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Animal and human tungiasis-related knowledge and treatment practices among animal keeping households in Bugiri District, South-Eastern Uganda

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ABSTRACT

Background: Zoonotic tungiasis caused by *Tunga penetrans* remains a serious public and animal health problem among endemic villages in Uganda and many sub Saharan African countries. Studies on human and animal tungiasis-related knowledge and treatment practices in endemic communities have never been undertaken, a limitation to development of sustainable control measures.

Methods: A cross sectional study using semi-structured questionnaires (Supplementary file S1) was conducted among 236 animal rearing households in 10 endemic villages in Bugiri District, South-Eastern Uganda. Focus group discussions and observation checklists were used to validate and clarify the findings.

Results: Most respondents knew the aetiology (89.4%), clinical signs (98%) and the ecology of *T. penetrans* as well as the major risk factors of human tungiasis (65.2%). In contrast, very few respondents were aware of animal tungiasis. Only 4.8% of those with infected animals on the compound knew that some of their animals were infected and 13.6% of the respondents had ever seen tungiasis-affected animals. Pigs (13.1%, n = 31) and dogs (0.85%, n = 2) were the only *T. penetrans* animal hosts known to animal owners. Affected humans were treated by extraction of embedded sand fleas using non-sterile sharp instruments in all households that reported occurrence of human tungiasis at least once (n = 227). Also, affected animals were mainly treated by mechanical removal of embedded sand fleas in households that have ever experienced animal tungiasis (four out of 12; 33.3%). In a few instances, plant and animal pesticides (n = 3) and other chemicals such as grease, paraffin and wood preservative (n = 3) were also used to treat animal tungiasis.

Conclusion: The study revealed a high level of knowledge on human tungiasis but inadequate knowledge on the zoonotic nature of tungiasis. Commonly applied methods for treatment of human and animal tungiasis are a health hazard by themselves. Concerted i.e. One Health-based efforts aiming at promoting appropriate treatment of tungiasis, adequate living conditions and increased awareness on tungiasis in the communities are indicated in order to eliminate tungiasis-associated disease.

1. Introduction

Infection with the female sand flea, *Tunga penetrans*, causes an inflammatory and debilitating skin disease. Tungiasis occurs in a wide range of mammals (Heukelbach et al., 2004; Mutebi et al., 2015) including humans (Pampiglione et al., 2009). Tungiasis-associated morbidity causes acute and chronic inflammation, fissures, ulcers, deformation and loss of nails/claws which eventually may lead to mutilation of the feet and disability (Mazigo et al., 2010; Mitchel and Stephany, 2013). Bacterial super–infection is constant and if caused by *Clostridium tetani* or *Clostridium perfringens*, it may be fatal (Feldmeier et al., 2003; Feldmeier et al., 2002; Veraldi et al., 2014). Current treatment methods are a health hazard by themselves and increase the risk of the transmission of blood borne pathogens such as Hepatitis B Virus, Hepatitis C Virus and HIV in humans (Feldmeier et al., 2014; Heukelbach, 2006).

Currently, tungiasis is prevalent in resource-poor communities in Latin America, the Caribbean and sub-Saharan Africa (Pampiglione et al., 2009). Although, epidemiological information from East Africa on tungiasis is very limited, available reports indicate that it occurs

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with high prevalence among the poor (Dassoni et al., 2014; Mazigo et al., 2012; Mwangi et al., 2015; Wafula et al., 2016). In a study in Kenya, Mwangi et al. (2015) identified lack of regular use of shoes, houses with earthen mud walls, sharing of living quarters with domestic animals and dusty floors in classrooms as significant risk factors in a multivariate analysis. Mazigo et al. (2010) reported a case of a mentally disabled person with very high parasite load (810 and 60 embedded fleas in feet and hands, respectively) leading to severe clinical presentations. In Uganda, tungiasis is endemic in all regions and periodically attains epidemic levels particularly during the dry season (Ministry of Health, 2010).

