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Evaluating the Efficacy of Teaching Methods Regarding Prevention of Human Epilepsy Caused by *Taenia solium* Neurocysticercosis in Western Kenya

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Abstract. *Taenia solium* neurocysticercosis is a major cause of adult-onset epilepsy in developing countries. A questionnaire was administered to 282 Kenyan farmers, followed by a workshop, a second questionnaire, one-on-one training, and a third questionnaire. People who attended workshops were more likely to know how *T. solium* causes epilepsy in humans in the third visit than the second ($P = 0.001$). The likelihood that farmers would tether their pigs 100% of the time, limiting exposure to tapeworm eggs, increased after the first ($P < 0.001$) and second visits ($P < 0.001$). Farmers were more likely to have heard of *Cysticercus cellulosae* in the second ($P = 0.001$) and third visits ($P = 0.007$), and to know how pigs acquire infection in the second ($P = 0.03$) and third visits ($P = 0.003$). Farmers with at least a grade 8 education were more likely to know how *T. solium* is transmitted to humans in the second ($P = 0.001$) and third visits ($P = 0.009$), and were more likely to understand the relationship between epilepsy and *T. solium* in the second ($P = 0.03$) and third visits ($P = 0.03$). Grade 8 education may enhance learning from written material. Workshops followed by individual on-farm training enhanced knowledge acquisition and behavior changes. Training local government extension workers contributed to the sustainability of this project.

INTRODUCTION

Neurocysticercosis caused by the larval stage of the pork tapeworm, *Taenia solium*, is the major preventable cause of adult-onset epilepsy in developing countries in Africa, Asia, and Latin America.[1–5] The *T. solium* life cycle includes the pig as an intermediate host, having larval cysts (*Cysticercus cellulosae*), and the human as the definitive host, developing adult tapeworms (taeniasis) after consumption of viable cysts. Humans also act as intermediate hosts (cysticercosis) when they consume tapeworm eggs, which then may lead to neurocysticercosis. This is the term used when the human brain is infected with *T. solium* cysts, leading to epilepsy.[6] Person-to-person transmission from a subclinically infected family member are probably the most common source of infective eggs, with infected pigs disseminating the infection.[5]

Taenia solium is emerging as a problem in smallholder pig keeping communities of south-western Kenya,[7] where most pigs are kept under free-range conditions.[7] The prevalence of human taeniasis, estimated at 2% in rural areas, is 4–10% in one division of Busia District where free-range pig keeping is practiced, and more cases of epilepsy are reported in this area.[7] The prevalence of porcine cysticercosis in Busia and Nyanza Districts of Kenya is between 10% and 14%.[8–10]

In 1992, cysticercosis was declared a potentially eradicable disease by the International Task Force for Disease Eradication,[11–13] depending on eliminating reservoirs of *T. solium*. Because tests on live pigs, which have very low sensitivity and inspection systems at slaughter in most developing countries, are poor,[2] it is difficult to identify reservoirs of infected pigs. Control may theoretically be achieved by mass treatment of human carriers of the tapeworm, but concurrent treatment of the entire swine population would be imperative.[12,14,15] However, the lack of capital resources available to Kenya suggest that the best prevention method may be education of farmers, who are in the most opportune position to interrupt the tapeworm life cycle.

In Kenya, 70% of the population live in rural areas and most are farmers owning less than two hectares.[16,17] Community behavioral and environmental practices must be modified to prevent continued transmission of cysticercosis and taeniasis.[16,18] The current low levels of awareness of *T. solium* in Western Kenya suggest that educational programs should target the general public, farmers, and public health personnel.[9] When developed along with community involvement, this type of education reduced opportunities for transmission of *T. solium* in the human-pig cycle in rural Mexico.[18–20] For a long-term effect, intervention programs must be associated with community participation and health education programs.[18–21]

The purpose of this study is to determine whether farmer training workshops conducted by local government staff and followed by one-on-one training by researchers were associated with acquisition of knowledge about the life cycle of *T. solium*, neurocysticercosis caused by the tapeworm, and management methods for pigs and cooking methods for pork that are effective in reducing transmission of the parasite to people.

MATERIALS AND METHODS

Selection of sample farms. This study was first conducted between June 2006 and February 2007 in the Butula and Funyula divisions of the Busia district of Western Kenya (Table 1). The study was repeated between July 2007 and October 2008 in the Shinyalu and Kolomani divisions of the Kakamega district of Western Kenya. All four divisions had known histories of small-scale pig keeping. One month before the field work began; a list of all smallholder pig keeping households was acquired by interviewing local village elders, government livestock staff, and pig farmers. Every village in the selected divisions was included in the study. Farms were randomly selected within each village proportional to the number of farms, to include 65–75% of all farms within every village.

