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Seroprevalence of circulating taeniid antigens in pigs and associated risk factors in Kongwa district, Tanzania

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ABSTRACT

The aim of this study was to investigate exposure to porcine cysticercosis (PC) and associated risk factors in the Kongwa District, eastern-central Tanzania. For the first time a cross-sectional investigation of the seroprevalence in pigs using a commercial genus specific cysticercosis enzyme linked immunosorbent assay (apDia Ag-ELISA) was undertaken in eastern-central Tanzania. Moreover, the identity of suspected *T. solium* cysts from pigs in the study area were confirmed by sequencing parasites' mitochondrial *cox1* gene. Structured questionnaires and direct observations were used to investigate risk factors associated with parasite transmission. A total of 102 pig-keeping households were surveyed during the dry season between July and August 2017 and 126 households in the rainy season between March and April 2018. Of the 447 examined pigs, 77 (17%, 95% C.I. 14%–20%) tested positive in the ELISA. Seroprevalence was higher in pigs examined during the rainy (21%, 95% C.I. 16%–26%) than dry (12%, 95% C.I. 7%–17%) season ($p = 0.019$). Eight cyst-positive-pigs were confirmed to be infected with *T. solium* by sequencing. Risk factors associated with PC seropositivity included origin of piglets or pigs (OR = 0.27, 95% C.I. 0.13–0.42, $p = 0.001$), socioeconomic factors and pig production system (OR = 0.22, 95% C.I. 0.07–0.37, $p = 0.005$) and sanitation and hygiene practices (OR = 0.19, 95% C.I. 0.04–0.34, $p = 0.014$). This study has recorded a high *Taenia* spp. seroprevalence in pigs in Kongwa suggesting the presence of people in the community carrying the adult parasite, *Taenia solium*. Our findings also suggest risk of infection by *T. solium* to people in urban centres and cities consuming pigs from rural areas in Kongwa. The high seroprevalence in Kongwa calls for further studies on taeniasis and cysticercosis in the human population in order to determine suitable control strategies.

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1. Introduction

Pig production has tremendously increased in the past few years in many rural areas in countries in the East African Community (FAO, 2012; Maziku et al., 2017). The increase in pig production has been due to low cost of investment, high rate of pig growth, high demand for pork in both rural and urban areas as well as quick economic returns (Phiri et al., 2003; Ngowi et al., 2004a). Consequently, realization of benefits from pig production in rural communities has been increasing and the sector potentially contributes to food security, improved nutrition and increased incomes (Maziku et al., 2017). However, one of the problems facing the piggery industry in many resource poor countries including Tanzania, is the existence of parasitic zoonoses including the pork tapeworm, *Taenia solium*. Infection by *T. solium* in pigs is commonly known as porcine cysticercosis (PC) while human harbours the adult form of the parasite, a condition referred to as taeniasis. However, human can also be infected by the larval form of the parasite resulting into human cysticercosis (HC). Infection of the larval form of the parasite in both pigs and human results into significant veterinary, public health and economic concerns (Trevisan et al., 2017). There is reduced market value and condemnation of infected pork carcasses or omission of infected carcasses from the food chain (Praet et al., 2009). The public health and socioeconomic costs due to *T. solium* cysticercosis in endemic areas is also a notable concern (Trevisan et al., 2017).

Both pigs and humans contract cysticercosis by ingestion of eggs shed in faeces of a *T. solium* human carrier (Johansen et al., 2014). Humans acquire cysticercosis by either autoinfection or ingestion of water or food contaminated with eggs from faeces of a *T. solium* carrier. Cysticercosis in human becomes more serious when the manifestation involves the central nervous system (CNS), neurocysticercosis (NCC). NCC is the predominant helminthic infection of the human CNS and the major cause of acquired epilepsy in endemic regions (Mwang'onde et al., 2012; Mwape et al., 2015; Mwanjali et al., 2013; WHO, 2007; Assana et al., 2013). The annual number of NCC associated epilepsy incident cases and deaths in Tanzania is estimated at 17,853 (95% Uncertainty Interval (UI), 5666-36,227) and 212 (95% UI, 37-612) (Trevisan et al., 2017), respectively. For the year 2012, disability adjusted life years (DALYs) per thousand person-years for NCC-associated epilepsy was 0.7 (95% UI, 0.2−1.6) (*Ibid.*). Trevisan and colleagues also reported that around 5 million USD (95% UI, 797,535−16,933,477) were spent due to NCC-associated epilepsy and nearly 3 million USD (95% UI, 1,095,960−5,366,038) were potentially lost due to PC. Most farmers in endemic areas know about cysts in pigs, but few are aware of how it is related to taeniasis and HC. Therefore, The ever-continued persistence of PC poses great public health and veterinary concerns in terms of healthy years and socioeconomics.