A wide spectrum of animal species are susceptible to an infection by *T. penetrans* (Mutebi et al., 2015). Besides acting as reservoirs for human infections, domestic and sylvatic animals suffer from severe morbidity (Mutebi et al., 2016a, 2016b). The persistence and outcomes of tungiasis among endemic communities is driven by a wide range of socio-economic, physical and behavioural factors (Muehlen et al., 2006; Ugbomoiko et al., 2007). Many of these factors in turn depend on the attitudes towards the disease, the level of knowledge on tungiasis as well as on practices with regard to the management of the disease (Kimani et al., 2012). It is, therefore, logical that before control measures can be designed and implemented, tungiasis-related knowledge and practices have to be investigated in the target communities.

There are only very few studies on human tungiasis-related knowledge and management practices available (Kimani et al., 2012; Winter et al., 2009) while those on animal tungiasis are non-existent. In order to inform the development of sustainable tungiasis control measures in Uganda, a study was conducted among animal rearing households in 10 purposively selected endemic villages in Bugiri District, South-Eastern Uganda aimed at assessing the level of tungiasis-related knowledge, treatment and prevention practices.

2. Materials and methods

2.1. Study area

The study was carried out in 10 purposively selected tungiasis-endemic rural villages distributed in three neighbouring parishes in Bugiri district, Busoga, South Eastern Uganda (Mutebi et al., 2015). The study villages included Busano, Isakabisolo, Busakira, Busindha, Makoma, Masolya, Namungodi, Matyama which constitute Makoma Parish; Nagongera in Bulidha Parish and Kibuye in Wakawaka parish all located in Bulidha sub county of Bugiri District. The overall prevalence of human and animal tungiasis among animal rearing households in the ten villages were 71.4% (95% CI 45.4–88.3%) and 33.9% (95% CI 28.2–40.2%), respectively (Mutebi et al., 2015). People depend mainly on rain-fed subsistence crop and animal agriculture which is largely practiced with no regard to appropriate husbandry practices.

2.2. Study design

This was a cross sectional study which applied both quantitative and qualitative methods executed from January to March 2014. The study targeted animal rearing households and these were selected using the criteria of having at least one pig, dog or cat (which were considered to be the major animal reservoirs of tungiasis at the time of the study). All households which met these inclusion criteria in all the ten study villages were included in the study. Out of estimated 3214 households in the 10 villages, 239 met the inclusion criteria and 236 were sampled. The other three declined to participate in the study.

2.3. Data collection

For consenting households, semi-structured questionnaires with both closed and open ended questions were administered to the household heads. Whenever other family members were present, they supported the household head in responding to the questions which were asked. The questionnaire contained questions on the knowledge as well as on risk factors of tungiasis, the ecology of the parasite, control of tungiasis and how affected humans and animals are treated in the community. Onsite observations guided by an observation guideline were also made in individual households to validate some responses to the questionnaire. Two focus group discussions (FGDs), one for men (12 participants) and another for women (21 participants) drawn from all the ten villages were conducted to validate, clarify and complement the data collected using the questionnaires. FGDs were conducted in the most spoken local language in the area (“Lusoga”) and lasted for two hours. Participants in the FGDs were drawn from households that did not participate in the questionnaire survey and these were mainly those that had other animal species other than pigs, dogs or cats and to avoid bias on human tungiasis related information; some participants were drawn from households without animals. Focus group discussion guides (Supplementary file S2) were used to direct the discussions. Simple and precise open ended questions aligned to the survey questionnaire were asked during the sessions. The age of participants in the FGDs ranged from 23 to 76 years. Notes on responses were taken by two different persons throughout the FGDs.

2.4. Statistical analysis

Quantitative data from the questionnaires were entered into Microsoft Excel sheets 2007, double checked against data collection tools and then transferred to Stata® Software package, Version 13 (Stata Corporation, College Station, Texas 77845 USA, stata@stata.com) for analysis. Descriptive statistics were generated. Either mean (for normally distributed data) or median (for skewed data) were used as indicators of central tendency and dispersion of data was presented as ranges. Fisher’s exact or chi-square and binomial tests (for mutually exclusive events) were used to establish the significance of differences between proportions. A Student’s *t*-test was used to ascertain if there was a significant difference in age of respondents between those who had ever encountered animal tungiasis and those who had never. Odds ratios were also computed to establish associations between independent and dependent variables. Only p-values of < 0.05 were considered to be statistically significant. Qualitative data from the FGDs proceedings was sorted, merged and summarised according to themes. Representative quotations were selected from the composite summary for presentation.

