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Study and Ranking of Determinants of *Taenia solium* Infections by Classification Tree Models

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Abstract. *Taenia solium* taeniasis/cysticercosis is an important public health problem occurring mainly in developing countries. This work aimed to study the determinants of human *T. solium* infections in the Eastern province of Zambia and rank them in order of importance. A household (HH)-level questionnaire was administered to 680 HHs from 53 villages in two rural districts and the taeniasis and cysticercosis status determined. A classification tree model (CART) was used to define the relative importance and interactions between different predictor variables in their effect on taeniasis and cysticercosis. The Katete study area had a significantly higher taeniasis and cysticercosis prevalence than the Petauke area. The CART analysis for Katete showed that the most important determinant for cysticercosis infections was the number of HH inhabitants (6 to 10) and for taeniasis was the number of HH inhabitants > 6. The most important determinant in Petauke for cysticercosis was the age of head of household > 32 years and for taeniasis it was age < 55 years. The CART analysis showed that the most important determinant for both taeniasis and cysticercosis infections was the number of HH inhabitants (6 to 10) in Katete district and age in Petauke. The results suggest that control measures should target HHs with a high number of inhabitants and older individuals.

INTRODUCTION

Taenia solium taeniasis/cysticercosis is an important public health problem, and endemic in many developing countries of sub-Saharan Africa, Asia, and Latin America.[1,2] Neurocysticercosis, caused by the metacestode larval stage of the tapeworm, is reported as a major cause of seizures and acquired epilepsy in endemic countries.[1,3] The occurrence of *T. solium* has been associated in multiple studies with poverty, poor sanitation caused by absence of latrines, free-range pig management, backyard slaughter of pigs, and inadequate or total lack of meat inspection.[4–6] The consumption of uninspected and undercooked infected meat is the major source of human taeniasis with carriers consequently becoming a major risk factor for cysticercosis to themselves and others in the household or community. Ingestion of infective eggs either by autoinfection, direct contact with a tapeworm carrier, or indirectly by ingestion of contaminated food, water, or hands leads to cysticercosis in humans resulting in larval tapeworm cysts developing in the muscles, eye, and central nervous system.[7] Prevention through the controlling of free-range pigs, meat inspection, and the detection and treatment of taeniasis carriers would greatly reduce *T. solium* infections in endemic areas.[8] However, the parasite occurs in resource-poor communities who cannot afford to house their pigs and commonly slaughter the pigs in their backyards without veterinary control. Furthermore, the lack of cheap and sensitive diagnostic tests for taeniasis makes the detection of tapeworm carriers a challenging undertaking.[9] Other control methods include treatment of pigs positive for cysticercosis, meat inspection, proper cooking of pork, and improved basic sanitation and hygiene.[8]

In most studies, data analysis methods that determine associations between infection and a particular determinant have been used. Commonly used are the multinomial models such as the classical logistic regression analyses that use linear combinations as the primary method of expressing relationships between variables. These models fail to rank the factors according to their importance in light of multiple interactions among the various predictor variables.[10] This ranking is an important tool for the establishment of a decision guide for control measures, as it helps to determine the priority foci of prevention/control methods. However, until now, these analyses have not been carried out for the determinants of *T. solium* infections.

The classification and regression tree (CART) is a useful statistical model that can deal with a large number of independent variables and allows exploring the relationship and the relative importance of the variables and also their possible interactions. The method was successfully applied in different parasitological contexts.[10–13] The CART analysis has been used as a decision support tool that could provide an important contribution toward the prevention and control of malaria by identifying the major risk factors. It was applied in studies in Vietnam and Africa to study and rank important risk factors associated with malaria and provided insights as to which factors to target in control programs.[10,12,13] In a study on visceral leishmaniasis in Nepal, CART was able to show that goats could play a role in the transmission of the disease.[11]

Two community-based studies were conducted in two endemic districts of Eastern Zambia to evaluate relationships between predictor variables (risk factors) and disease outcome (taeniasis and cysticercosis) and to rank the factors in order of importance using the CART analyses.