Study timeline. The study was conducted in three key parts. It began with a questionnaire intended to identify farmers' recognition of tapeworm segments in stool, knowledge of the

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Table 1

Farmers and government staff involved with farmer questionnaires and farmer training workshops in Western Kenya 2006–208*

	Questionnaires							Workshop		
				Interviewees who attended workshop†		No. of farmers interviewed			Attendance	
Location	Date of interview	No. interviewed	% of farmers interviewed who were women	% of male farmers who were interviewed who also attended the workshop	% of female farmers who were interviewed who also attended the workshop	Same person in all 3 visits	Same person in last 2 visits	Date	Gov't staff‡	Farmers
Busia	Jun 06	157	66%	43%	48%	57	75	Butula (Jul 06)	12	109
	Nov 06	156	70%					Funyula (Jul 06)	11	133
	Feb 06	132	70%							
Kakamega	Jul 07	125	68%	48%	34%	42	56	Shinyalu (Jul 07)	22	45
	Dec 07 + May 08	120	73%					Ikolomani (Jul 07)		91
	Jun + Oct 08	104	69%							

* Questionnaires and workshops focused on farmers' knowledge concerning occurrence and transmission of taeniasis and neurocysticercosis caused by *Taenia solium*. The researchers, speaking English and Kiswahili, used a 1-day workshop to train local government staff to teach the farmers' workshops.
† Percentages of men and women who were interviewed and who also attended the workshop.
‡ Government staff included animal health providers, community health workers, agriculture staff, public health officers, social workers, adult education specialists, teachers, veterinarians, and livestock production officers.

T. solium life cycle, and means by which taeniasis and cysticercosis are transmitted, methods of pig keeping, and personal hygiene habits likely to affect transmission of *T. solium* eggs from either pigs or people. Administration of the questionnaire was followed by a workshop, and continued with two subsequent farm visits, each including a questionnaire followed by one-on-one training. Farms were visited three times at 3- to 10-month intervals for administration of questionnaires. When farmers were not present at their homes, it was necessary to return to these farms several times to complete the research visits. The researchers intended to interview the person who was most responsible for pig care. If that person was unavailable on the first visit, the family were asked if a return visit could be made later in the week. If that was not possible, a family member who assisted with pig care was interviewed.

Farm visits were conducted in Busia district in June 2006, November 2006, and February 2007 and in Kakamega in July 2007, December 2007, and June 2008. Political violence in Kenya after the 2007 election interfered with some visits planned for 2008. Kakamega farmers that we did not have time to visit in December 2007 and June 2008 were visited in May 2008 and October 2008, respectively. During each visit, the farmer was interviewed in Kiswahili and their pig was restrained, measured, weighed, and treated with a subcutaneous injection of ivermectin. Tongue palpations were conducted on all pigs present at the time of the visits.

In the first visit, the questions asked that were related to *T. solium* were "Have you heard of a disease in pigs where cysts are found in pigs' muscles?" and "What percent of time do you keep your pig tethered or confined in a barn during harvest, planting, and growing seasons?"

A second farm visit was made to Busia in November 2006, and visits were made to Kakamega, where another questionnaire was used (Table 2), both in December 2007 and May 2008. Farmers were interviewed and asked whether they still owned pigs. Demographic information was collected from respondents by recording their name and gender and then asking them what was the highest education level they completed. Questionnaires were designed to test the farmers' knowledge of signs of human infection of *T. solium,* transmission of taeniasis and neurocysticercosis, and recognition of proglottids (Table 2). Farmers were also asked to describe what proportion of time they kept their pig tethered during the harvest, planting, and growing seasons of the year. During the first farm visit, farmers were asked if they owned a working latrine and if so, what proportion of the time the adults and the children in the compound used the latrine for defecation. After the questionnaire was completed, one-on-one training was provided for farmers who had not attended the seminars. We also responded to questions and re-described the *T. solium* life cycle to all farmers. A third visit was made to Busia in February 2007 and to Kakamega both in June 2008 and October 2008, when yet another questionnaire was administered, and again we responded to farmers' questions (Table 2). The farmers were also asked in an open-ended question to list up to three things that they learned either in the workshops or from the researchers during the farm visits.

This research was approved by both the Human Ethics Board and the Animal Care Committee of the University of Guelph. Informed consent was obtained from all human adult participants and from parents or legal guardians of minors. The research including the farmer interviews and training and

TABLE 2
Questions and answers about *Taenia solium* that were asked of pig farmers in Western Kenya between June 2006 and October 2008