2.5. Ethical considerations

The study was presented for review and was approved by the ethical committees of the College of Veterinary Medicine, Animal Resources and Biosecurity Makerere University (Ref. VAB/REC/14/101) and the Ministry of Health, Vector Control Division (Ref.: VCD-IRC/054) before it was accredited with the National Council of Science and Technology (Ref.1621). All participants gave a written consent on accepting to participate in the study.

3. Results

3.1. Characteristics of households

The demographic information of respondents and animal species owned by the households in the study is summarised in Tables 1 and 2, respectively. The average age of the respondents was 48 years (range 15–87 years) and the median household size was 8 (range = 1–24) while the median homestead (number of households on the same compound) size was 2 (range = 1-8). The estimated mean monthly income was 118,000 Uganda shillings (range = 5000–2,000.000 Uganda Shillings).

In all the villages; sheep, goats and cattle were mainly tethered

Table 1
Demographic and socio-economic characteristics of households (n = 236).

	Number (n)	Percentage (%)
Village of residence of the household heads/respondents		
Kibuye	45	19.07
Masolya	32	13.56
Makoma 1	30	12.71
Busakira	19	8.05
Busanu	17	7.20
Nagongera	19	8.05
Isakabisolo	20	8.47
Busindha	14	5.93
Namungodi	25	10.59
Matyama	15	6.66
Sex of the household head/respondent		
Male	192	81.36
Female	44	18.64
Ethnic group of the household head/respondent		
Bantu[a]	85	36.02
Luo[b]	100	42.37
Nilohamites[c]	51	21.61
Level of education attained by the household head		
None	78	33.05
Primary	130	55.08
Secondary	16	6.78
Tertiary	12	5.08
Major economic activity		
Subsistence crop agriculture	220	93.22
Others[d]	16	6.78
Age of household head		
15–35	51	21.61
36–55	111	47.03
56–87	74	31.36
Size of the household[e]		
1–5	48	20.33
6–10	138	58.48
11–24	50	21.19
Estimated monthly income of the household (UG)shs[f]		
5000–130,000	166	70.34
Above 130,000	70	29.66

[a] These included Basoga, Bagishu, Samya, Banyole and Bagwere.
[b] Constituted by the Japadhola.
[c] Constituted by Ateso.
[d] Included petty trade, fishing, casual labour, subsistence animal rearing, brick laying, motor cycle transportation, formal employment.
[e] Number of people having meals together daily.
[f] Exchange rate at the time of the study: 1US$ = Uganda Shs 3300. Income was estimated as the sum of the estimated income from all economic activities in a year divided by 12 months.

Table 2
Animal species kept in the households (n = 236).

Animal species	Number of households (n)[a]	Percentage (%)
Pigs	155	65.68
Dogs	120	50.85
Goats	154	65.25
Cattle	47	19.92
Cats	19	8.05
Chicken	203	86.0
Sheep	2	0.85
Rabbits	3	1.27
Turkeys	3	1.27
Pigeons	17	7.20
Guinea fowls	5	2.1

[a] Keeping of animal species in households was not mutually exclusive.

while all poultry species, dogs, cats and rabbits were all free ranging throughout the year with or without shelters. However, pigs were confined during the rainy (crop growing) season and were released intermittently to roam during the dry (crop harvesting) season. With the exception of poultry species and rabbits which are housed in make shift structures or human houses at night, other mammalian species mostly had no formal housing structures. They were either tied on trees or shrubs near human compounds at night (cattle, goats, sheep, pigs) or left to roam freely without any housing (cats, dogs). In a few instances temporary shelters existed (Fig. 1).

3.2. Knowledge on human tungiasis

All respondents in the survey and FGDs had ever heard of tungiasis and it was locally called "*enfunza*" and "*sunja*" in Lusoga and Japadhola (Luo), respectively, which are the most spoken languages in the study area. "*Enfunza*" is a descriptive term which literally means "a condition that causes rotting (of the feet)". Out of the 236 respondents who participated in the study, only nine (3.8%) reported that to the best of their knowledge none of their family members had ever suffered from tungiasis. The remaining 227 (96.2%) household respondents reported to have experienced at least one case of tungiasis among family members. For households that reported at least one case of tungiasis among any family member, the time point of the last episode of tungiasis varied greatly (median = 3 months, range = 0–360 months).

