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Assessment of the Role Played by Housing Conditions in Exacerbating Tungiasis in Kandara Sub-County, Kenya

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ABSTRACT

Jigger infestation, also referred to as Tungiasis, is a skin health problem usually associated with poor people. It is caused by penetration of female jigger flea, *Tunga penetrans* into the skin of a disposed host and, the consequent hypertrophy of the parasite. The disease is zoonotic in nature. The objective of this survey was to assess the role that housing conditions play in aggravating tungiasis in Kandara Sub-County of Murang'a County. This was a 50:50 case-control survey involving 776 participants. The participants filled questionnaires with the assistance of community health extension workers. Univariate regression analysis was conducted between case and control variables. Variables showing significant differences were then analyzed in a multivariate regression to identify those that were independent in abetting jigger problem. The results showed that the infested participants were 1.6 times more likely to live in earthen houses while the floors of their houses were 4.2 times more likely to be earthen when compared to the control. About 54% of these house floors were also cracked and dusty while 49 % of them had cracked rough walls. There was no single parameter that stood out as an independent variable. The findings of the study demonstrated a high relationship between dilapidated housing and jigger infestation in Kandara Sub- County. These results will enable efficacious interventional measures to ultimately control jigger infestation.

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1. Introduction

Tungiasis is a parasitic disease caused by penetration of the female sand flea (*Tunga penetrans)* into the epidermis of both human and animal hosts and the subsequent hypertrophy of the parasite (Heukelbach, *et al*., 2003). *Tunga penetrans* is a flea of order Siphonaptera in the Hectopsyllidae family. The flea originally occurred in South America and Caribbean islands but was inadvertently, introduced into sub-Saharan Africa, in late 19th century (Heukelbach et al.,2001; Maco et al.,2011). In Kenya, tungiasis is endemic in Coastal and Rift valley counties, Nyanza region, Western and the central parts of the country

(ROK,2014). Kandara Sub-County has recently become an area of much concern to the Kenya government public health personnels due to the perennial jigger health problem in the area. According to medical authorities in the Sub-County, not much has been done in evaluating the risk factors that could be aiding in aggravating tungiasis in the region. Housing factor was the focal point of this survey. In many circumstances, housing has acted as a major social determinant of health, affecting both mental and physical wellbeing of human beings (WHO,2018). Poor housing can thus affect human negatively and encourage development of diseases. Tungiasis is among many diseases aggravated by poor housing (WHO,2018). Sand flea hides in cracks and crevices on the walls of houses, floors and furniture; it normally avoids light (Wafula et al.,2016). Breeding occurs in the sleeping and resting places of the predisposed hosts, usually in dust, dirt, rubbish, carpets, birds' nests and animal burrows (Nsanzimana et al.,2019). Human are infested when they come into close contact with the floor, soil or clothing harboring the adult sand flea (Feldmeier & Keysers, 2013). Ordinarily infestation occurs inside classrooms and dwelling houses with no solid floors. Peridomicile has also been a potential source of infestation (Feldmeier & Keysers, 2013).

The kind of the wall and floor of a house, and their prevailing condition are thus a dominant factor in tungiasis. Poor houses are normally a characteristic of economically deprived people. People like these also keep the little foodstuffs they harvest, like grains, in their dwelling houses (Feldmeier & Keysers, 2013). This attracts peridomestic animals like rats to come and make their burrows, especially in the corners of the earthen houses establishing more sites for sand flea to multiply. Rats act as sylvatic hosts in the spread of tungiasis (Mutebei et al,2015). This has been observed in shanties and shacks which are common dwelling structures found in slums like the favellas of Brazil where tungiasis is rampant (Mutebei et al,2015). Heavy infestation with sand fleas in a dwelling house is predictable by stains of undigested blood expelled by the fleas on the beddings and general clothing. Off host stages of jigger flea life cycle (egg, larva, pupa) occur in the soil. Thus, the prevailing edaphic factors inside the house and the accompanying structural conditions are very crucial in jigger infestation (Mutebei et al,2015). Most of the dwelling houses in Kandara Sub-Count are earthen with uncemented floors.

According to the findings of the pilot study, the role of housing factor in tungiasis prevalence has not been assessed in the study area in spite of the heavy burden this disease has meted on the local community. This was according to the confessions of the local public health officer who indicated that past chemical-based interventions by the government had been largely unsuccessful in taming the jigger menace. A case- control survey was conducted to establish whether deprived housing settings may have contributed in deteriorating jigger problem in this region of central Kenya. This was to test the hypothesis that poor housing conditions contribute in abating jigger infestation.