Question	Correct answer(s)	Incorrect answer(s)	Included in questionnaires*
Kakamega and Busia (N = 296)			
Have you heard of a disease where cysts are found in pig's muscles?	Yes	No	Busia (1, 2, 3) Kakamega (1, 2, 3)
Do you know how pigs get the disease?	Yes	No, don't know, NA	Busia (2, 3) Kakamega (1, 2, 3)
If your pork meat has these cysts, what can you do to make the meat safe to eat?	Cook well OR boil in water for 10 minutes OR bury the carcass	Nothing, don't know, other responses	Busia (2, 3) Kakamega (3)
Do you tether your growing and adult pigs 100% of the time?	Yes	No	Busia (1, 2, 3) Kakamega (1, 2, 3)
Do you tether your growing and adult pigs more than 75% of the time?	Yes	No	Busia (1, 2, 3) Kakamega (1, 2, 3)
Busia only (N = 157)			
Have you heard about tapeworms in people?	Yes	No	Busia (2, 3)
Farmer was shown a picture of tapeworm segments. Have you ever seen these kinds of worms in someone's stool (feces)?	Yes	No, don't know	Busia (2, 3)
If you saw these worms in the stool of someone in your family, what do you think you should do?	Seek medical attention	All other responses	Busia (2, 3)
How do you think people get infected with these tapeworms? (including only responses correct for the tapeworm)	Eating raw OR uncooked OR improperly cooked OR undercooked AND meat OR pork	All other responses	Busia (2, 3)
How do you think people get infected with these tapeworms? (including responses correct for neurocysticercosis or epilepsy)	Raw OR uncooked OR improperly cooked OR undercooked OR dirty AND meat OR pork OR food	All other responses	Busia (2, 3)
Kakamega only (N = 139)			
Do you have a working latrine?	Yes	No	Kakamega (1, 2, 3)
How often do you use the latrine?	Always	Sometimes, never	Kakamega (1, 2, 3)
How often do your children use the latrine?	Always	Sometimes, never	Kakamega (1, 2, 3)

*Questionnaire 1 administered in Busia June 2006 and in Kakamega July 2007; Questionnaire 2 administered in Busia Nov 2006 and in Kakamega Dec 2007 and May 2008; Questionnaire 3 administered in Busia Feb 2007 and in Kakamega June and Oct 2008.

the maintenance and care of experimental animals complies with the standard of treatment approved by the Veterinary Director General of Kenya.

Interviewer and translator training. Each question and the detail required of the responses were discussed between the research team and the translators. It was stressed that an exact translation of what the farmer said was required, and that translators were not to prompt the farmer to give any specific response. The researchers observed one interview by a senior researcher and completed the questionnaire. Results were compared and discussed, the roles were then reversed, with the senior researcher observing and each researcher asking the questions. The senior researcher interrupted the interviews as necessary to provide the quality of data required. Survey results were again compared. This process was repeated for each of the translators: each watched one interview and was observed for a second interview before conducting interviews independently.

Summary of workshops. The workshops were held to teach farmers about pig feeding, housing, breeding, diseases, and the lifecycle of the *T. solium* tapeworm, including a section on preventing neurocysticercosis. A training-of-trainers (TOT) approach was used for the workshops. The researchers (Drs. Cate Dewey and Florence Mutua), speaking English and Kiswahili, respectively, trained the local staff using a 1-day workshop and a 27-page booklet that included sections on the life cycle of the pig, care of the pig by phase of production (nursing piglet and newly weaned, growing, and breeding pigs), management, feeding, housing, health problems (parasites and salt poisoning), and life cycle, prevention, and human health impact of *T. solium*. Participants in the trainers' workshops included local government staffs who were animal health providers, community health workers, agriculture staff, public health officers, social workers, adult education specialists, teachers, veterinarians, and livestock production officers. The local assistant chief also attended the workshops. Government staff, each participating in 2–4 workshops and using a lecture and flip charts or posters, then taught the material to the farmers in Kiswahili and Luhya. Diagrams of the lifecycle of *T. solium* were provided, with explanations written in Kiswahili. The researchers, including Dr. Florence Mutua, who speaks Swahili, attended the workshops to answer questions and clarify misconceptions.

Every pig farmer in each village was invited to the workshop closest to them, with farmers from 3 to 4 adjacent villages meeting together. Publicity for the workshops, including dates and venues, was completed by the assistant chiefs and village elders in the office of the provincial administration, along with local government livestock officers. Workshops were held at locations (local pig farmers' compounds) believed to be convenient for all farmers.

Data entry and analysis. Data were entered into Microsoft Office Access 2007 (Microsoft Corp; Redmond, WA) and exported to Statistix 7 for Windows (2000 version; Analytical Software, Tallahassee, FL) for statistical analyses. For each question asked, responses were coded as correct or incorrect (Table 2). The farmers were asked during the second visit whether they had personally attended farmer training. In the third visit, in an open-ended question, farmers were asked if they had acquired information during the workshops, with up to three topics per person recorded. These two questions were used to place farmers in workshop attendance categories. Farmers received one-on-one training at the second interview. If a different person from the same compound was interviewed

TABLE 3

Proportion of small-holder pig farmers who were interviewed 3 times over one year, knew about *Taenia solium,* understood its life cycle, and tethered their pigs in Western Kenya, 2006–2008*