The majority of the respondents (89.4%, n = 211) knew the cause of tungiasis which they readily described as a "very small flea which lives in dust". Interestingly, even eight of the nine respondents who reported to have never experienced tungiasis in the household clearly described the cause of tungiasis. However, 10.6% (n = 25) of the respondents did not know the exact cause of tungiasis and believed that any type of flea can cause tungiasis. During FGDs, a few individuals still believed that the free living fleas on the bodies of animals and *Echidinophaga gallinacea* on *the eyes of chicken were the cause of* tungiasis. One participant reported: "*jiggers are caused by fleas which are commonly found on the bodies of rats, dogs, goats and the eyes of chicken*". (Male, Masolya, 56 years old).

The great majority of the respondents (98.3%, n = 232) knew the clinical signs of tungiasis and only four could not mention at least one clinical feature of tungiasis. Two of these were among those who had reported that they had never experienced tungiasis in their households. Itching of the affected area was the most mentioned in all cases while the characteristic appearance of the lesion was only accurately described by two respondents (0.86%). During the FGDs; pain at affected sites, alteration of gait, loss of nails and an itchy dark spot were mentioned as key manifestations of tungiasis. One participant (47 years of age) in the male's FGD likened an embedded sand flea to a maize seed ("duuma"): "[……] *how can someone plant maize in their feet?"*. Most FGDs participants believed heavy T. penetrans infections can cause death. This assertion was based on the death of two persons who were heavily infected by *T. penetrans* in Nagongera and Kibuye villages.

More than half of the respondents (65.2%, n = 154) knew that dust and/or filthy environmental conditions as favourable sites for the sand fleas. However, the life cycle of the sand fleas was not well known to the majority of the participants. In the FGDs, one female participant (41 years of age) stated: "*I see the fleas in the dust but I don't know where they come from! May be dust becomes fleas*". It was a popular belief that there are specific breeding sites for sand fleas which included specific sites in the bushes and some termite mounds. "*There are mounds for jigger fleas from which they emerge during the dry season*" (Male participant, 56 years). Another participant (Male, 35 years) said "*there was a sand flea mound in Muterere which was harbouring sand fleas and the people in its vicinity used to suffer from heavy infections of jiggers. […….] when the mound was destroyed, jiggers stopped affecting people in that area*". Another male participant from Busindha village informed the meeting that: "*there is a man in Busindha who dug up the floor of his house to identify the sand flea mound when his family members were persistently heavily affected by jiggers*."

Some participants believed that animals especially rats, chicken,

Fig. 1. Confinement structure for pigs in the study area.

goats, pigs and dogs pick up the fleas from the primary breeding sites to human dwellings. "*I abandoned pig rearing because they brought jiggers to my household. [……] When I was still keeping pigs, all family members were almost dying from jiggers! The infection in pigs can be too heavy to the extent that even their testes and penis get infected.*" (Male, 48 years).

More than half of the respondents mentioned at least one plausible predisposing factor to human tungiasis during the survey (65.2%, n = 154). Up to nine factors were reported to predispose humans to tungiasis (Table 3). The specific question asked was "What factors predispose humans to jiggers?" Although, only one respondent reported occurrence of severe tungiasis among specific families and tribes during the questionnaire survey, the majority of the participants in the FGD strongly believed that severe tungiasis is a problem of few specific families. One participant in the FGDs reported that his pregnant daughter got heavy infections because he got married to a specific tribe. "[…….] *My daughter is now affected because she got married to a man from a tribe which suffers from jiggers*" (Male, 58 years).

Witchcraft was also reported as a possible cause of tungiasis. During the FGDs, one male participant from Masolya village reported that: "*There is a young man in Kibuye who is about to die of jiggers due to witchcraft from fellow traders because he had prospered better than many of them*". All respondents knew about the seasonal variation of occurrence of tungiasis and heavy infections were reported to occur during the dry seasons. Myths were also reported as a factor contributing to the persistence of tungiasis in the community. "*In the past, it was believed that a child could only be clever if he/she has ever suffered from jiggers. So some community members cherished seeing their children having jiggers.*" (Male, local leader).

Table 3
Respondents' view on factors predisposing to tungiasis (n = 236).