Many poor rural communities in developing countries have perceived increased pig production in recent years. These communities resort to traditional practices of pig farming which facilitate the prevalence and persistence of the *T. solium* transmission cycle as they are strongly associated with poor hygiene and sanitation. This is evidenced by not only the increasing number of PC reports worldwide but also increasing levels of reported PC prevalence in endemic communities. For instance, in sub-Saharan Africa, PC prevalence is reported to range between 0.12% to over 50% (NBS, 2016; Ngowi et al., 2010; Shonyela et al., 2017). PC has been reported from many rural areas in Tanzania especially from the northern and southern highlands where more than 50% and less than 10% of the pigs are raised, respectively. Free-range pig husbandry system is pronounced in those areas (WHO, 2007; Boa et al., 2006) with as high as 33% seroprevalence of PC (NBS, 2012; Mkonda and Xinhua, 2017; NBS, 2014). Similarly, in those areas, the seroprevalence of HC is as high as 16% with about 76% of the seropositive to HCC revealing lesions suggestive to NCC under imaging diagnostic tools such as CT scan (Mwang'onde et al., 2018). There is also anecdotal reports of PC in the central part of the country (Dodoma and Singida regions), where about 15% of the pigs in Tanzania are raised (NBS, 2016). However, data on PC in the area is missing. This information is important in understanding the epidemiology of PC, which is vital for designing strategies for control and prevention. Herein, we report on the seroprevalence of porcine cysticercosis in Kongwa district and potential risk factors behind its persistence and thereby provide information that is useful in curtailing future cases in Tanzania and elsewhere in endemic regions.

2. Material and methods

2.1. Study area

This study was conducted in Kongwa district (Fig. 1). Kongwa is one among the seven districts constituting Dodoma region, the capital of Tanzania, located in the eastern-central part of the country. It is bordered by Mpwapwa district to the south, Chamwino to the west, Manyara region to the north and Morogoro region to the east. Kongwa is primarily semi-arid and covers an area of 4041 square kilometers (NBS, 2012). It is located between latitudes 5°30′ & 6°0′ south of the equator and longitudes 36°15′ & 36°0′ east of Greenwich meridian with an altitude ranging between 900 and 1000 m above sea level. The total annual rainfall ranges between 400 and 800 mm and mean annual rainfall is around 500 mm (Mkonda and Xinhua, 2017).

In 2012 the population of Kongwa was 309,973 people with an average of 4.9 persons per household and it was projected to reach 343,975 people in 2017 (NBS, 2014). Ninety-two percent of the households (61,907) are involved in various forms of agriculture of which 38% are involved in the production of livestock such as cattle, goats, sheep, pigs and poultry (NBS, 2012). Kongwa with an average of four pigs per household, has the largest number of pigs (56,498 pigs, 48%) compared to other districts in Dodoma region such as Mpwapwa (37,015 pigs, 32%), Dodoma urban (10,373 pigs, 10%) and Chamwino (10,024 pigs, 10%) (NBS, 2012). Kongwa was of interest because it is among the major pig suppliers to towns and cities such as