2. Materials and methods

Survey area and population

This research was carried out in Kandara Sub-County in Muranga County. The Sub-County is located approximately 60 km from Nairobi city. The area has two rainy seasons with the precipitation ranging between 1200 and 1600 mm. The temperature ranges between 20 and 36 °c. Kandara Sub-County is precisely located at latitude 0 ° 54’ 0 S and longitude 37° 0’0 E. The Sub-County has an area of about 237 sq km with a population of 175098 people as indicated by 2019 national census (Kenya National Bureau of Statistics,2019). The living conditions of this community is characterized by decrepit earthen housing, overcrowding and high unemployment. Unhygienic conditions and illiteracy are also widespread. Poverty level is high with most families managing to survive on an income of below $ 50 per month. The following is the map of Kandara Sub-County depicting the six wards where the study was conducted (Figure 1).

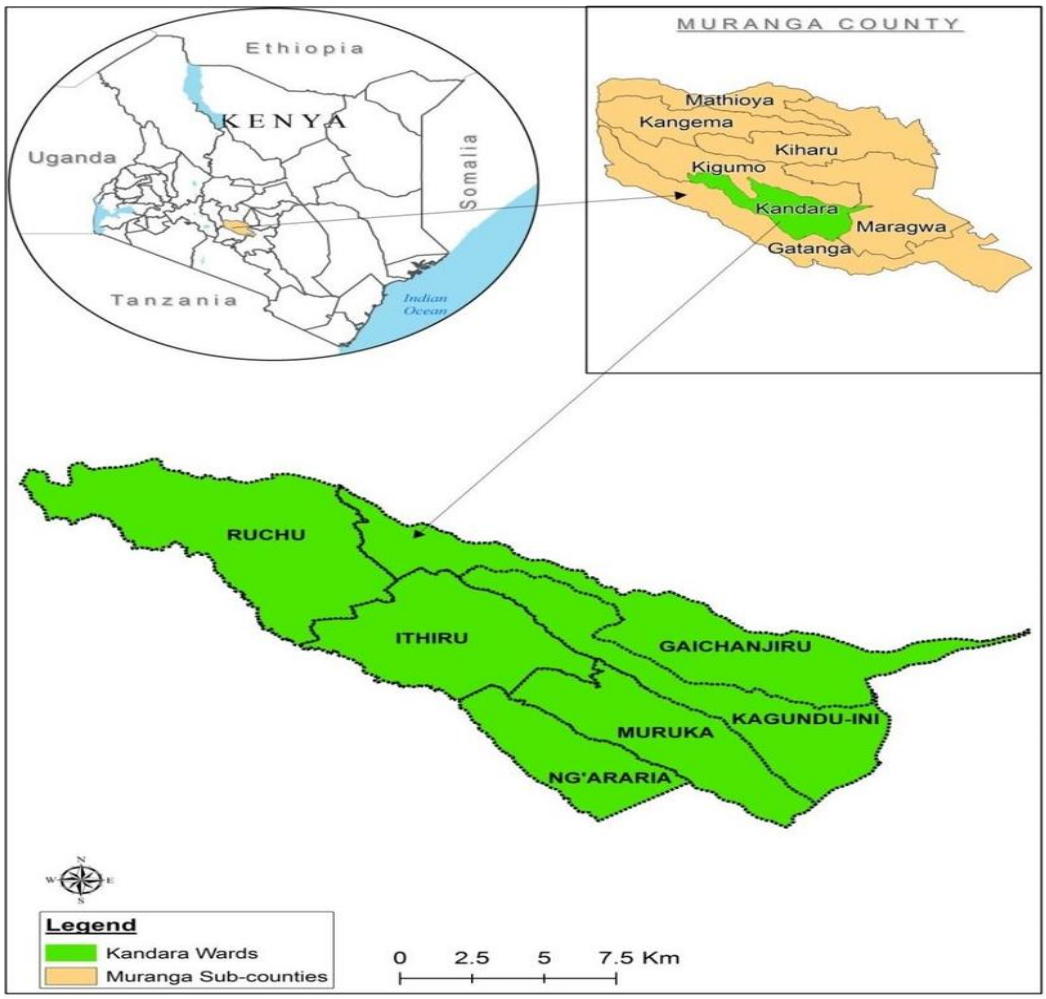

Figure 1: Map of Kandara Sub- County

Ethical clearance and consenting

This study was cleared by Kenyatta National Hospital & University of Nairobi ethics committee (KNH-ERC/A/331). Participants were entreated to fill consent forms only after willingly agreeing to join the study. The consent form in the local language (Gikuyu) was provided for those who were poor in English. The respective guardians were called upon to sign forms for the mentally handicapped, children and those elderly. Witnesses were also called in to assist the illiterate and those unable to write.

