Mr. Simon Njeya
Secretary
KNCHREC

Chairperson
KNCHREC

:

RESEARCH OUTPUTS

(i) Publications

Bandi, V., Ngowi, B., Mpolya, E., Kilale, A. M., & Vianney, J. M. (2024). Prevalence and Risk Factors of *Human Taenia solium Cysticercosis* in Mbulu District, Northern Tanzania. *Zoonotic Diseases*, *4*(2), 135-145.

Bandi, V., Ngowi, B., Mpolya, E., Kilale, A. M., & Vianney, J. M. (2024). Prevalence of *Taenia solium cysticercosis* in domestic pigs following albendazole deworming intervention in rural communities of Mbulu district, Tanzania. *Food and Waterborne Parasitology*, *36*, e00234.

(ii) Poster presentation