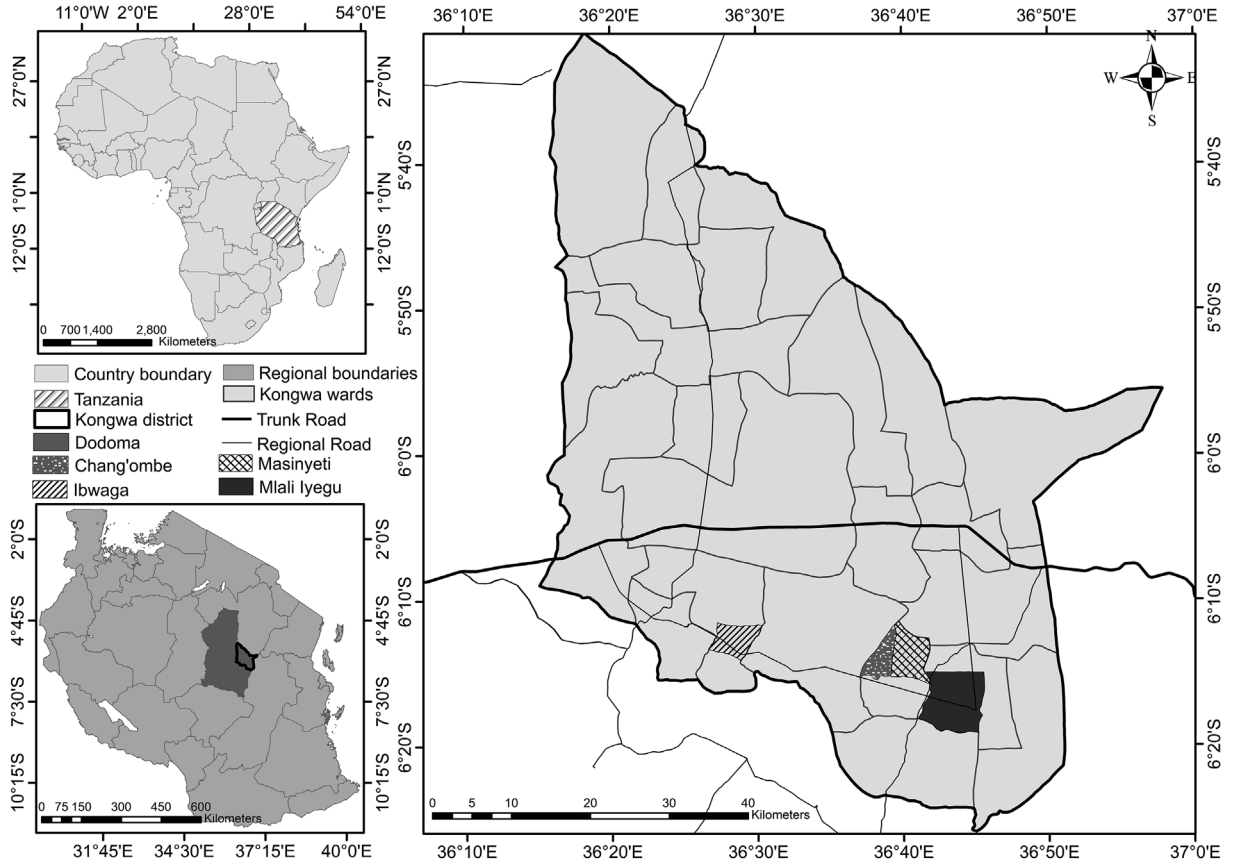

Fig. 1. Map of Kongwa district showing the study villages.

Dodoma, Morogoro and Dar es Salaam. We investigated pigs from different households in four villages in Kongwa: Chang'ombe, Ibwaga, Masinyeti and Mlali Iyegu (Fig. 1) during the dry season, July to August 2017 and rainy season, March to April 2018.

2.2. Study design and sample size estimation

Two cross-sectional surveys were conducted to assess the seroprevalence of circulating antigens of *Taenia* spp. in Kongwa. The first survey was conducted during the dry season between July and August 2017, while the second survey was conducted during the rainy season between March and April 2018. Villages were selected based on available anecdotal PC reports. Briefly, names of eight villages were written on small pieces of paper, folded and mixed thoroughly. Then, only four pieces of paper with names of villages to be surveyed were picked one after the other. Twenty five (25) pig-keeping households were similarly randomly selected for study from 35 households per selected village. Pregnant and suckling sows and two-months-old piglets from each village were excluded from this study.

Sample size was estimated using the equation $n = Z^2PQ/L^2$ (Thrusfield, 2002); where n is the number of pigs included in this study, P is an estimated seroprevalence in Kongwa (10%) based on data from nearby regions (Ngowi et al., 2010), (Maganira et al., 2018), Z is the score of the desired confidence interval (95%), $Q = 1 - P$ and L is the desired precision (5%). Therefore, the minimum samples size of pigs in this study was 138; however, by including several pigs from the same household a clustering effect may be expected. Structured questionnaire and observation were used to collect information for persistence of PC infection in the study villages.