Community entry

The study team started by first familiarizing themselves with the research area and resident population. After submitting permit and ethical approval certificates copies to county administrators, authorization was then sought from director for health in Muranga County and local administrative leaders including chiefs and village headmen. Support of the County Public Health Officer and his community health extension workers (CHEWS) was sought at the commencement of the survey to aid in identifying the homes with jiggers. This survey was carried out between August and November 2019, a period which is generally dry and when jigger problem is usually high in Kenya.

Inclusion and exclusion criteria

All categories of people including the very aged, children, mentally challenged and illiterate persons qualified for this survey because the witnesses and guardians aided in handling such cases. Those who had not lived in the research area for the past two months were nevertheless excepted from the survey since they might have moved into the area while already infested, and hence the factor under investigation may not have contributed.

Pretesting of data collection tools

Data sheets and questionnaires were tested in a pilot study carried out in the research area, an undertaking that aided in obtaining information that would assist in perfecting the main research. It was also crucial in helping the survey team to acquaint with the participants and the area of the study.

Study design

Case- control survey design (Figure 2) was employed in this study.

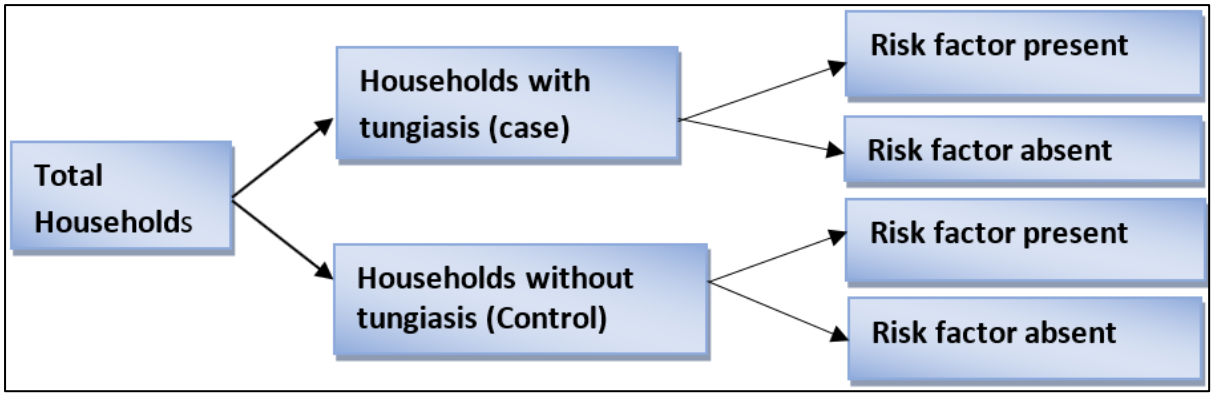

Figure 2: An illustration of Case-Control study design

Sampling method and sample size determination procedure

A case- control study sampling design was used to establish sample size basing on prior surveys conducted in Nigeria, Kenya and Brazil (Elson et al, 2019). Epi Info, a software developed by Centers for Disease Control and Prevention (CDC) was used to autogenerate the sample size basing on the following assumptions: hypothetical proportion of controls with exposure 80%; case-control-ratio of 1:1; least detectable odds ratio of 1.5; confidence level 95%; power of the test 80%. This necessitated the use of 388 cases and 388 individuals for the control.

Case group and control recruitment

Case category individuals were randomly chosen from the six wards in Kandara with the help of Community Health Extension Workers (CHEWS). Due to the numerous tungiasis eradication campaigns carried out in Murang'a County, CHEWS have data of all tungiasis afflicted homes in the wards. With the help of this data, 67 jigger infested people (case) were randomly selected from each ward using randomly generated numbers. This made it possible to attain the 388 needed for the study and, an extra 14 individuals to take care of any eventual drop out of participants. The actual number of infested participants for the analysis was however 388. Only one person per home was selected for the study so as to include as many households in the survey as possible. From the immediate locality of each tungiasis afflicted home chosen, five homesteads without tungiasis were earmarked for selection of the control and allotted random numbers. From a cluster of these five, one home was randomly selected to be part of the control. Consequently, a total of 67 individuals were selected for the control resulting in a ratio of 1:1. All the participants were entreated to fill questionnaires for the survey. The geographical distribution of the study homesteads, by the use of a GPS, was shown on Kandara Sub- County map (Figure 3).