Cause of tungiasis/association with tungiasis	Number of respondents[a]	Percentage (%)
Dusty living environment	84	35.6
Proximity to animals	31	13.1
Proximity or access to sand flea infested termite hills/mounds	36	15.3
Dirty environment	34	14.4
Poor body hygiene[b]	02	0.85
Proximity or access to bushes	02	0.85
Family and tribal predispositions[c]	01	0.42
Closeness to affected humans	01	0.42
Do not know	82	34.8

[a] The responses were not mutually exclusive. Up to three responses were given by the respondents.
[b] Such as irregular washing of the body.
[c] Some families and tribes were reported to be more susceptible to tungiasis than others.

Only 25 (31.2%) household heads admitted to have at least one family member infected at the time of the study but in fact 80 (33.9%) households with at least one infected person were identified. Three of those who reported that the disease was currently occurring in their households, did not have any case.

3.3. Knowledge on animal tungiasis

Only three (4.8%) of the 62 household heads where at least one infected animal was detected knew that their animals were infected by *T. penetrans* during the study. All the three household heads who knew that their animals were infected, owned pigs. These were, however, very few (5.6%) compared to the number of households where infected pigs were detected (n = 54; $p < 0.0001$). None of the households with other infected animal species in a household reported animal tungiasis (dogs, n = 14; goats, n = 2; cat, n = 1). Only 32 (13.6%) of the respondents reported that they saw *T. penetrans*-infected animals at least once in their lifetime.

Pigs (n = 31, 13.1%) and dogs (n = 2, 0.85%) were the domestic mammalian animal species which animal owners reported to have ever seen infected with *T. penetrans*. However, none of the respondents considered tungiasis to be a serious animal health issue warranting veterinary interventions. Chicken were also reported to get infected. However, all respondents that mentioned chicken were actually describing *Echidinophaga gallinacea* (n = 25, 10.6%) (Fig. 2). During FGDs, rats and goats were also mentioned as animal hosts for *T. penetrans*. Nevertheless, descriptions were pointing to non penetrating sand fleas. It was claimed that the prevalence of animal tungiasis especially among pigs has generally reduced. "*Jiggers in pigs used to be common over twenty years ago*" (Male, 66 years).

Although those household heads who had ever seen animal tungiasis were slightly older (mean = 52 years, range = 15–85) than those who had never encountered animal tungiasis (mean age = 47, range = 16–87), the age did not differ significantly ($p = 0.07$). Also, the number of years spent by an individual while rearing animals was not associated with an increase in the odds of one encountering animal tungiasis (OR = 1.03, CI = 1.01–1.06; $p = 0.019$).

3.4. Tungiasis prevention and treatment practices

When asked if a deliberate effort was taken to prevent tungiasis in the households, 152 (64.4%) reported to implement preventive measures from time to time (Table 4). Bathing daily and washing clothes, sweeping the human dwellings and application of fresh cattle manure on floors of human dwellings were the main tungiasis control methods reported by the communities during FGDs. None of the respondents had a specific regular interval for the interventions mentioned. Medical care or advice regarding human tungiasis control or treatment were never

Fig. 2. Chicken with *Echidinophaga gallinacea* around the eyes, wattles and ear lobe. Some respondents misidentified *E. gallinacea* as *T. penetrans*.

Table 4
Tungiasis preventive measures against human Tungiasis (n = 152).

Measure	Number of Respondents[a]	Percentage (%)
Smearing the floor with fresh cattle manure	90	59.2
Spraying the house floor with insecticides	14	9.2
Proper body hygiene[b]	57	37.5
Sweeping of the house and compound	29	19.1
Application of greese on feet	01	0.66
Application of petroleum jelly on feet	01	0.66
Application of insecticide on feet[c]	02	1.3
Outdoor dwelling place and house floor wetting with water	04	2.6
Application of paraffin on feet	01	0.66
Regular feet inspection and extraction	03	1.97
Keep animals away from compounds	01	0.66
Sleep on beds	01	0.66
Treatment of animals with insecticides[d]	01	0.66

[a] Responses were not mutually exclusive.
[b] Bathing daily, washing and changing clothes.
[c] Plant pesticides applied (e.g. Ambush) when fleas are detected in the house.
[d] Amitix was used.

sought among the vast majority of the households (n = 234, 99.15%) and only two (0.9%) reported to have ever sought medical care when a family member got infected by *T. penetrans*.