MATERIALS AND METHODS

Study area and population. The study was conducted in Katete and Petauke districts of the Eastern province of

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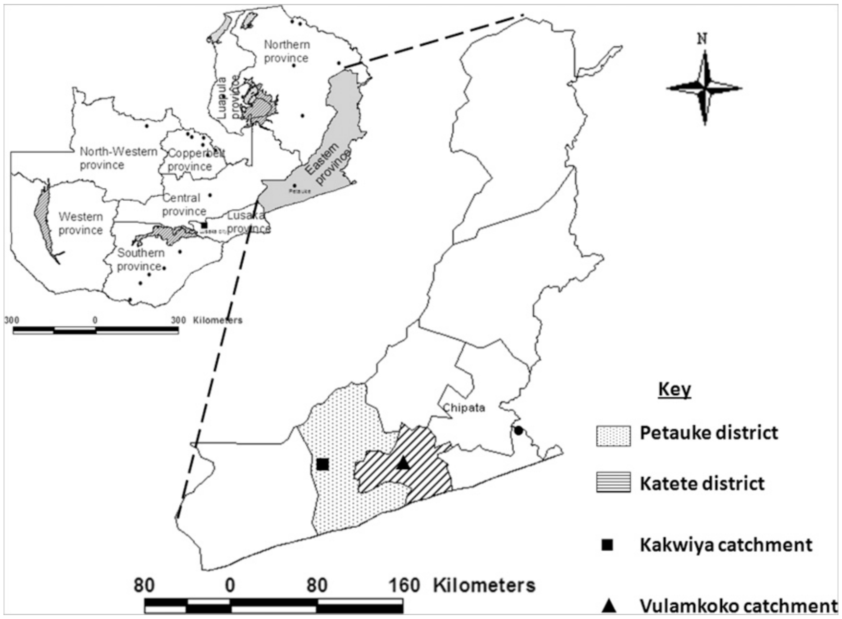

FIGURE 1. Map of Zambia showing the districts of Petauke and Katete and the two catchments of Kakwiya and Vulamkoko Rural Health Centers, respectively.

Zambia (Figure 1). The two districts are reported to be endemic for *T. solium* in both pigs and humans,[14–16] and preliminary visits revealed the presence of free-roaming pigs.

The climate is tropical and modified by altitude with two main seasons, the rainy season (November to April) and the dry season (May to October). The most common ethnic groups in Katete and Petauke districts are the Chewa and Nsenga people, respectively. Both groups practice subsistence agriculture raising animals like cattle, goats, pigs, and chickens and growing crops like maize, groundnuts, bananas, and cotton.

Study design. Two community-based questionnaire cross-sectional surveys, one in Petauke and another in Katete, were conducted between July and November 2009. The two communities in the two districts were selected because of free-roaming pig keeping, lack of active ongoing sanitation programs, and the common observation of cysticerci in slaughtered pigs. The willingness of the community to participate in the study and the Rural Health Center (RHC) to collaborate was also taken into account. All villages within a radius of 7 km from the local RHC were conveniently selected, and all households within this community invited to the RHC or village center to participate in the study. All individuals who chose to participate from each household (HH) were requested to give a stool sample (taeniasis detection and other helminths) and blood sample (cysticercosis detection) after written informed consent. A questionnaire covering all known risk factors, adapted from the questionnaire developed by the Cysticercosis Working Group in Eastern and Southern Africa was formulated, translated into the local language, back translated, and pre-tested in a neighboring district before administration in the study communities. One member of all participating HHs (HHs from which at least one individual gave either a stool or a blood sample) was selected for the questionnaire survey. These HHs were visited and the HH Head was the targeted respondent and where not available, an adult member (> 18 years of age) of the HH was interviewed. The questionnaire covered aspects of HH characteristics and knowledge of *T. solium* infection in humans (taeniasis and cysticercosis) and pigs as shown in Table 1. For cysticercosis, questions included having seen or heard of anyone in the village suffering from epilepsy, chronic headaches, madness (those individuals with signs of mental illness or derangement), and skin nodules.

Sample analyses. The methodologies for sample collection and laboratory analyses are reported in Mwape and others (2012).[15] Briefly, the serum obtained from participants was used for cysticercus antigen detection using the B158/B60 antigen enzyme-linked immunosorbent assay (sero-Ag ELISA) as described by Dorny and others (2004).[17] Presence of helminth ova in stool was done microscopically using the formalin-ether concentration technique as described by Ritchie (1948).[18] The presence of a taeniid egg on a slide was recorded as being positive for taeniasis and the presence of other helminths was also noted during the examination. A copro-Ag ELISA was used to detect adult *T. solium* antigens in the stool samples as described by Allan and others (1990).[19]