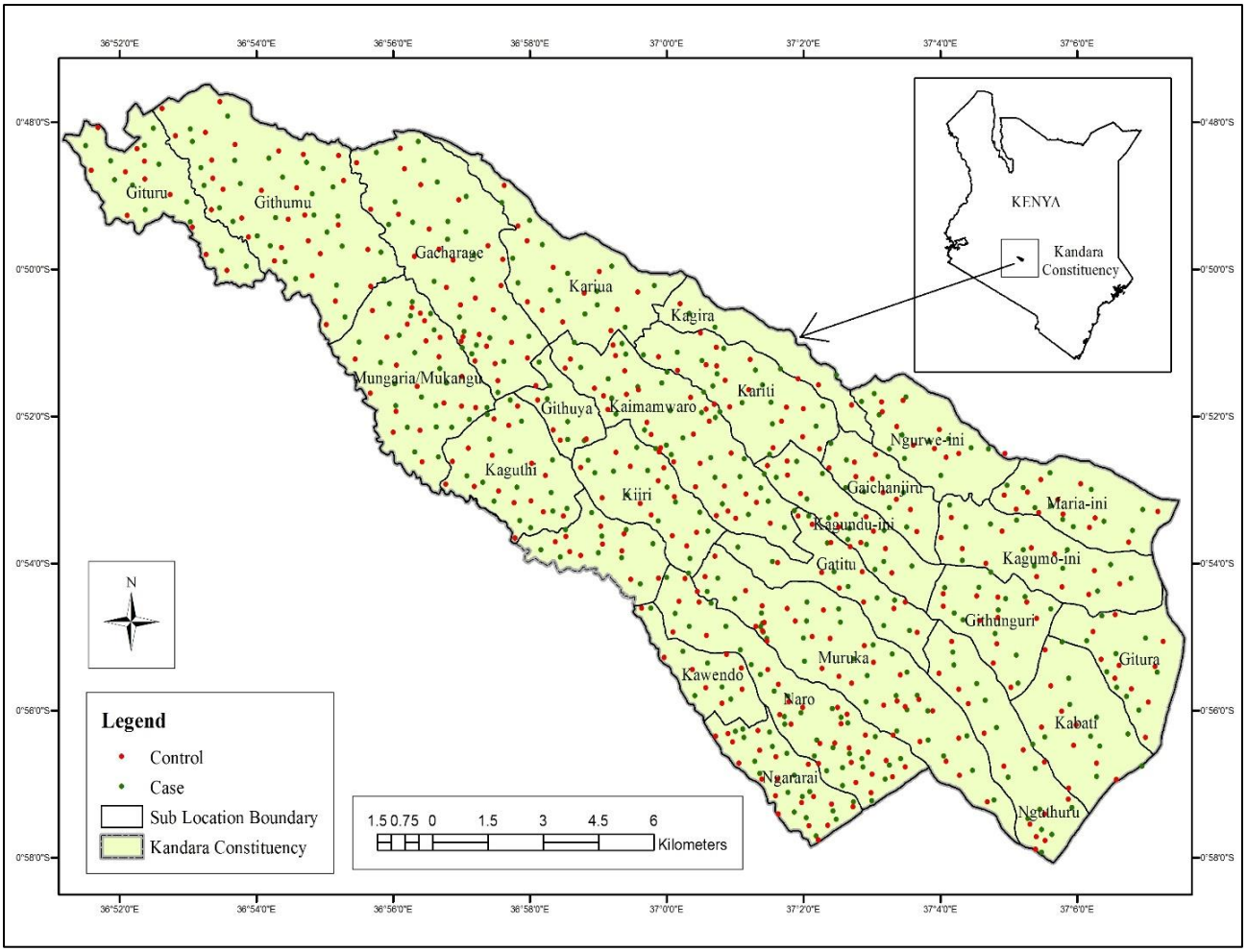

Figure 3: Kandara Sub County map showing the location of the study homesteads

Data collection and analysis

Research participants filled specially structured questionnaires with the assistance of CHEWS. The survey involved the assessment of the various parameters associated with housing. The questionnaires thus had questions concerning the type of the house and the condition of the floor and the wall (Table 1). The data attained were recorded in excel spreadsheets and examined for any arising typographical errors. They were then entered into SPSS (23.0) for univariate regression analysis to determine the Odds Ratios together with their 95% confidence intervals.This was in order to establish the significance of the differences in housing parameters between the case and the control groups. After this analysis, all the variables depicting significant differences were further analysed in a multivariate regression to find out those that stood out independently in aggravating the jigger health problem in Kandara Sub- County.