Question	Questionnaire†			Odds ratios [95% confidence intervals] *P* value		
	1	2	3	1–2	1–3	2–3
Combined data from Kakamega and Busia ($N = 99$)						
Have you heard of a disease in pigs where cysts are found in the pig's muscles?	44% (44/99)¶	62% (61/98)‖	77% (72/94)**	OR = 1.3 [0.6–3.0] $P = 0.013$	OR = 1.6 [0.6–4.2] $P = 0.000$	OR = 1.5 [0.6–4.0] $P = 0.033$
Do you know how pigs get the disease?‡	–	34% (40/119)¶	49% (59/120)‖	–	–	OR = 1.5 [0.7–3.3] $P = 0.024$
Do you tether your growing and adult pigs 100% of the time?	34% (33/97)¶	51% (47/93)‖	63% (53/84)**	OR = 2.7 [1.1-6.8] $P = 0.008$	OR = 1.5 [0.6–3.8] $P = 0.000$	OR = 4.3 [1.6–11.4] $P = 0.023$
Do you tether your growing and adult pigs more than 75% of the time?	59% (57/97)¶	67% (62/93)¶	79% (66/84)‖	NS	OR = 1.7 [0.6–4.9] $P = 0.000$	OR = 2.9 [1.0–8.5] $P = 0.034$
Busia only ($N = 75$)						
Have you heard about tapeworms in people?	–	93% (64/69)	90% (62/69)	–	–	NS
Farmer was shown a picture of tapeworm segments. Have you ever seen these kinds of worms in someone's stool (feces)?	–	49% (34/70)	53% (37/70)	–	–	NS
If you saw these worms in the stool of someone in your family, what do you think you should do?	–	86% (56/65)	77% (50/65)	–	–	NS
How do you think people get infected with these tapeworms? (Correct for *T. solium* parasite)	–	25% (17/68)¶	41% (28/68)‖	–	–	OR = 5.3 [1.6–17.4] $P = 0.016$
How do you think people get infected with these tapeworms? (Correct for Neurocysticercosis/ epilepsy)	–	46% (31/68)	57% (39/68)	–	–	NS

*Within-farmer comparison of knowledge and behavior from farm visits 1, 2, and 3. The comparison groups were proportions at the first and second farm visit (1–2), first and third farm visit (1–3), and second and third farm visits (2–3). Only farms where the same person was interviewed each visit were included in these analyses.

†Questionnaire 1 administered in Busia June 2006 and in Kakamega July 2007; Questionnaire 2 administered in Busia Nov 2006 and in Kakamega Dec 2007 and May 2008; Questionnaire 3 administered in Busia Feb 2007 and in Kakamega June and Oct 2008.

‡Includes farmers matched in Questionnaires 2 and 3.

¶‖ **Values with different superscripts within a row differ significantly ($P < 0.05$). NS = not significant.

at the third visit, that person would not have received one-on-one training.

The initial analyses included only farmers who were interviewed more than once. For the two questions that were repeated in all three farm visits in both Busia and Kakamega districts, this included 99 farmers (Table 3). For the other questions, these analyses included the 131 farmers who were interviewed during the second and third visits (Table 4). A McNemar's χ^2 test was used to measure changes in knowledge and behavior within farmer over time. Farmers were classified by level of education, which was based on whether they had completed at least grade 8. It was unlikely that a relevant difference in knowledge would be detected as the age of the farmer increased by 1-year increments, but it was possible that there would be a detectable difference if 5-year increments were used. Thus, each farmer's age was divided by five before being entered into the multi-variable model to provide odds ratios that can be interpreted. Next, within these groups of farmers, the association between providing the correct answer in the second or third farm visit and attending farmer workshops, age, gender, and education was determined using multiple logistic regression and a backward-elimination variable selection process. Variables were retained in the model if $P < 0.05$ or if a co-variable confounded the association between the correct answer and another putative factor. Confounding was defined as either changing the level of significance of the association or changing the coefficient by 20%.[22]

A second set of analyses was conducted using data from all farms whether the same person was interviewed on all farm visits. The association between attendance at the workshop and knowledge was assessed by responses in the second farm visit. The association between one-on-one training and knowledge was assessed by responses in the third farm visit (Table 5). The association between knowledge and age, gender, and level of education were also examined using the multivariable logistic regression as described previously.

RESULTS

In total, 282 farmers were included in the study, 157 in Busia and 125 in Kakamega (Table 1). The numbers of farmers decreased to 276 in the second questionnaire because six farmers who no longer owned pigs chose not to participate. Only 236 farmers participated in the third questionnaire because the team attempted to interview only the people who had owned pigs during both the first and second farm visits. Those who were interviewed did not necessarily provide answers to all questions. More farmers were women (66–73%) than men

TABLE 4

Association between personally attending a farmer-training workshop and knowledge or behavior regarding *Taenia solium* and after controlling for gender, age, and level of education in small-holder pig farmers who were interviewed 3 times in Western Kenya, 2006–2008*