Statistical analysis. All collected data were double entered, checked, and cleaned in an Excel (Microsoft Office Excel 2007, Microsoft Corp., Redmond, WA) spreadsheet. A CART (Salford Predictive Miner, Version 6.6 Salford Systems Inc., Berkley, CA) analysis was conducted on the data set. As the disease prevalences in the two areas were significantly different, entailing marked epidemiological differences, the analysis was conducted separately. Disease positivity (taeniasis by copro-Ag ELISA and cysticercosis by sero-Ag ELISA) was used as the dependent variable and a set of different variables as independent or predictor variables. The predictor variables introduced in the CART analysis are listed in Table 1 for both taeniasis and cysticercosis in the two districts. The household was the unit of analyses. Data collected at household level, such as pork consumption, presence/absence of a latrine, were extrapolated to all individuals living in the respective households. Data collected at the individual level were age, gender, disease status for taeniasis

TABLE 1
Predictor variables introduced in the CART analysis for both taeniasis and cysticercosis

Variable classes	Predictor variables
Host characteristics	Age
	Gender
	Not taken an anthelmintic in past year
	Coproantigen positivity*
	Positive for other helminth infections
Household characteristics	Number of inhabitants
	Income (farming/salary/other)
	Highest education level
	Pork consumption
	Boiling of pork before consumption
	Keeping of pigs
	Free range keeping of pigs
	Slaughtered a pig in the backyard
	Slaughtered pig inspected
	Presence of a latrine
Knowledge of helminth infection in humans	Heard of helminth (tapeworm) infections
	Knew how to acquire the infection
	Seen subcutaneous nodules
	Heard of someone with chronic headache
	Heard of someone with madness
Knowledge of infection in pigs	Observed cysts in pork
	Knew what cysts were
	Knew how pigs acquired infection
	Ate infected pork
	Sold infected pork
	Threw away infected pork

*Predictor variable only introduced in the analysis for cysticercosis.
CART = classification and regression tree.

and cysticercosis, and other helminth infections. The CART analysis is a non-linear and non-parametric model that is fitted by binary recursive partitioning of multidimensional covariate space.[20] The analysis successively splits the data set into increasingly homogeneous subsets until it is stratified to meet a specified criterion.[10,20] The building of a classification tree begins with a root (parent) node, containing the entire set of observations, and then through a process of yes/no questions, generates descendant nodes. Beginning with the first node, CART finds the best possible variable to split the node into two child nodes. To find the best variable, the software checks all possible splitting variables (called splitters), and all possible values of the variable to be used to split the node. In choosing the best splitter, the program seeks to maximize the average "purity" of the two child nodes so that the child nodes will be as homogeneous as possible with respect to the outcome variable. In terms of "purity," CART aims at obtaining nodes with only positive or only negative observations and in this respect the determinants are especially appropriate in isolating positive or negative observations.[21] The Gini index was used as the splitting method. A 10-fold cross-validation was used as the method for testing the predictive capacity of the obtained trees. The one-standard error rule was used to select the best tree.[10,12] The CART also provides a score indicating the importance of the different variables. This discriminatory power is reported relatively to the most important variable (which is given a score of 100).

The Pearson χ^2 test was used to check for differences between the two districts.

Ethical statement. Ethical clearance was obtained from the University of Zambia Biomedical Research Ethics Committee (IRB0001131) and further approval obtained from the Ministry of Health of Zambia and the local District health authorities. Meetings were held with the community leaders (village headmen) to explain the purpose of the study and request their permission to conduct the study in their areas. Finally, permission was sought from the individual subjects to take part in the study after detailed disclosure of the research procedures. Participation was voluntary, following written informed consent and included all ages. For individuals < 16 years of age, written informed consent was sought from their parents or guardians. All participants with positive test results received treatment when required according to the National Guidelines.

TABLE 2
Study population baseline demographic information in Katete (N = 969) and Petauke (N = 712) and overall (N = 1681)

	Katete no (%)	Petauke no (%)	Total no (%)
Number of HH			
Sex	425	255	680
Male	403 (41.6)	290 (40.7)	693 (41.2)
Female	566 (58.4)	422 (59.3)	988 (58.8)
Age groups			
< 10 y	306 (31.6)	258 (36.2)	568 (33.6)
11–20 y	224 (23.1)	219 (30.8)	443 (26.4)
21–40 y	250 (25.8)	109 (15.3)	359 (21.4)
41–60 y	141 (14.6)	73 (10.3)	214 (12.7)
> 60 y	48 (5.0)	53 (7.4)	101 (6.0)
Education level in HH			
None	36 (8.5)	35 (13.7)	71 (10.4)
Primary	269 (63.3)	110 (43.1)	379 (55.7)
Secondary or higher	120 (28.2)	110 (43.1)	230 (33.8)
Farming as main HH income	425 (100.0)	250 (98.0)	675 (99.3)
Household size			
Mean	6.4	6.0	6.2
Median	6.0	6.0	6.0
Mode	6.0	5.0	6.0
Range	1–15	1–13	1–15

HH = household.