Although all households with non concrete floors (n = 210, 89%) smeared cattle manure on the floor at variable time intervals to minimise dust in the house (Fig. 3), only 90 (42.9%) respondents mentioned it as a tungiasis prevention strategy. The rest practiced it for aesthetic reasons only. The interval of application of cattle manure on the floor of the house was subject to the availability of water and cattle manure. It was predominantly a women's task and intervals were reported to be prolonged during the dry season but shorter during the rainy season. During one of the FGDs, one lady (Masolya Village) said: "*Personally, I work on the floor during the rainy season when water is readily available*". In some instances, when cattle manure was not available, mud was used. However, one respondent reported that he had abandoned the use of cattle manure because it increased the intensity of fleas in the house and had resorted to using only mud on the floor. A variety of insecticides were used for environmental and on human body tungiasis control. These included Doom®, DDT, malathion, gammatox®, Dudumatch® and Amitix® (Amitraz). These were mostly applied whenever fleas were observed in the house.

In all the 227 households where tungiasis had ever been experienced, extraction of embedded sand fleas was the only treatment method which was reported to be used. Six different extraction instruments were used by the communities to extract embedded sand fleas (Table 5). The majority of the respondents (n = 151, 66.8%) reported that instruments used for extraction of embedded sand fleas were shared among family members. Nobody reported sharing of the extraction instruments between households. Extraction of sand fleas from affected household members was majorly performed by women (76.6%, n = 173) and children (31.9%, n = 72) but also men were involved (16.8%, n = 38).

Extraction of embedded sand fleas frequently resulted in sores which had to be treated by some households (n = 95; 41.9%) (Table 6). In one of the FGDs, one participant said: "*After extraction of the fleas, I*

Fig. 3. Human house floor smeared with cow dung to minimise dust.

Table 5
Extraction instruments used in humans (n = 227).

Extraction instrument	Number of respondents[a]	Percentage (%)
Safety pins	142	62.6
Thorns	86	37.9
Sewing needle	28	12.3
Sharpened bicycle spokes	01	0.4
Pointed geometry set instruments	04	1.8
Fish bones	01	0.4

[a] Use of instruments was not mutually exclusive.

Table 6
Treatment of sand flea extraction sores in humans (n = 95).

Extraction sore treatment method[a]	Number of respondents[b]	Percentage (%)
Petroleum jelly	09	9.5
Wood ash	09	9.5
Salt	04	4.2
Greese	14	14.7
Paraffin (kerosene)	59	62.1
Red pepper	03	3.2
Soot	02	2.1
Cattle manure	01	1.1
Insecticides[c]	01	1.1
Soil/dust	09	9.5
Tablets and antibiotic capsules[d]	05	5.3
Antiseptic[e]	01	1.1
Wash feet	02	2.1

[a] Occassional treatment methods.
[b] Responses were not mutually exclusive.
[c] Plant pesticides are used (Ambush®).
[d] Paracentamol tablets and chloramphenicol or erythromycin capsules.
[e] Iodine tincture.

wash the feet and rub the wound with a stone" (Male, 50 years).

3.5. Treatment of animal tungiasis

Out of the 32 household heads who reported to have ever recognised tungiasis among their animals, only 12 (37.5%) reported attempts to treat the affected animals. The treatment methods for tungiasis reported by the respondents are summarised in Table 7. On recognising tungiasis-affected animals, only 19 (59.4%) of the 32 respondents made deliberate efforts to eliminate infections from their animals. The methods of tungiasis elimination from animals where it was once detected by their owners are summarised in Table 8.

During FGDs, less than half of the participants in both groups had ever encountered tungiasis among their animals. Those whose animals (all pigs) were once infected, sold them to get rid of tungiasis affected animals. One participant reported that the affected pig died but she could not confirm if tungiasis was the suspected cause of death. At the time of the study, only two activities had been implemented to address tungiasis in the area. These included shoe donations by a Non Government Organisation and a survey by government health workers to establish the extent of tungiasis. At the time of the study, no educative seminars had ever been conducted to sensitise the community members on appropriate tungiasis control practices.

Table 7
Animal tungiasis treatment methods used by animal owners (n = 12).