Results and interpretation

Univeriate analysis results were presented in table 1 as shown below. The odds ratios of value 1.0 demonstrated a situation of equal risks of exposure to tungiasis between the case and control. Odds ratios of values greater than 1.0 indicated that the parameter being

investigated may have exposed the case participants to tungiasis more than the control.Odds ratios of values less than 1.0 were an indicator that the factor being investigated had not contributed in aggravating jigger problem among the case participants and in some cases the specific factor may have been protective against the disease.If the p – value was equal or less than 0.05, the difference in exposure to tungiasis between the case and control was significant.

Table 1: Univariate analysis of housing related parameters

Variables	**Case (%) (N=388)**	**Control (%) (N=388)**	**OR (95%CI)**	***P* value**
Type of the house				
Adobe	52 (13.0)	28 (6.5)	1.99 (1.23-3.23)	.003
Earthen	124 (32.6)	88 (22.8)	1.60 (1.16-2.20)	.002
Concrete/stony	56 (14.1)	154 (40.8)	0.26 (0.18-0.36)	< .001
Wooden	46(11.4)	28 (6.5)	1.73 (1.05-2.83)	.015
Iron sheets	110 (28.8)	90 (23.4)	1.31(0.95-1.81)	.051
Type of floor				
Earthen	310 (81.5)	198 (51.1)	4.2 (2.6-6.8)	< .001
Cemented	78(18.5)	190 (48.9)		
Condition of the floor				
Cracked and dusty	203 (53.8)	77 (19.6)	4.43 (3.22-6.09)	< .001
Cracked without dust	61 (15.2)	67 (16.8)	0.89 (0.61-1.31)	.281
Smooth and dusty	23 (4.9)	27 (6.0)	0.84 (0.47-1.49)	.279
Smooth without dust	101 (26.1)	217 (57.6)	0.27(0.21-0.38)	< .001
Condition of the wall				
Rough with cracks	189(49)	79 (20.1)	3.71(2.71-5.10)	< .001
Rough without cracks	57 (14.1)	53 (13.0)	1.09 (0.73-1.63)	.340
Smooth with cracks	23 (4.3)	19 (3.8)	1.22 (0.65-2.29)	.263
Smooth without cracks	119(31.0)	237 (63.0)	0.28(0.21-0.38)	< .001

***P*-value ≤ 0.05 indicated a significant difference in the level of exposure between the case and control participants**.

There were significant differences in almost all the variables examined. The jigger infested people were 1.60 times more likely to live in earthen houses (1.60;95%CI:1.16-2.20; *P*< .002). They were also 4.2 times more likely (Figure 4) to live in earthen floored houses (4.2;95%CI:2.6-6.8; *P*< .001). Majority of the case participants houses (54%) had dusty cracked floors (Figure 5). Jigger infested individuals were also 3.71 times more likely (Figure 6) to live in houses with rough and cracked walls (3.7;95%CI:2.7-5.1; *P*<.001).

All the variables depicting significant differences in univariate analysis were subjected to a multivariate analysis to establish those that would exacerbate jigger infestation independently. Adjusted odds ratios (AOR) together with their P-values were calculated. A P-

value greater than 0.05 indicated that the parameter being analyzed would not independently abate tungiasis regardless of its adjusted odds ratio value. As shown by all the P-values (which were greater than 0.05), there was no specific housing variable that exhibited independence in aggravating jigger problem in Kandara Sub County (Table 2).