RESULTS

Population baseline characteristics. The study population baseline characteristics and the risk factors associated with *T. solium* infections in the two districts are shown in Tables 2 and 3, respectively. A total of 680 HH from the two districts

TABLE 3
Household risk factors for *Taenia solium* infections at baseline in Katete (N = 425), Petauke (N = 255) areas, and overall (N = 680)

	Katete No (%)	Petauke No (%)	Total No (%)
Pig keeping HH*	287 (67.5)	84 (32.9)	371 (54.6)
HH without latrines	198 (46.6)	118 (46.3)	316 (46.5)
Pork consumption in HH	409 (96.2)	241 (94.5)	650 (95.6)
Slaughtered a pig at HH*	309 (72.7)	112 (49.8)	421 (61.9)
Slaughtered pig inspected	2 (0.6)†	0 (0.0)‡	2 (0.5)
Observed cysts in pork meat*	960 (99.1)§	692 (97.2)¶	1652 (98.3)
Did not know what cysts were	767 (79.1)§	459 (64.5)¶	1216 (72.3)
Consumed pork with cysts*	272 (29.1)‖	145 (21.7)**	417 (26.0)
Sold infected pork*	149 (36.3)††	46 (19.4)‡‡	195 (30.1)
Threw away infected pork*	167 (39.3)	181 (71.0)	348 (51.2)

*Statistically significant differences (P < 0.05) observed between the two districts.
†N = 309; ‡N = 112; §N = 969; ¶N = 712; ‖N = 934; **N = 668; ††N = 410; ‡‡N = 237.
HH = household.

TABLE 4
Ranking of cysticercosis risk factors by overall discriminatory power in Katete district

Variable	Power
Number of inhabitants in household (HH)	100
Age	58.88
Slaughtering a pig in the backyard of the HH	49.44
Gender	40.77
Knowledge of someone with madness	40.12
Keeping pigs	40.06
Not boiling of pork before consumption	38.90

(425 HH, 33 villages in Katete; 255 HH, 20 villages in Petauke) participated in the study. The age ranged between 1 and 96 years with an overall median age of 15 years. The predominant ethnic grouping in Katete was the Chewa speaking people (98.9%), whereas in Petauke it was the Nsenga speaking people (99.7%). A significantly higher number of HHs kept pigs in Katete (67.5%) than in Petauke (32.9%). The main source of income for most HHs (99.3%) in both areas was farming, although the highest education level attained in the participating HHs was 10.4%, 55.7%, 33.15%, and 0.7% for no education, primary, secondary, and tertiary, respectively. Pork was consumed in 95.6% of the HHs in the two areas and was consumed in a variety of ways including boiling, frying, roasting, and in various combinations of these. Over 60% of the HHs in both areas reported backyard slaughtering of pigs. Only 0.5% of those had their meat inspected.

In Petauke, 6.3% of the fecal samples were found positive for taeniasis on copro-Ag ELISA, whereas circulating cysticercus antigen was detected in 5.8% of the individuals. In Katete, a taeniasis prevalence of 12.0% and cysticercosis prevalence of 12.2% was determined. Katete district recorded a significantly higher prevalence of parasitic infections than Petauke (taeniasis, $\chi2 = 7.66$, $P = 0.006$; cysticercosis, $\chi2 = 19.44$, $P = 0.000$).

Analysis of risk factors by CART. *Cysticercosis.* Katete area. According to the discriminatory power in the analysis, the number of inhabitants in an HH emerged as the strongest overall discriminating determinant for cysticercosis infection followed by age. The other important determinants listed as important are shown in Table 4.