Treatment method	Number of respondents	Percentage (%)
Extraction of embedded sand fleas with sharp instrument	04	33.3
Chemical treatment using pesticides[a]	03	25.0
Other chemical treatments[b]	03	25.0
Immersing of the digits in water[c]	02	16.7

[a] Plant (Ambush®) and animal pesticides.
[b] Wood preservative, paraffin, greese application on the lesions.
[c] Water ponds or swampy areas.

Table 8
Methods of tungiasis elimination from animals used by the community (n = 19).

Method	Number of respondents	Percentage (%)
Selling of affected animals	13	48.2
Management practices[a]	3	11.1
Immersed digits of pigs in swamps or water ponds	3	11.1

[a] Changed animal dwellings (n = 2), improved cleanliness of the animal dwellings (n = 1).

4. Discussion

To the best of the authors' knowledge, this is the first study on knowledge and practices relating to animal tungiasis. In Uganda especially among the rural communities, household heads are often entirely responsible for the welfare of their households and are conversant with the state of affairs of their respective households. These were therefore targeted as primary respondents for the study. Proper information on the knowledge and practices towards tungiasis management is critical for development of appropriate and acceptable interventions for endemic communities.

Despite the low levels of formal education and lack of public health education among the community members in the study villages of Bugiri district, levels of knowledge on human tungiasis were quite high but comparatively very low on animal tungiasis. Since public health education targeting tungiasis had never been conducted, most of the knowledge could have been acquired through personal experiences and passed on from senior community members to the young generation. Similar findings on human tungiasis have been reported in tungiasis-endemic villages of Brazil (Winter et al., 2009) and Kenya (Kimani et al., 2012).

With a few exceptions, the major predispositions to human tungiasis were well known to most respondents. Although no human tungiasis risk factor study has ever been conducted in the study area, studies in South America (Muehlen et al., 2006), Nigeria (Ugbomoiko et al., 2007) and the neighbouring district of Mayuge, Uganda (Wafula et al., 2016), reported animal reservoirs, dusty dwellings and poor environmental sanitation as key determinants for tungiasis in humans which were well known to most community members.

Due to the occurrence of severe tungiasis among neglected individuals such as the mentally and physically disabled, elderly, neglected children and alcoholics who rarely observe good body hygiene, some community members tended to associate the occurrence of tungiasis with poor body hygiene. Dirty clothes and dirty feet have also been associated with tungiasis among humans (Wafula et al., 2016). Similar observations have been reported in rural Kenya (Kimani et al., 2012).

The communities reported termite mounds and bushes as favourable ecological sites for sand fleas and these sites are also preferred habitats of rodents. Peri-domestic rodents have been reported as important animal reservoirs for *T. penetrans* (Heukelbach et al., 2004; Ugbomoiko et al., 2008). However, 65 rats trapped during the survey period from the study area were not infected with *T. penetrans* (Mutebi et al., 2015). This calls for further studies regarding the contribution of peri-domestic and sylvatic reservoirs to the epidemiology of tungiasis in the study area.

The high prevalence of tungiasis in the study community (Mutebi et al., 2015), may have prompted more than half of the households to actively undertake measures towards the prevention of human

tungiasis. Since the sand flea ecology and tungiasis predispositions were known to most community members, preventive measures are partially based on a sound rationale, but applied only irregularly and are not validated. Floor smearing with cattle manure is an old practice of minimising dust in human dwellings in Uganda but its effectiveness in tungiasis control has never been investigated.

The low level of knowledge about animal tungiasis could be attributable to the low coverage of veterinary extension services and limited knowledge of animal health workers on animal tungiasis (Mutebi et al., 2017). A few community members reported to have ever seen tungiasis among dogs and pigs and only few pig owners knew that their pigs were infected with *T. penetrans* during the study. Pigs and dogs had the highest prevalence, intensity of infections (Mutebi et al., 2015) and most severe infections of *T. penetrans* (Mutebi et al., 2017; Mutebi et al., 2016a). However, as the case with humans (Feldmeier et al., 2004), a few individual animals usually carry the highest parasite load and the majority have only a few embedded sand fleas (Mutebi et al., 2015). Also, some heavily infected animals, especially pigs, may carry high parasite loads without any apparent effect on animal health (Mutebi et al., 2016a). These facts coupled with the extensive management practices of animals in the study area may explain the low detection rates of tungiasis among animal owners hence its consideration as a mere nuisance among animals, a phenomenon also reported in endemic villages for humans (Winter et al., 2009). It is not surprising that no deliberate effort towards animal tungiasis control was reported among most households.