Table 2: Multivariate analysis of housing variables

Variable	AOR (95% CI)	P- value
Type of house		
Concrete/stony	*Reference*	
Adobe	1.1 (0.1-9.1)	0.928
Earthen	0.7 (0.2-3.3)	0.669
Wooden	3.7 (0.6-23.7)	0.164
Iron sheets	2.2 (0.4-10.8)	0.337
Type of floor		
Earthen	3.6 (0.9-14.5)	0.069
Cemented	*Reference*	
Condition of the floor		
Cracked and dusty	3.6 (0.7-18.2)	0.128
Smooth without dust	*Reference*	
Condition of the wall		
Rough with cracks	0.7 (0.1-3.5)	0.649
Smooth without cracks	*Reference*	

***P*-value ≤ 0.05 indicates that the specific variable would aggravate jigger infestation independently (without a reinforcement by other variables)**

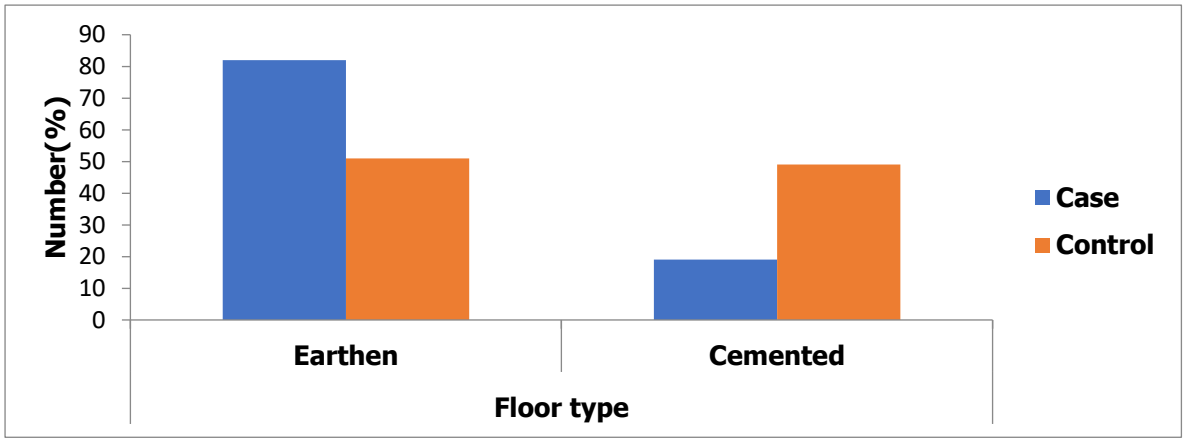

Figure 4: Difference in floor type

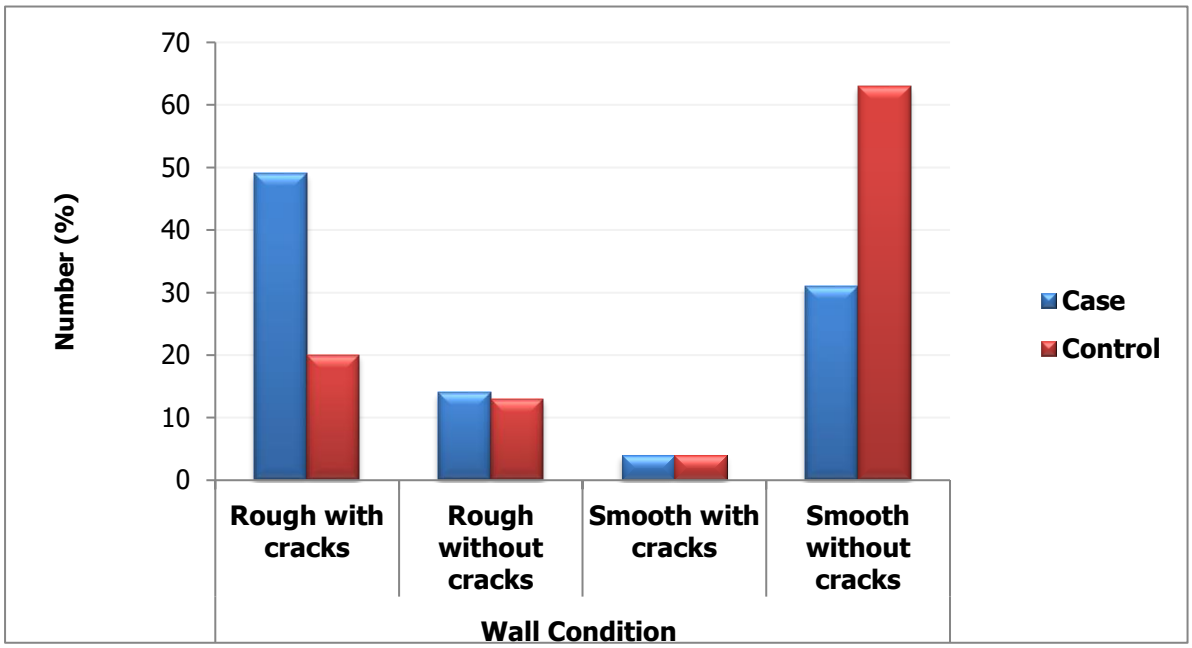

Figure 5: Difference in floor conditions between the case and control groups houses