The corresponding classification tree showed that the number of inhabitants in an HH was the first splitter (Figure 2) with cysticercosis prevalence being higher in HHs with < 10 inhabitants (12.7%) compared with HHs with > 10 (2.0%). In the former group, prevalence was higher for those without knowledge of a mad person (16.6%) compared with those who had (10.5%). For those with knowledge of a mad person, age was

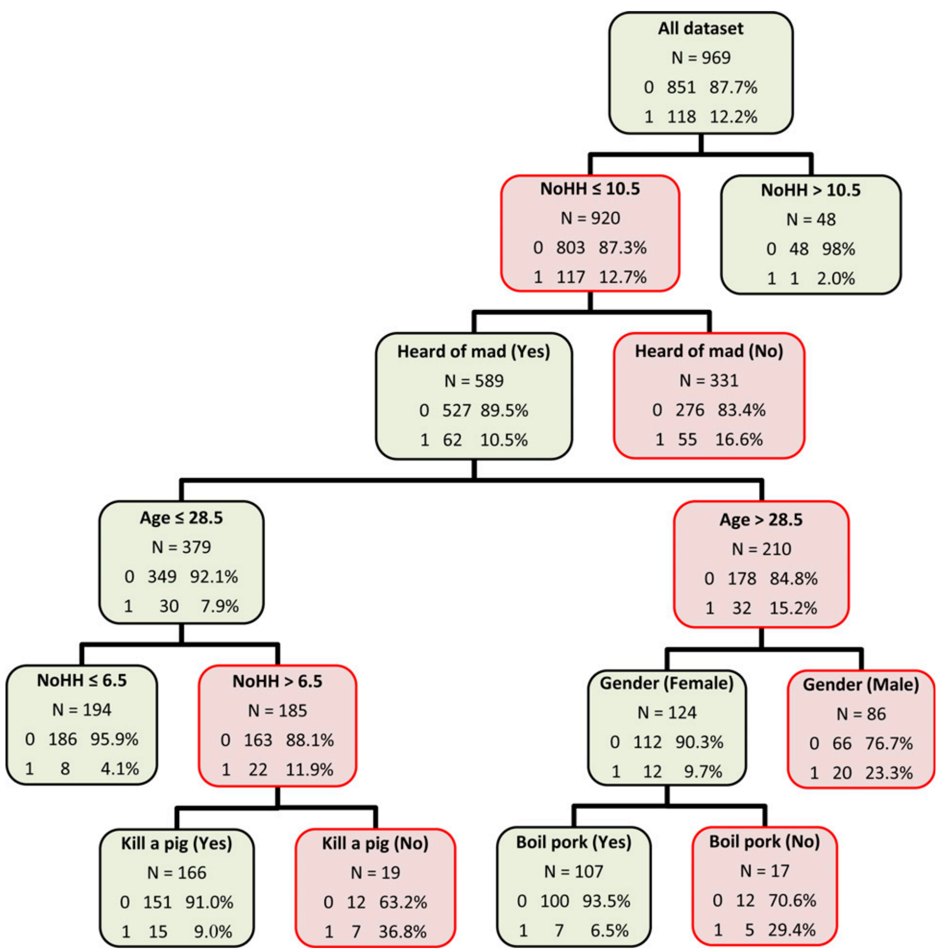

FIGURE 2. Classification tree of the risk factors for cysticercosis infection in the Katete study area. The high-risk groups are represented by a red outline. In each node 0 stands for a negative sero-Ag enzyme-linked immunosorbent assay (ELISA) results and 1 for a positive result. NoHH stands for number of inhabitants in a household.

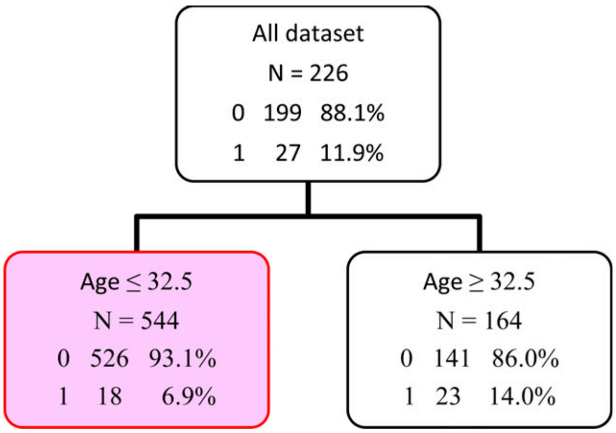

FIGURE 3. Classification tree of the risk factors for cysticercosis infection in the Petauke study area. The high-risk groups are represented by a red outline. In each node 0 stands for a negative sero-Ag enzyme-linked immunosorbent assay (ELISA) results and 1 for a positive result.