2.3. Blood samples collection

We collected blood from one to a maximum of 6 randomly selected pigs from each household. Out of the 447 sampled pigs, 12 came from two households each with over 6 pigs owned by different household's members and indeed kept in different separate pens. The maximum number of pigs sampled from the rest of the households was three. The sampling focus was to pigs aged three months and above. During blood sampling, pigs were restrained using a hog catcher and the ear was cleaned

with 70% alcohol. A 23-gauge needle was used to draw blood from the auricular vein of the pigs following strict venepuncture procedures. Sterile gauze was used to stop bleeding from the blood sampling site for approximately 2 min. About 4 ml of auricular venous blood was collected. Collected blood was then stored in 5 ml vacutainer tubes at 4 °C in a cooler box. Serum samples were recovered by centrifuging the collected blood within 6–8 h after collection at 2000xg for 10 min and then stored in 1.8 ml cryogenic vials at - 20 °C until further analysis. Serum recovered from blood samples of pigs were grouped in different age groups (piglets: 3-5 months, adults: 6 months and above).

2.4. Cysticercosis antigen ELISA test

The seropositivity of *Taenia* spp. antigens in serum was measured using a commercially available cysticercosis enzyme-linked immune-sorbent assay (Cysticercosis antigen ELISA, apDia, Belgium). The assay can determine down to one viable cysticercus but does not differentiate between different species (such as *T. solium, T. hydatigena, T. asiatica*) in porcine serum samples (Akoko et al., 2019), (Deckers and Dorny, 2010). The apDia cysticercosis Antigen ELISA was used following manufacturer's protocol. The optical density (OD) of the controls and samples were determined at 450 nm within 15 min after stopping the reaction by adding 50 µl of 0.5 M H_2SO_4 solution. The mean OD of the negative controls was used to calculate the cut-off by multiplying its value by 3.5 (Cut-off value = mean ODneg x 3.5). The antigen index (Ag Index) of each sample was calculated by dividing the OD value of the sample by the cut-off value (Ag Index = mean ODsample/Cut-off value). A sample with an Ag Index below or equal to 0.8 was considered negative reaction whereas a sample with an Ag Index above or equal to 1.3 was considered a positive reaction. Samples reactions with an Ag Index between 0.8 and 1.3 were considered as doubtful and were retested.

2.5. Molecular studies for cyst positive pigs

Suspected viable *T. solium* cysts were collected at slaughter by a member of the research team, the first author, from eight pigs (two pigs from each surveyed village) found during meat inspection in the dry season between July and August 2017. Cysts were removed from infected pigs and stored in absolute ethanol. Cysts from infected pigs were found in the neck, hind legs, fore legs, diaphragm, heart and brain. Total DNA was extracted from cysts with QIAamp DNA Mini Kit (Qiagen, Hilden, Germany) according to the manufacturer's protocol. Quality of the DNA was assessed by running extracted DNA on 1% Agarose gel. Parasite species were then identified after sequencing using JB3/JB4.5 forward (F) and reverse universal primers (R) (Bio-Rad Laboratories). JB3 and JB4.5 primers were 5′-TTTTTTGGGCATCCTGAGGTTTAT-3′ and 5' −TAAAGAAAGAACATAATGAAAATG-3' (Eurofins Genomics) respectively (Bowles and McManus, 1994), (Bowles et al., 1992). Conventional PCR was run in a Kallur thermal cycler (Applied Biosystems) and then the mitochondrial cytochrome c oxidase I (*cox1*) gene was sequenced. The PCR reactions were performed in a total volume of 25 µl containing 3 µl template DNA, 0.5 µM of each primer, 2.5 µl 10× PCR buffer, 2 µl MgCl2, 0.65 µl dNTPs, 15.7 µl H2O and 0.13 µl AmpliTaq Gold DNA polymerase. The following PCR protocol was used: 95 °C for 10 min followed by a set of 40 cycles, 95 °C for 30 s, 50 °C for 30 s and 72 °C for 1 min and final elongation at 72 °C for 5 min. *T. solium* positive control and negative control (no template control) were also included. The amplified PCR product, 5 µl, was then subjected to 1% agarose gel electrophoresis. Positive samples were purified using Illustra ExoProStar 1-step and sent to Macrogen (Amsterdam, Netherlands) for sequencing. The obtained sequences were edited and trimmed using CodonCode Aligner version 7.1.2 (https://www.codoncode.com/aligner/) and then blasted in GenBank to determine the species identity.