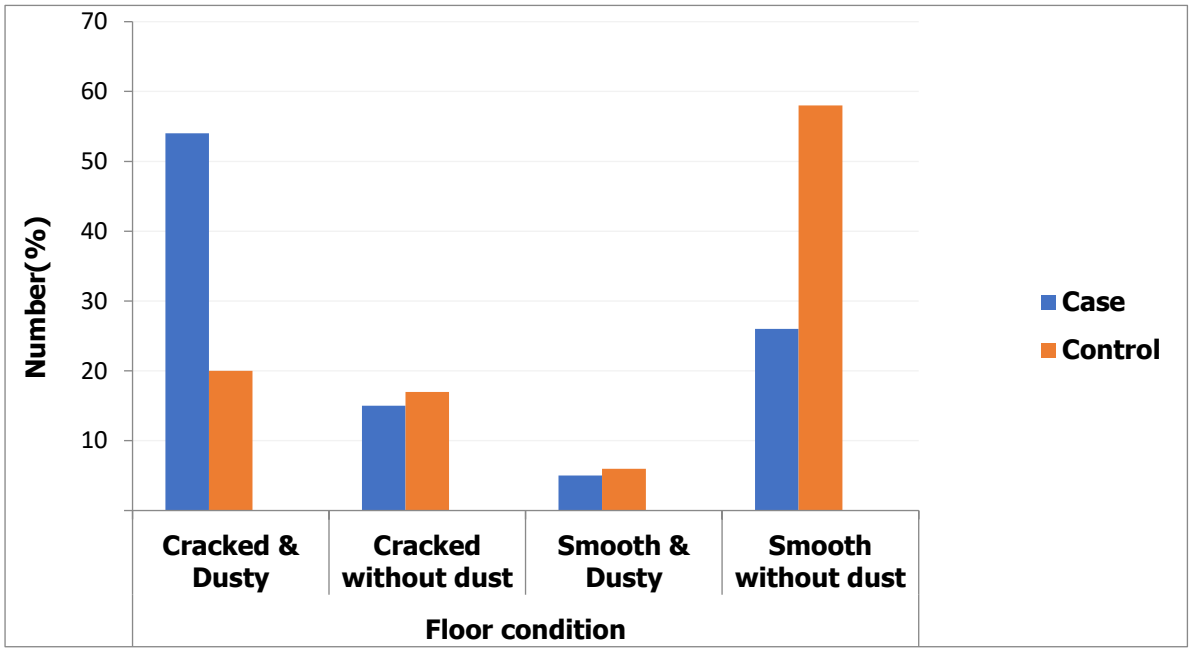

Figure 6: Difference in wall condition between case and control participants houses

Figure 7: a. A woman resting outside her earthen house.
b. Woman's feet showing jigger infestation.
c. An earthen cracked-walled house whose occupants presented with jigger infestation.

Figure 8: A cemented cracked floor of a house of jigger infested occupants.

Figure 9: A dilapidated earthen wall of a house of jigger infested occupants.

3. Discussion

Poor housing plays an important role in jigger health problem as most stages of sand flea life cycle occur in the soil neighboring the host. In Kandara Sub- County, majority of the jigger infested individuals live in earthen houses (Figure 4). This is attributed to the fact that jigger infested people are normally very poor, earning below the demands of human basic needs (Mazigo et al., 2011; Feldmeier et al.,2016). They hence cannot afford to build concrete houses at the expense of their basic needs, especially food. This concurs with many studies conducted in Nigeria, Tanzania and Brazil where the researchers concluded that tungiasis is a disease of the poverty-stricken people who live in earthen houses where jigger flea can breed and multiply with ease (Mazigo et al., 2011; Feldmeier et al.,2016; Ruttoh et al.,2012; Kamau et al., 2014).

Surveys conducted in Kenya, Brazil and Nigeria have indicated that living in houses with earthen floors is a risk factor for jigger infestation as off- host stages of the flea are normally completed indoors (Waruguru et al., 2015). Survey of soil samples in Brazil indicated that those picked from peoples' sleeping houses were mostly infested with sand fleas. Infestation was especially high in the samples obtained from part of the floor under the hammocks and beds (Linardi et al., 2010). This has also been corroborated by other studies conducted in Uganda and Kenya which showed that earthen houses largely contribute in jigger flea multiplication (Elson et al., 2017).