the best discriminator with a threshold of 28.5 years; those above this threshold had a higher prevalence (15.2%), especially so if they were male (23.3%) as compared with females (9.7%). For females above the age threshold, prevalence was higher if they did not boil pork before consumption (29.4%) than if they did (6.5%). In the group less than the 28.5 years threshold, they had a lower prevalence if they came from an HH with < 6 inhabitants (4.1%) than an HH with more than this number of inhabitants (11.9%). For the latter group, prevalence was higher if they did not slaughter a pig at home (36.8% versus 9.0% if they did). Each terminal node is categorized as 1 (positive) and 0 (negative) depending on whether the proportion of the ones exceeds the proportion of ones in the population (12.2%). From all negative individuals, 57% (485 of 851) were properly classified as negative and from all positives, 74% (87 of 118) were properly classified as positive.

Petauke area. The important determinant for cysticercosis infection in the Petauke area, according to the discriminatory power included age and not having heard of helminth infections with powers of 100 and 23.89, respectively (Table in supplemental notes, Supplemental Table 1). The corresponding tree for the district revealed only one important splitter, which was age (Figure 3). Cysticercosis prevalence was higher in people above the age of 32.5 (14.0%, N = 164) than those equal to or less than this age (3.3%, N = 544). The analysis properly classified 79% (526 of 667) of the negatives as negative and 56% (23 of 41) of the positives as positive.

Taeniasis. Katete area. The overall discriminatory determinants for taeniasis infection in the Katete area are listed in Table 5 with number of inhabitants in an HH being the most

TABLE 5

Ranking of taeniasis risk factors by overall discriminatory power in Katete district

Variable	Power
Number of inhabitants in a household	100
Knowledge of someone with chronic headache	64.91
Not having taken an antihelmintic in the past 1 year	55.47
Free range keeping of pigs	51.02
Knowledge of someone with epilepsy	22.14

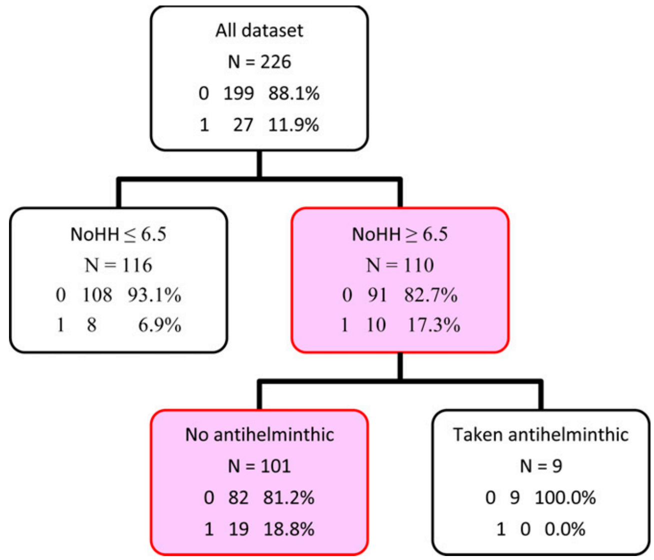

FIGURE 4. Classification tree of the risk factors for taeniasis infection in the Katete study area. The high-risk groups are represented by a red outline. In each node 0 stands for a negative copro-Ag enzyme-linked immunosorbent assay (ELISA) results and 1 for a positive result.

important followed by having heard of someone with chronic headache and history of not having taken an antihelmintic one year before the study.

The best splitter in the corresponding tree was number of inhabitants in the HH with a threshold of six (Figure 4). Groups above this threshold had a higher taeniasis prevalence (17.3%, N = 110) than those below it (6.9%, N = 116). For the group above the six inhabitants in an HH, prevalence was even higher for those with a history of not having taken any antihelmintic in the year before the study (18.8% versus 0.0% for those that did). For all negative individuals the tree classified 59% (177 of 199) properly as negatives and 70% (19 of 27) positives were properly classified as positives.

Petauke area. Table 6 shows the determinants and their discriminatory powers determined as being important for taeniasis infection in Petauke district. Age was the most important factor followed by not boiling pork before eating and consumption of pork.