2.6. Household questionnaire

A structured questionnaire was administered to the head or one of the family members in each household from which pig blood samples were collected. Information related to pig production system, awareness of PC, socio-cultural settings, hygiene and sanitary conditions were collected.

2.7. Ethical considerations

Ethical clearance permit to conduct this study was obtained from the University of Dar es Salaam on behalf of the Tanzania Commission for Science and Technology (COSTECH) as well as from district and village authorities in Kongwa. Heads of pig keeping households surveyed also gave informed oral consent to participate in this study.

2.8. Data analysis

Statistical data analyses were performed in R version 3.4.3 (Windows) (R. Core Team, 2017) and or SPSS version 24 software. The seroprevalence was computed using descriptive statistics. The Chi-Square test of independence was used to compare differences between seasons, villages and pig age groups. The associations between risk factors for Ag ELISA results were also assessed using the Chi-Square statistic while strengths of associations were determined using the odds ratio. Risk factors with $p < 0.05$ were considered significant. The forward step-wise binary logistic regression model was used to compute predictors of PC transmission (Mwanjali et al., 2013, Shonyela et al., 2017, Kavishe et al., 2017).

3. Results

3.1. Characteristics of studied subjects

In total 447 pigs from four villages in Kongwa were surveyed in two seasons. The mean age of the pigs was 8 months. The majority of the pigs (n = 416, 93%) were between 3 and 12 months old. Approximately 30% (n = 54) and 1% (n = 2) of pigs surveyed in the dry season were less or equal to 6 months and greater or equal to 12 months old, respectively, with maximum age of 14 months. On the other hand, about 54% (n = 146) and 11% (n = 29) of the pigs surveyed in the rainy season were less or equal to 6 months and greater or equal to 12 months old, respectively, with maximum age of 36 months. There was no significant age difference between sexes of pigs studied ($\chi^2 = 2.15$, $p = 0.143$). Female pigs were 53% (n = 239) and male pigs were 47% (n = 208). More pigs were surveyed during the rainy period (n = 269, 60%) compared to in the dry season (n = 178, 40%) ($\chi^2 = 18.53$, $p < 0.001$).

One hundred and two questionnaires were used to collect information on risk factors associated with PC transmission from households in the four villages. The questionnaires were administered during the dry season only. Out of 102 respondents, 57 (56%) were females while 45 (44%) were males. Respondents were between 17 and 89 years old with mean age of 40 ± 13. The majority of the respondents (75%) had attained a primary school education while only a few had either informal education (19%) or ordinary level secondary school education (6%).

3.2. Seroprevalence in examined pigs

Of the 447 serum samples from the surveyed pigs, 370 (83%, 95% C.I. 80%–86%) tested negative while 77 (17%, 95% C.I. 14%–20%) tested positive in the apDia cysticercosis antigen ELISA. The seropositivity was higher in the rainy season than dry season ($\chi^2 = 5.50$, $p = 0.019$) with individual village prevalence ranging between 13% to 32% and 8%–18%, respectively (Table 1).

3.3. Taenia spp in cyst positive pigs

Sequencing data showed that, 100% of DNA isolated from cyst belonged to *T. solium*. The similarity identity of their sequences ranged between 98.8% and 100%.

3.4. Risk factors associated with PC transmission in Kongwa

Risk factors associated with PC transmission were investigated through structured questionnaires in pig keeping households. Linear regression analysis showed that open defecation, pig source and nature of pig husbandry were important risk factors associated with PC transmission (Tables 2 and 3).

More than 50% of toilets in Kongwa district were made from annual crop remains and remained open as they lacked doors. There was also no single slaughterhouse in the study villages and therefore pigs were slaughtered at convenient places such as at home, local brew clubs and market places. Pigs were fed with maize and rice bran and other locally available feedstuffs such as legumes, potato and banana peels. Ruminants (sheep and goats) and canines (dogs) were commonly found in some of the surveyed households.