Irrespective of level of knowledge, inappropriate methods of tungiasis treatment were applied in both humans and animals which may be health hazards themselves. Extraction of sand fleas using a variety of instruments is the preferred method of tungiasis treatment in the communities. Extraction of embedded sand fleas is a very old practice of tungiasis treatment (Vaira et al., 2014) which is wide spread even in other endemic communities in Kenya (Kimani et al., 2012), Brazil (Winter et al., 2009) and other parts of Uganda (Wafula et al., 2016). Mechanical removal of sand fleas using non sterile instruments is not only painful but may also predispose individuals to secondary bacterial infections and the sharing of sharp extraction instruments is a potential portal for the transmission of blood borne infections such as HIV and hepatitis viral infections (Feldmeier et al., 2012). The pain associated with the extraction of the embedded sand fleas may also discourage their removal amidst persistent infections especially among children. This may contribute heavy infections among individuals.

In most households, extraction sores were never treated to control sepsis further compounding the risk of secondary bacterial infections. In a few instances, where attempts were made to treat the extraction sores, inappropriate methods were used. Some methods such as use of cattle manure and dust on wounds increase the risk of secondary bacterial infections while some chemicals applied such as insecticides may be toxic. Also, the use of various antibiotic formulations may contribute to antimicrobial resistance.

Chemical treatment of tungiasis ought to be introduced and its use disseminated in the communities to avoid the dangers and difficulties that are associated with sand flea extraction. Zanzarin, a coconut extract (repellent) (Thielecke et al., 2013) and dimeticone, a physical tungicidal remedy (Feldmeier 2014; Nordin et al., 2017; Thielecke et al., 2014) have been demonstrated to abate tungiasis-associated morbidity. In Malawi, benzyl benzoate paint and liquid paraffin have also been used successfully in the treatment of morbidity due to tungiasis in Malawi (Mitchel and Stephany, 2013). These may be adopted as safe alternatives to sand flea extractions. However, this requires enormous financial resources which are far from the reach of the poor. Moreover, Zanzarin is no longer on market. Thus, public and private sector synergies are critical for optimal results.

Animal tungiasis has the potential to discourage livestock farmers to abandon their favoured enterprises. For example, 13 of the 19 respondents who attempted to eliminate tungiasis from their animals considered the sale of infected animals as the most effective method of eliminating tungiasis from their households. This may in the long run worsen the economic challenges in endemic communities. For better animal health and elimination of human health hazards due to animal infections, affordable and effective animal tungiasis treatment methods ought to be introduced. Recently, a topical aerosol containing chlorfenvinphos 4.8%, dichlorphos 0.75%, and gentian violet 0.145% was shown to be very effective against embedded sand fleas and abates severe morbidity due to tungiasis in pigs (Mutebi et al., 2016c). More alternative effective tungicidal and prophylactic formulations for use in combination with protective management practices ought to be identified.

In the study communities, tungiasis in humans does not result in seeking health care, probably because people know that health workers may not help them and they may suffer stigma. The study revealed that public interventions towards animal and human tungiasis control are greatly lacking. This confirmed the concern that tungiasis is an extremely neglected tropical disease (Heukelbach et al., 2001). Therefore, more efforts should be geared towards the control of tungiasis through public, private and academic sector partnerships. One of the major limitations of the study is that in depth investigations of the attitudes of respondents was not undertaken.

5. Conclusions and recommendations

The study has revealed high levels of knowledge on human tungiasis but very limited levels of knowledge on animal tungiasis. There are however, many myths about tungiasis, some of which may contribute to stigmatisation of affected persons and persistence of tungiasis. Inappropriate methods of human and animal tungiasis treatment are applied in the communities posing serious dangers to human and animal health. Therefore, more efforts should be put into community sensitisation and education regarding appropriate tungiasis control and treatment practices to minimise and eventually eliminate tungiasis.

Competing interests

Authors have no competing interests to declare.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.actatropica.2017.10.003.

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