Question	Questionnaire†	Multivariable logistic regression using backward elimination modeling technique			
		Attended personally	Gender	Age	Level of education
Combined data from Kakamega and Busia ($N = 131$)					
Have you heard of a disease in pigs where cysts are found in the pig's muscles?	2	OR = 4.1 [1.8–9.1] $P = 0.001$	NS	NS	NS
	3	OR = 2.9 [1.2–6.7] $P = 0.007$	OR = 9.2 [1.2–72.7] $P = 0.035$	NS	NS
Do you know how pigs get the disease?	2	OR = 2.5 [1.1–5.7] $P = 0.034$	NS	NS	NS
	3	OR = 3.3 [1.5–7.3] $P = 0.003$	NS	NS	NS
Busia only ($N = 75$)					
Farmer was shown a picture of tapeworm segments. Have you ever seen these kinds of worms in someone's stool (feces)?	2	NS	NS	NS	NS
	3	NS	NS	OR = 0.6 [0.4–0.9] $P = 0.019$	NS
How do you think people get infected with these tapeworms? (Correct for *T. solium* parasite)	2	NS	OR = 0.65 [0.1–3.5] $P = 0.618$‡	OR = 0.9 [0.5–1.4] $P = 0.565$‡	OR = 13.7 [3.1 = 61.0] $P = 0.001$
	3	NS	OR = 4.3 [0.9–19.2] $P = 0.061$‡	NS	OR = 9.1 [1.8–47.3] $P = 0.009$
How do you think people get infected with these tapeworms? (Correct for Neurocysticercosis/epilepsy)	2	OR = 1.1 [0.3–3.4] $P = 0.897$‡	OR = 0.7 [0.2–2.7] $P = 0.652$‡	NS	OR = 11.3 [1.3–97.8] $P = 0.028$
	3	NS	NS	NS	OR = 10.2 [1.3–81.3] $P = 0.028$

* Includes only farmers who were matched between the second and third farmer visits.
† Questionnaire 2 was administered in Busia Nov 2006 and in Kakamega Dec 2007 and May 2008; Questionnaire 3 was administered in Busia Feb 2007 and in Kakamega June and Oct 2008.
‡ Although $P > 0.05$, the variable was kept in the model because of confounding. NS = not significant.

(Table 1). Less than half of the farmers interviewed attended the workshops. Altogether, 73 of 157 farmers in Busia (46%), and 46 of 125 farmers in Kakamega (37%) attended the workshops. Thirty people in Busia and 20 people in Kakamega who did not answer the question about whether they had attended were assumed to have not attended.

Among the 1,290 pigs examined by tongue palpation for *T. solium* cysts, pig-level prevalence of positive tests was 4%. On 14% of farms, at least one positive pig was identified. Most farms in Busia and Kakamega had a working latrine (98–99%) and most farmers who were interviewed said they used the latrine each time they defecated (98–100%), although this proportion was slightly lower for the children in the compound (88–99%).

Overall proportions. The proportion of all farmers who had the correct knowledge or used the ideal behavior for prevention of *T. solium* are shown in Table 6. Farmers were 2.8 times more likely to tether their pigs 100% of the time in the second visit than the first visit ($P < 0.001$), an increase from 32% to 51%. They were also 2.7 times more likely to tether their pigs 100% of the time in the third visit than the second ($P < 0.001$), an increase from 51% to 62%. Likewise, farmers were 3.5 times more likely to tether their pigs 75% of the time in the second visit compared with the first ($P < 0.001$), and 2.4 times more likely in the third visit compared with the second ($P = 0.02$). In Busia, people were 3.7 times more likely to know how humans get epilepsy from *T. solium* in the third visit than the second ($P = 0.001$).

Matched proportions. Ninety-nine farmers were interviewed during all three visits in both Busia and Kakamega, and the proportions of those who had the correct knowledge or used the ideal behavior for prevention of *T. solium* are found in Table 3. As the study progressed, farmers were more likely to have heard of *C. cellulosae* during each visit than at previous visits ($P < 0.04$). Similarly, farmers were more likely to tether their pigs as the study progressed ($P < 0.03$). In Busia, farmers were 5.3 times more likely to know how people get infected with *T. solium* in the third visit than the second ($P = 0.02$). Farmers were 1.5 times more likely to know how pigs get *C. cellulosae* in the third visit than the second ($P = 0.02$). During the third survey, 59% of all farmers (113 of 190) knew how to make pork safe to eat if it contained cysts, whereas 66% of the farmers who were interviewed all three times knew (55 of 83 farmers).

Association between training and knowledge acquisition among matched farmers. The association between training and knowledge or behavior regarding *T. solium* was determined for the 131 farmers matched from the second and third visits in Kakamega and Busia (Table 4). Farmers were 4.1 and 2.9 times more likely to have heard of *C. cellulosae* in the second ($P = 0.001$) and third visits ($P = 0.007$), respectively, if they had personally attended the farmer training workshop than if they had not attended. Farmers were 2.5 and 3.3 times more likely to know how *C. cellulosae* is transmitted to pigs in the second ($P = 0.03$) and third visits ($P = 0.003$), respectively, if they had personally attended the farmer training workshop. Men were 9.2 times more likely to have heard of *C. cellulosae* than women in the third visit ($P = 0.03$).