Though majority of jigger infested individuals live in earthen houses, house type does not appear to be an independent factor in this study as almost 50% of the control living in earthen houses were jigger free. This is similar to other studies conducted in Murang'a (Kenya) and Nigeria, where house type is not an independent factor in jigger infestation but is linked to

the floor type, cracks on this floor and on the wall of the specific house (Njau et al.,2012; Kamau et al., 2014; Ugbomoiko et al.,2007). In addition, other studies have reported that house type may also be associated with the level of lighting, as jigger flea prefers to hide in dark environment. Waruguru *et al*. (2016) reports that majority of jigger infested people used paraffin lamps, which normally provide inadequate lighting.

The earthen houses where most of the jigger infested people in this study lived had dusty walls and floors, largely with cracks (Figures 5, 6 & 7). Earthen walls tend to emit dust and sand that serve as breeding places of *Tunga penetrans* (Wiese et al.,2017). Some studies conducted in Africa and Brazil have reported that jigger flea breeds with utmost success in dusty sandy soil (Ugbomoiko et al,.2007). The cracks in both wall and floors act as hideouts for adult sand fleas in the pupa state where they wait for the susceptible hosts' vibrations to trigger them into action. Building concrete walls therefore can reduce jigger prevalence by 64% (Feldmeier et al.,2004). It is noted that smoothening walls and floors with clay or a mixture of cow dung and ash in earthen houses also destroy these hideouts (Mwangi et al.,2015). Where African communities have used this mixture as a jigger control measure, tungiasis prevalence has been seen to decline (Mwangi et al.,2015). Dung is a potential nutrient for sand flea larva and thus the opposite is, expected to happen if applied alone. When ash is however added, positive results have been reported (Mwangi et al.,2015). Further studies are thus called for to establish whether the ash brings about the desiccation on the larva or some other unknown but important aspect in jigger control.

Cementing the floors of concrete houses, likewise, helps in lowering the prevalence of tungiasis as this interferes with the ecology of jigger flea. Recent studies conducted in Brazil, Kenya, Ethiopia and Nigeria associated jigger infestation largely with cracks (Figure 8) and dusty floors (Muehlen et al.,2006; Suresh Kumar et al.,2016). Floor type and condition are also linked to the level of the prevailing moisture, Ph, temperature and organic matter content as the larva depends on the latter as food(Kimani et al.,2012;Feldmeier et al.,2003).Too much water in the soil is known to clog up the larva spiracles bringing about their death. This is why the most common means of jigger control has been pouring water on the floor.Organic matter also determines the level of moisture in the soil. Soil Ph influence(Brandy & Weil, 1999)the activities of microbes involved in the breakdown of organic materials(Brandy & Weil, 1999).Soil Ph is in turn influenced by moisture and temperature.Ph levels affect the osmotic balance of sand flea and thus significant in its life cycle(Brandy & Weil, 1999).Neutral Ph favours the multiplication of jigger flea while extreme levels negatively affects its life cycle(Pilger et al.,2008).

In earthen houses, rats are able to make their burrows especially in the inaccessible corners of the dwelling structures (Figure 9). This is mostly common in cases where people keep foodstuffs like grains that can attract rats. These burrows act as good breeding sites for jigger flea due to the rats' excrements, together with the rodent itself playing a sylvatic host to the ectoparasitosis (Pilger et al.,2008).

4. Conclusion

It was found that 81.5 % of Kandara jigger infested residents live in earthen floored houses with 53.8% of their houses having dusty cracked floors, and 049% of them with cracked walls. These three factors were found to create a favorable environment for the multiplication of the sand flea. This poor housing status has largely contributed to the perennial tungiasis health problem in the area in spite of the many chemical-based interventions by the government. 0

5. Recommendations

The ministry of land, housing and urban development should demolish the poor earthen houses in Kandara sub-County and replace them with cemented concreate ones, so as to help abate the jigger health problem in the area. As the poor housing factor is not independent in exacerbating tungiasis, there should be concerted efforts by the ministry of health and other stake holders like African health and development international to eradicate poverty in this region; poverty makes people resort to building poor dwelling structures which aid in abating diseases like tungiasis. Robust anti- jigger campaigns should be conducted in kandara Sub-County in which the residents are educated on tungiasis control and preventive measures, especially on the importance of concrete houses in the management of jigger health problem.

6. **Conflict of interest**: All the authors declare that there is no conflict of interest in this study

7. Acknowledgement

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