4. Discussion

This study investigated for the first time the seroprevalence of *Taenia* spp. in pigs and the potential risk factors associated with PC transmission in the Kongwa district in eastern-central Tanzania. Findings from the two cross-sectional studies carried out both during the dry and rainy seasons suggest that, there is high rate of exposure to cysticercosis in Kongwa, where 17% of the pigs were found seropositive. Although the findings from this study are comparable to studies from elsewhere in the world (Bowles et al., 1992; R. Core Team, 2017), the seroprevalence in this study is higher than that recently reported using the same diagnostic test in Ludewa district (10%) in the southern highlands (Maganira et al., 2018), but lower than that reported in Nyasa district (33%) in the southern highlands (Shonyela et al., 2017) and Babati (25%) in the northern highlands (Kavishe

Table 1
Cysticercosis seropositivity in pigs from four villages in Kongwa district.

	Dry season			Rainy season			Dry vs Rainy	
Village	#Pigs	% Prev	95% C.I.	#Pigs	% Prev	95% C.I.	# Pigs	% Prev
Chang'ombe	50	8	1–16	80	20	11–29	p = 0.009	p = 0.007
Ibwaga	28	14	1–27	55	15	6–24	p = 0.003	p = 0.248
Masinyeti	28	18	4–32	55	13	4–22	p = 0.003	p = 0.564
Mlali Iyegu	72	11	4–18	79	32	22–42	p = 0.569	p = 0.003
Total	178	**12**	7–17	269	**21**	16–26	p = 0.000	p = 0.019

Key: #Pigs = Number of examined pigs; % Prev = Percentage prevalence of seropositive pigs; C.I. = Confidence Interval.

Table 2
Risk factors associated with PC transmission in Kongwa district.

Factor	Level	#Pigs	%Prev	p-value
Sex	Male	93	14	0.402
	Female	85	9	
Age	Piglet	30	17	0.429
	Adult	148	11	
Latrine	Present	174	12	0.488
	Absent	4	0	
Open defecation	Yes	115	17	0.005
	No	63	2	
Pig source	On-farm	60	23	0.003
	Elsewhere	118	6	
Pig husbandry	Free-range	130	16	0.006
	Confined	48	0	

Key: %Prev = Percentage seroprevalence of positive pigs; Age = Piglets: 3-5 months, Adults: 6 months and above; Pig source = Elsewhere: within the village, outside the village.

et al., 2017) of Tanzania. These local differences suggest differences in exposure to *T. solium* eggs by human carriers in different districts in Tanzania. The confirmation of suspected *T. solium* cysts from pigs in Kongwa by sequencing of the *cox1* gene proves that PC is prevalent. The prevalence of the parasite is also supported by findings from a previous study in the district involving schoolchildren, in which *T. solium* proglottids were recovered from stool of a 14 year-old girl from Ijaka village (Eom et al., 2011). However, to what extent other taeniid worms bias the results needs to be clarified. Caution needs to be taken when interpreting seroprevalence results because of cross-reactivity and inability of the Ag-ELISA to differentiate different *Taenia* spp. (Akoko et al., 2019), (Dermauw et al., 2016). However, an experimental study (Dorny et al., 2017) indicated that exposure of piglets to eggs of a tapeworm species that does not cause natural infection in pigs such as *T. sagitana*, does not result in cross reactivity in the Ag-ELISA as reported by (Lightowlers et al., 2016). Nevertheless, the high PC seroprevalence in the study area calls for further studies on taeniasis also in the human population for informed control strategies of the parasite. Moreover, assessment of contamination levels of *T. solium* eggs in the environment remains to be important to better understand the role of soil in the transmission of porcine and HC in Kongwa.