The important splitter in the corresponding tree was consumption of pork by at least one member of the HH (Figure 5). No cases were recorded in those that did not consume pork, whereas prevalence was highest in the group that consumed pork (6.7%). In the latter group prevalence was higher for those with a secondary or tertiary level of education in the HH (9.2%) than those with a primary or

TABLE 6

Ranking of taeniasis risk factors by overall discriminatory power in Petauke district

Variable	Power
Age	100.00
Not boiling pork before consumption	71.50
Pork consumption by member(s) of the household (HH)	53.64
Highest education level in HH	46.25
Number of inhabitants in HH	45.52
Positive for other helminth infections	31.54
Observed cysts in pork	27.85

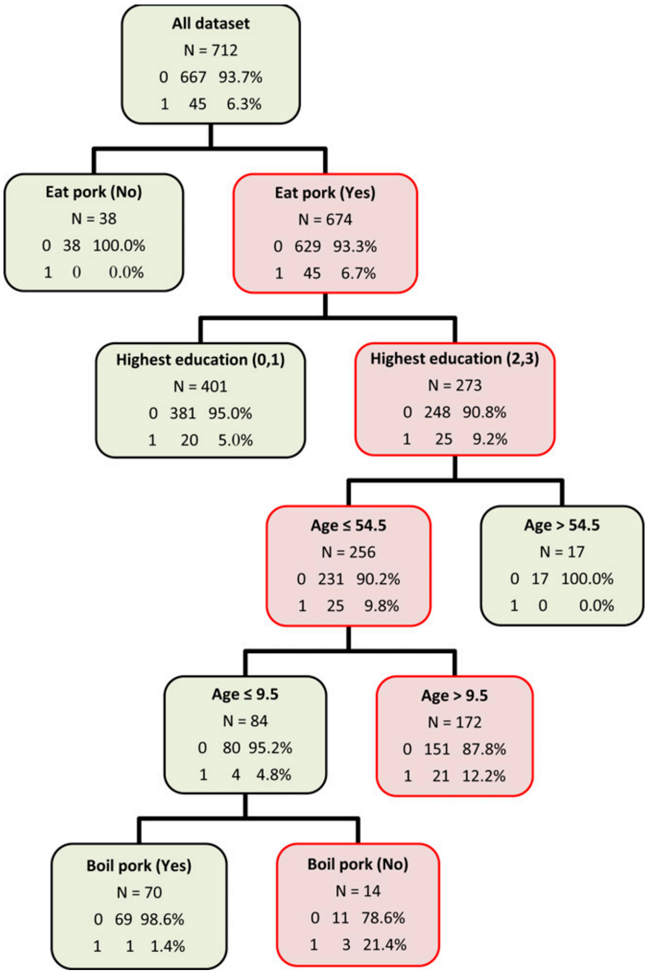

FIGURE 5. Classification tree of the risk factors for taeniasis infection in the Petauke study area. The high-risk groups are represented by a red outline. In each node 0 stands for a negative copro-Ag enzyme-linked immunosorbent assay (ELISA) results and 1 for a positive result.

no education at all (5.0%). Among those with secondary and tertiary education, belonging to the group with age equal to or below 54.5 years but being older than 9.5 years of age were important determinants for taeniasis infection (prevalence 12.2%). For those < 9.5 years of age, prevalence was higher in the group that did not boil pork before consumption (21.4% versus 1.4% for those that did). The tree correctly classified 76% (505 of 667) of all negatives as negative and 52% (24 of 45) positives as positive.

DISCUSSION

The use of both parametric and non-parametric methods to study determinants of human *T. solium* infections can be useful in providing insights into this complex disease and to rank all the potential factors related to the disease prevalence. The CART, which expresses its results in the form of a decision tree, differs from the classical regression analyses, which use linear combinations to express relationships between variables. It does not need relationships to be linear or additive and interactions do not need to be pre-specified or of a particular multiplicative form.[20] The overall discriminatory power of each variable can be determined and the tree allows the exploration of relationships between variables and their relative importance.[10] This study is to our knowledge the first to use the CART method to rank factors that are associated with both human taeniasis and cysticercosis, and the first in Zambia to quantitatively investigate the determinants of human *T. solium* infections.

The number of inhabitants in an HH and age were determined by the CART analyses as the most important factors in the Katete and Petauke study areas, respectively. Change point analyses in earlier studies have indicated that the number of people with active infections (cysticercosis) increases from a certain age onward. In Ecuador, this change point was determined to be at 60 years of age,[22] whereas in Zambia (Petauke study area) this change point was observed at 30 years of age.[15] The analyses from this study corroborate the latter finding, indicating an increased risk for cysticercosis after the age of 32.5 for the Petauke area and 28.5 for the Katete area.