In Busia, 75 farmers were matched between the second and third visits. Those with an education level of grade 8 or higher were 13.7 and 9.1 times more likely to know how *T. solium* is transmitted to humans in the second ($P = 0.001$) and third visits ($P = 0.009$), respectively. Those with at least a grade 8 education were also 11.3 and 10.2 times more likely to understand the relationship between epilepsy and *T. solium* in the second ($P = 0.03$) and third visits ($P = 0.03$), respectively, than farmers with less education. Older farmers were more likely to report having seen proglottids in stool in the third visit ($P = 0.02$) than younger farmers.

TABLE 5

Association between knowledge of *Taenia solium* and personally attending a farmer-training workshop and/or receiving one-on-one training with a researcher after controlling for gender, age, and level of education in all small-holder pig farmers involved in a research project in Western Kenya, 2006–2008

		Multivariable logistic regression using backward elimination modeling technique				
Question	Questionnaire*	Attended personally	Gender	Age	Level of education	One-on-one training†
Combined data from Kakamega and Busia ($N = 296$)						
Have you heard of a disease in pigs where cysts are found in the pig's muscles?	2	OR = 2.8 [1.6–4.8] $P = 0.000$	NS	NS	NS	–
	3	NS	NS	NS	NS	OR = 2.3 [1.3–4.1] $P = 0.003$
Do you know how pigs get the disease?	2	OR = 3.2 [1.8–5.8] $P = 0.000$	NS	NS	NS	-
	3	OR = 2.0 [1.1–3.7] $P = 0.026$	OR = 1.4 [0.7–2.6] $P = 0.379$‡	NS	OR = 1.6 [0.8–3.1] $P = 0.179$‡	OR = 1.5 [0.8–2.9] $P = 0.256$‡
Data from Busia only ($N = 157$)						
Have you heard about tapeworms in people?	2	OR = 6.4 [1.3–31.4] $P = 0.023$	NS	NS	NS	–
	3	OR = 0.2 [0.0–1.1] $P = 0.066$‡	OR = 3.2 [0.6–16.4] $P = 0.170$‡	NS	OR = 3.1 [0.5–18.6] $P = 0.219$‡	OR = 11.1 [1.6–78.0] $P = 0.015$
Farmer was shown a picture of tapeworm segments. Have you ever seen these kinds of worms in someone's stool (feces)?	2	OR = 0.4 [0.2–0.9] $P = 0.023$	NS	OR = 0.8 [0.6–1.0] $P = 0.029$	NS	–
	3	OR = 0.5 [0.2–1.4] $P = 0.211$‡	OR = 2.9 [1.2–7.3] $P = 0.022$	OR = 0.8 [0.6–1.0] $P = 0.029$	NS	OR = 3.1 [1.1–8.7] $P = 0.036$
How do you think people get infected with these tapeworms? (Correct for *T. solium* parasite)	2	NS	NS	NS	OR = 5.4 [2.2–13.3] $P = 0.000$	–
	3	NS	NS	NS	NS	NS
How do you think people get infected with these tapeworms? (Correct for Neurocysticercosis/epilepsy)	2	NS	NS	NS	OR = 16.9 [4.0–71.9] $P = 0.000$	–
	3	NS	NS	NS	OR = 4.5 [1.4–14.0] $P = 0.010$	NS

* Questionnaire 2 administered in Busia, Nov 2006 and in Kakamega, Dec 2007 and May 2008; Questionnaire 3 administered in Busia, Feb 2007 and in Kakamega, June and Oct 2008.
† One-on-one training was given after administration of the second questionnaire.
‡ Although $P > 0.05$, the variable was kept in the model because of confounding. NS = not significant.

TABLE 6

Association between farm visit and the proportion of farmers who correctly answered questions about *Taenia solium* and who tethered their pigs based on all farmers involved in a research project in Western Kenya, 2006–2008

Question	Questionnaire*			Odds ratios [95% confidence intervals] *P* value		
	1	2	3	1–2	1–3	2–3
Combined data from Kakamega and Busia ($N = 296$)						
Have you heard of a disease in pigs where cysts are found in the pig's muscles?	41% (114/279)	59% (158/269)	66% (150/229)	NS	NS	NS
Do you know how pigs get the disease?	NA	32% (79/246)	44% (97/221)	NA	NA	NS
Do you tether your growing and adult pigs 100% of the time?	32% (89/277)	51% (124/245)	62% (128/205)	OR = 2.8 [1.6–4.8] $P = 0.000$	NS	OR = 2.7 [1.5–5.0] $P = 0.001$
Do you tether your growing and adult pigs more than 75% of the time?	60% (165/277)	71% (175/245)	76% (156/205)	OR = 3.5 [1.9–6.2] $P = 0.000$	NS	OR = 2.4 [1.2–4.8] $P = 0.016$
Data from Busia only ($N = 157$)						
Have you heard about tapeworms in people?	NA	92% (135/146)	88% (114/129)	NA	NA	NS
Farmer was shown a picture of tapeworm segments. Have you ever seen these kinds of worms in someone's stool (feces)?	NA	51% (78/152)	52% (67/130)	NA	NA	NS
If you saw these worms in the stool of someone in your family, what do you think you should do?	NA	89% (130/146)	85% (106/124)	NA	NA	NS
How do you think people get infected with these tapeworms? (including only responses correct for the tapeworm)	NA	24% (36/148)	36% (45/124)	NA	NA	NS
How do you think people get infected with these tapeworms? (including responses correct for neurocysticercosis or epilepsy)	NA	50% (74/148)	60% (75/124)	NA	NA	OR = 3.7 [1.7–8.1] $P = 0.001$