Although, our expectation was to collect equal numbers of serum samples in the two seasons, the number of pigs sampled during the dry season was significantly lower due to an outbreak of the African Swine Fever (ASF), which occurred before this study commenced. The seasonal differences in the observed seroprevalence may also be attributed to the occurrence of the ASF in the study area, which decimated the pig population. Seasonal variation in the prevalence of PC could also be a result of different seasonal production systems. This is because during the rainy season most households confine their pigs at home feeding them with crops from their farms and other foodstuffs locally available, while in the dry season pigs are in general left to freely roam and scavenge around after crops have been harvested. Interestingly, we recorded a significantly higher seroprevalence in the rainy than in the dry season. We noted that during pig confinement in the rain season, potato, cassava and banana peels and other plant materials including legumes formed the greatest portion of pig feed. This type of pig feeding system may also have accounted for the high seroprevalence in this study. In addition, a previous study by (Braae et al., 2014) indicated that confinement of pigs as a sole intervention does not prevent PC. Significant age differences of the sampled pigs may also explain the seasonal differences in seroprevalence. Contrary to the pigs sampled in the dry season, the majority of the pigs in the rainy season were less than a year old. It has been reported that pigs can be infected with PC at a very young age (De Aluja et al., 1998) and can be detected by cysticercosis Ag-ELISA as early as two weeks after infection (Nguekam et al., 2003). However, the risk of PC still remain and has also been reported to increase with the age of the pigs (Mkonda and Xinhua, 2017; R. Core Team, 2017; Dermauw et al., 2016). In this study, most piglets were left to freely scavenging and this might have increased their chances of being exposed to infection.

The source or origin of pigs, free-range pig husbandry system and open defecation were identified in the study area as significant risk factors for cysticercosis. Free-range pig farming system together with the practice of open defecation give pigs unrestricted access to *T. solium* eggs originating from human carriers. Pigs may be infected by either ingestion of faeces and/or soil, feed-stuff and water contaminated with *T. solium* eggs (Mwang'onde et al., 2018; Braae et al., 2014). Other studies in

Table 3
Predictors of PC on Ag-ELISA results following linear regression.

Predictor	Level	Odds Ratio	95% C.I.	p-value
Pig source	On-farm	6.27	1.98–19.82	0.002
	Elsewhere	Ref.		
Pig husbandry	Free-range	2.62	0.63–10.19	0.185
	Confined	Ref.		
Open defecation	Yes	9.75	1.17–81.14	0.035
	No	Ref.		

Tanzania have reported free-range and open defecation as risk factors for PC (Ngowi et al., 2013; Mkonda and Xinhua, 2017; Nsadha et al., 2014; Dorny et al., 2017). Pig farming system has also been reported as an important risk factor for PC transmission elsewhere in the world (Khaing et al., 2015). In addition, the source or origin of piglets or pigs reared in village households is reported herein as another risk factor.

In this study, pigs with cysticercosis were exclusively found in households in which latrines were present. Similar observations have been reported in the Angónia district in Mozambique (Pondja et al., 2010). On the contrary, higher PC prevalence was reported in households without latrines in a study carried out in the Mbulu district in Tanzania (Ngowi et al., 2004b). As observed in the present study area, pigs had direct access to latrines because most of them were made of weak annual plant materials and lacked doors. In addition, the occurrence of indiscriminate defecation in the study area suggests poor latrine use that may have provided access to *T. solium* eggs from human with taeniasis. Lack of official slaughterhouses in the study area makes meat inspection difficult and some infected pigs may enter the food chain without inspection. The prevalence and persistence of risk factors for PC transmission in Kongwa as seen in this study mainly depends on a combination of low level of literacy and socio-cultural practices.

5. Conclusion

For the first time *T. solium* cysts and a high seropositivity to cysticercosis were recorded in pigs from the Kongwa region in eastern-central Tanzania. Combined, these results suggest that people in this region are contributing to environmental contamination by *T. solium* eggs. In order to plan for proper and efficient control strategies, further studies to ascertain the level of environmental contamination by *T. solium* egg carriers are vital. Important risk factors such as pig farming system and occurrence of open defecation, which we believe if appropriately intervened future PC infection may be abated. We recommend utilization of simple intervention strategies including public health education, pig confinement, proper meat inspection and proper use of latrines and other locally adapted strategies in the control of the parasite in the study area. Health education is important to minimize the risk of taeniasis and cysticercosis infection. The proposed control strategies should be strengthened by formulation of bylaws that can be locally be enforced.

Data availability

The data used to support the results of this study are available from the corresponding author upon request.

Declarations of interest

None.

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