This is the first time that HH size is identified as a possible determinant of *T. solium* infection. Households with between 6 and 10 members, which are considered as large households, seem to be related to higher infection proportions for both taeniasis and cysticercosis, probably as a result of factors such as bulk food preparation and hence chances of undercooking, more people consuming pork, low levels of hygiene, and therefore increased risk of infection. The presence of a tapeworm carrier in a HH has been reported to be a major risk factor for human cysticercosis,[23,24] and this corroborates our findings because more people are exposed in larger households and the listing by the CART that being taeniasis positive was an important risk factor. However, the results show that the risk reduces in households with more than 10 individuals. An explanation for this could be that HH with more than 10 individuals probably do not consume pork frequently because of the costs involved.

Other important factors identified were knowledge of someone with chronic headache, not having taken an antihelmintic 1 year before the study, free-range pig keeping, not boiling pork, consumption of pork (for taeniasis); backyard slaughter of pigs, gender, and having heard of madness (for cysticercosis). Most of these have been described in other studies[6,25–27]; however, they were never ranked in order of importance. The reduced risk for taeniasis in individuals who had taken an anthelmintic during the last year could be explained by the common use of albendazole (for soil-transmitted helminths) and praziquantel (for schistosomiasis) in the local health centers. Praziquantel has been reported to be very effective against taeniosis,[28–30] whereas albendazole has a rather poor efficacy.[31,32]

The higher taeniasis prevalence in HHs with a high education level was unexpected and contrary to results described by Sanchez and others (1997) in a study in Honduras.[26] However, in our study area, people, whether educated or not, were not aware of what the cysts in pork were (Table 2) and assumed that the meat was "harmless," as reported in studies in Kenya and Tanzania.[33,34] As higher education generally means more HH income and hence increased consumption of (infected) pork, this can entail a higher risk of acquisition of the infection.[35]

Absence of latrines, one of the most commonly described risk factors,[6,34] was not identified as an important factor in this study. Almost 50% of HHs had no latrines, and therefore, the environment may have been contaminated, even for the HHs with latrines. Living with a carrier in a household has been reported to be associated with increased cysticercosis risk,[23] and cases tend to aggregate in neighboring HHs.[36] Recent reports state that human cysticercosis cases significantly surround tapeworm carriers,[37] indicating contamination of the community environment. In the future, it may be interesting to define a population-level threshold of HHs needing to have latrines to observe an effect on cysticercosis prevalence.

The finding that most people had heard of someone suffering from chronic headaches (87.9%), epilepsy (95.6%), and madness (73.0%) (data not shown) in their communities is alarming, indicating a possible high level of neurocysticercosis (NCC). Recent studies indicate that in endemic areas, NCC accounts for almost 30% of acquired epilepsy.[38] We have determined high cysticercosis prevalences in both pigs,[14] and humans in our study area,[15] indicating an urgent need to investigate the prevalence of NCC and its association with epilepsy in these areas.

A limitation of the study might be the non-inclusion of certain unknown variables in the analyses. The authors have used an exhaustive questionnaire including all known risk factors, to limit this possibility as much as possible. Furthermore, the extrapolation of questionnaire data recorded from the household head to all other household members assumes that the replies of the interviewed person apply to all household members. For most of the data (such as presence/absence of latrines, household income, keeping of pigs) this can surely be assumed. However, for other data such as replies relating to knowledge, this is less certain. Another possible study limitation is the fact that the number of households that declined to participate could not be assessed. Furthermore, the non-availability of gold standard diagnostic tests for taeniasis and cysticercosis diagnosis is a limitation. The copro-antigen ELISA has a reported sensitivity and specificity of 85% and 92%, respectively,[9] with that of the sero-Ag ELISA being 90% and 98%, respectively.[39]

In conclusion, the CART approach has given insights into the important factors at play with regards to *T. solium* infections. This study has confirmed the importance of most commonly described factors and has ranked them. It has also recorded obvious differences in the presence and ranking of factors between the two study areas that significantly differ in disease prevalence as well, hence describing two different epidemiological situations. This raises the question of whether control programs should be area-specific focusing on a few identified risk factors or rather be created for an entire multicountry region, addressing multiple human and animal host-related factors in a multidisciplinary way; and which approach would be the most cost effective. The ranking of disease determinants will help prioritize control efforts targeting specific important factors. The identification of specific age groups (> 30 years) and also specific HHs (with number of inhabitants between 6 and 10 years of age) because people with a higher risk of infection can help identify the primary target group of control programs.

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