*Questionnaire 1 administered in Busia, June 2006 and in Kakamega, July 2007; Questionnaire 2 administered in Busia, Nov 2006 and in Kakamega, Dec 2007 and May 2008; Questionnaire 3 administered in Busia, Feb 2007 and in Kakamega, June and Oct 2008.
NA = not applicable, question not asked; NS = not significant.

Association between training and knowledge acquisition among all farmers. The association between training and knowledge was also conducted for all 296 farmers interviewed in Kakamega and Busia (Table 5). In the second visit, farmers were 2.8 times more likely ($P < 0.001$) to have heard of *C. cellulosae* if they had attended the farmer training workshops personally, and 2.3 times more likely in the third visit ($P = 0.003$) if they had received one-on-one farmer training. Farmers were 3.2 and 2.0 times more likely to know how *C. cellulosae* is transmitted to pigs in the second ($P < 0.001$) and third visits ($P = 0.03$), respectively, if they had attended the farmer training workshops.

In Busia, 157 farmers were interviewed. In the second visit, farmers were 6.4 times more likely to have heard about *T. solium* if they had attended the farmer training workshop ($P = 0.02$). In the third visit, farmers were 11.1 times more likely to have heard about *T. solium* if they had received one-on-one training ($P = 0.02$). Farmers were more likely to report having seen proglottids in people's stools if they were younger in the second visit ($P = 0.03$) and the third visit ($P = 0.03$). In the third visit, men were 2.9 times more likely to have seen proglottids in people's stools ($P = 0.02$), and those who had received one-on-one training were 3.1 times more likely ($P = 0.04$). Farmers were 5.4 times more likely to know how *T. solium* is transmitted to humans in the second visit ($P < 0.001$), and were 16.9 and 4.5 times more likely to understand the relationship between epilepsy and *T. solium* in the second ($P < 0.001$) and third visits ($P = 0.01$), respectively.

DISCUSSION

Overall, the workshops and one-on-one training enhanced the farmers' knowledge and awareness of the life cycle of *T. solium* and the transmission of neurocysticercosis. The one-on-one training sessions improved farmers' awareness of tapeworms in people and recognition of proglottids in stool. It is important that workshops are followed up by individual training sessions between farmers and researchers so that the material is presented more than once, in more than one training method, and that attending farmers have an opportunity to ask questions in a safe and private environment.

During the course of this study, the proportion of farmers who tethered their pigs and the proportion of farmers who knew how the tapeworm is transmitted to people increased. When farmers were matched, the proportion of people who had heard of *C. cellulosae* increased, as well as the proportions of those who knew how *C. cellulosae* is transmitted to pigs, the practice of tethering, and how *T. solium* is transmitted to humans. This study was concerned with whether the teaching interventions—farmer training workshops and one-on-one training—were effective. The results are convincing that these teaching interventions altered the farmers' knowledge and behavior, empowering them to prevent transmission of *T. solium*.

In agreement with our study, a World Bank project in Kenya found that over 80% of farmers who are taught recommended practices choose to adopt them.[17] The workshops had both a positive short- and long-term impact.[17] Farmers in this area of Western Kenya are now more likely to implement behavioral changes, such as tethering their pigs, which prevent the spread of *T. solium*.

The one-on-one training was an important method of conveying the information about *C. cellulosae* in pigs and *T. solium* in people, including the recognition of proglottids in stool. The life cycle of *T. solium* is complicated because it involves a definitive and an intermediate host. *Taenia solium* infection in people is further complicated because taeniasis and neurocysticercosis each has its own mode of transmission. One-on-one

training enabled the farmer to ask the researcher questions as she explained the lifecycle of *T. solium*. Furthermore, the farmer was able to hold a picture of the life cycle during the training rather than relying on following a poster at the front of the classroom. In the whole group of farmers, one-on-one training was also associated with having heard of the tapeworm in people and having seen the proglottids in a person's stool. This may have been because the researcher showed a picture of the proglottids during the one-on-one training and then in the second and third farm visits, when the question was being asked.

In this study, men were more likely to know about *C. cellulosae* and were more likely to have seen proglottids than women. There are two possible reasons for this. First, in the Kenyan culture, where extended families share a compound, it is unacceptable for a man to use the same latrine as his daughter-in-law. With only a single latrine in a compound, men are more likely to defecate outside than women, and thus are more likely to see proglottids than women using a deep-pit latrine. Second, men are more likely to negotiate with butchermen than are women. Butchermen, not wanting to buy pigs likely to be condemned by government inspectors, may have told the men about *C. cellulosae*. However, farmers are better able to holistically prevent the spread of *T. solium* if both genders take part. Farmers of both sexes should be encouraged to attend workshops and one-on-one training sessions because of their complementary roles in society and their homes. One report from the United States Agency for International Development noted that it is of special importance to ensure access of education and training to women, as they are key contributors to the agricultural workforce and could further contribute if recognized as a priority audience.[23]

In this study, those who had prior education tended to benefit from the workshops to a greater degree than those who had never reached grade 8. The proportion of farmers who always tethered their pigs had increased. The information provided in the workshops and the one-on-one training, illustrating the need for tethering and providing recommendations for feeding confined pigs were likely to have contributed to the change in tethering practices. In the study by Leonard,[24] impact of training on knowledge in Kenyan farmers, TOT, prior knowledge of Swahili, and level of education all affected the capacity of the farmer to understand complex messages. Our study found that those with a grade 8 education were more likely to correctly describe how people become infected with the tapeworm form of *T. solium* and how people develop epilepsy. Farmers' awareness of tapeworms and knowledge of how *C. cellulosae* is transmitted to pigs also increased with increasing levels of education. This agrees with research concluding that educators must be well educated (i.e., have attained a grade 8 education) to convey clear and accurate messages.[25] Possibly, those who have already had a chance to learn at a grade 8 level may be better able to learn in workshops and one-on-one training environments. Farmers with at least a grade 8 education may have been able to learn from the written teaching tools that included flip charts, posters, and handouts, whereas farmers with a lower level of education may have been limited to learning only from the oral presentation.

The practice of tethering pigs 100% of the time increased after the farmer workshops. However, this increase in tethering pigs was not associated with either attendance at the workshops or one-on-one training. It could be that having the researchers visit the farms and talk about the benefits of tethering the pig to improve pig husbandry and reduce neighborhood conflicts were sufficient to effect this change.

One study found that the prevalence of porcine cysticercosis was higher in pigs reared in households lacking latrines than in pigs raised in households that had latrines.[26] Similarly, the decline in *T. solium* infections in parts of Europe over the past century was because of improved public sanitation, rather than to specifically targeted control measures.[27] From the initial survey, our study found that 98–99% of farmers had a working latrine, that 98–100% of farmers with latrines used it every time they defecated, and that 88–99% of their children used the latrine every time they defecated. Thus, the presence of latrines and the common use of latrines were widespread before this study began. The farmers were not questioned about the presence or use of latrines in subsequent surveys.

Older people in this study were less likely to have seen proglottids in their stool than younger people. Younger farmers may have made less regular use of the pit latrine than older farmers, or there may have been an age difference in the proportion of farmers who ate meat and became infected with *T. solium*. Pig keeping has been increasing in Kenya over the past 15 years,[10,28] therefore, the problem of *T. solium* and proglottids is relatively new in these districts. The potential for epilepsy caused by *T. solium* is ongoing in both older and younger generations, and education must continue to be delivered to people in these communities.

Capacity-building efforts must include a focus on sustainability if we are to have a long-term effect. This study included two factors aimed at sustainability. The first was the longitudinal study design that enabled the researchers to provide two workshops for the farmers, 2 years apart. Furthermore, we visited the farmers three times over a 1-year time period, allowing them to ask questions about pig management and clarifying misinformation. The second factor aimed at sustainability was the TOT model. We began each set of workshops by providing a specific training day for government extension workers, providing them with a detailed workbook and with the understanding of the background physiology necessary for them to understand the workshop information. We then required that they teach the material to the farmers while the researchers were present. Thus, misunderstanding by the extension workers was corrected immediately. The continuing role of these extension workers is to provide day-to-day, long-term assistance to the farmers. It is through them and the farmers who are village leaders that this effort will be sustained.

The major limitation of this study was that we did not ask all of the questions pertaining to *T. solium* during the first survey before conducting the workshops, which would have allowed us to measure the impact of the workshop on the knowledge we were hoping to convey. However, as this biases the results toward the null hypothesis, the impact of the workshops plus one-on-one training may have been larger than what was measured. The second limitation of the study was that we were unable to interview all of the same people during successive farm visits, reducing the sample size and reducing the power of the study to find a difference if a difference existed. The strength of the study was its longitudinal study design, which enabled us to measure retention of knowledge over time rather than just immediately after the workshop.

Farmers in Western Kenya are aware that humans may be infected with tapeworms and that medical attention is

required if a family member has proglottids in their stool. Half of the pig farmers in this study had seen proglottids in stool, revealing how widespread the problem of *T. solium* infection has become in this area. We must encourage and fund more research-based education to reduce the incidence of neurocysticercosis and malnutrition caused by *T. solium.*

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