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From Mud and Stick-Walled Houses to Corrugated Iron Sheet Houses: A New Strategy for Preventing Human-Vector Contact in Marigat Sub-County; a Leishmaniasis-Endemic Area in Kenya

Peter K. Ngure[1], Anastasia M. Nzau[1], Martha W. Kiarie[2], Abraham K.Waithima[2], Michael K. Bowen[2], Johnstone M. Ingonga[3], and Philip M. Ngumbi[3]

[1]Department of Technical and Applied Biology, Technical University of Kenya, Kenya
[2]Department of Science and Health, Daystar University, Kenya
[3]Centre for Biotechnology, Research and Development, Leishmaniasis Laboratory, Kenya Medical Research Institute, Kenya

***Corresponding author**
Anastasia Nzau, Department of Technical and Applied Biology, Technical University of Kenya, P. O Box 52428-00200, Nairobi, Kenya, Tel: 254-721-632-251; Email: stembinya@gmail.com

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- House improvement

Abstract

Objective: The objective of this study was to assess if improved housing would result in reduced sand fly-human contact which in turn would be assumed to result in reduced chances of leishmaniasis transmission. The transmission of leishmaniasis is heavily influenced by socio-economic factors and this is the main reason why it has been described as the disease of the poor.

Methods: This studied compared the sand fly densities in targeted houses before and after improvement. The houses to be improved were selected based on indoor sand fly density, construction materials and economic status of the household. These houses were upgraded to two-roomed corrugated iron sheet houses. Sand fly densities were determined using CDC light traps in the mud and stick-walled grass-thatched houses before moving the occupants to houses made of corrugated iron sheets. 146 houses were used, selected from 670 in the 4 villages.

Findings: There were significant differences ($p < 0.05$) in sand fly densities between the mud, stick-walled houses and the corrugated iron sheet houses; the improved houses had fewer sand flies. The average density of sand flies in stick-walled houses ranged from 32 to 13 compared to 4 to 1 in corrugated iron sheet houses.

Conclusion: The improved housing reduces the density of sand flies indoors; in turn reducing the vector–human contact hence reducing the chances of infective bites. This strategy is long lasting and has additional benefits to residents.

ABBREVIATIONS

VL: Visceral Leishmaniasis; CL: Cutaneous Leishmaniasis; WHO: World Health Organization; EVM: Environmental Modification; SERU: Scientific Ethical Review Unit; KEMRI: Kenya Medical Research Institute; NACOSTI: National Council of Science Technology and Innovation

INTRODUCTION

Leishmaniasis is a vector-borne disease caused by obligate intra-macrophage protozoa of genus *Leishmania*. Eastern Africa is one of the most affected regions, with an estimated annual incidence rate of 30,000 to 40,000 cases [1]. The countries most affected in this region are Sudan, South Sudan, Ethiopia, Eritrea, Somalia, Kenya, and Uganda. The disease typically affects poor communities residing in remote places characterized by poor infrastructure and lack of basic social amenities like proper housing [2]. This disease is caused by more than 20 *Leishmania* species and transmitted to humans by approximately 30 different species of phlebotomine sand flies.

The disease occurring in Baringo County presents in two forms; visceral leishmaniasis (VL) and cutaneous leishmaniasis (CL). The VL which is more prevalent is caused by *Leishmania donovani* and the main sand fly vector is *Phlebotomus martini* which breeds in termite hills, animal burrows, tree holes and house walls and transmission is believed to be anthroponotic [3]. The estimated average VL caseload per year in Kenya is about 600, according to the Ministry of Health, though in epidemic years caseloads have been reported to surpass 1,000 [4]. Half of the reported VL patients are between 5 and 14 years of age and 66% of them are males [5]. A recent study done in the area showed that the area is characterized by poor infrastructure and most of the residents (60%) live in poor houses which predispose them to the infective bite of the sand fly vector [6].

Like other vector-borne diseases, the first line of VL control world over, has been the control of the sand fly vector. Over the years, there has been advancement in methods of control and strategy. Initially repellents were used for protection against sand fly bites [7]. Later, other measures of control such as light traps, screening houses and then leaving windows of houses open in bedrooms at night to create constant air-movement, use of eucalyptus oil as repellent were introduced [7]. The use of animals, (lizards and geckos in cages) cows, goats and chickens near houses, have been employed to divert some sand flies from biting humans [8]. On strategy, there has been a shift from the application of one single method to the integrated approach with emphasis on community participation, while dealing with VL control among the poor [9,10].

The ecological distribution of the sand fly vector is wide and the *Leishmania* parasites are also diverse. This means that for a successful control program, the risk factors of VL in the region have to be well studied and clearly understood so as to tailor control to the risk factors in the given area. In Marigat Sub County, a good correlation between the proximity of houses or temporary settlements to termite hills and the risk of transmission has been established [6]. Having a low socio-economic status and lack of domestic animals in the compound was also identified as risk factors as observed in earlier studies [11]. Other works have reported mud plastered houses as suitable for the development of phlebotomine spp in the Indian sub-Continent [12], Brazil [13] and Kenya [14]. Based on this background; this study undertook to improve destitute housing so as to reduce sand fly densities in the houses as a new approach to the control of VL in Marigat Sub County.

MATERIALS AND METHODS

Study site

The research was done in the period April 2015 to March 2016 in the leishmaniasis endemic area of Marigat Sub-County in Baringo County, Kenya. This is the only region in Kenya where both visceral and cutaneous leishmaniases have been found together [14-16]. It covers an area of approximately 10,000 Km^2 and is located north of the Equator (N00^0 28' E035^0 58') in the Kenyan Rift Valley. The Sub-County is sparsely populated with a population of 555,561. Most of its populace 59.8% lives below a dollar a day [16-18]. The region exhibits arid to semi-desert climatic conditions and the terrain are very dry with little ground cover and dotted with numerous rodent burrows and termite mounds. The people depend on subsistence livestock rearing. The only areas where crops are grown are restricted to the Perkerra irrigation scheme where some commercial farming is practiced [6].

Most residents (60%) in the area live in huts made of either sticks closely stuck together and bound by rafters or wooden poles plastered with mud, while a very small minority lives in corrugated iron sheet houses [6]. Within the homestead, householders may live together in one house or in 2-3 houses which normally have one room or undivided space. In some homesteads one may find domestic animals including cows, goats, chickens and dogs; majority of these are good blood meal sources for sand flies [19]. Dogs also act as reservoirs of *Leishmania* parasites [20].

The area is home to a wide range of Old World sand fly species [18]. Visceral leishmaniasis caused by *Leishmania donovani* is endemic in the area and is of major public health concern. Half of the reported VL patients are between 5 and 14 years of age and 66% of them are male [5]. The main vector for the *L. donovani* parasite in this area is *Phlebotomus martini* [18]. The study was done in four villages namely: Rabai, Endao, Perkerra and Maoi. On average, thirty six houses were selected for upgrade in each of the four villages.

Trapping of sand flies and selection of houses for improvement

The selection of houses for improvement was based on sand fly densities inside the houses, construction materials, architecture and social economic status of the household. On selection, the houses were mapped using Geographical Positioning System (GPS).

Sand fly densities were determined using a CDC light trap. To trap sand flies in the houses, CDC light traps were set in houses at 1800hr and picked the following morning at 0600hr (Figure 1). The collection nets were well labeled with a number, type of house and village where trapping had occurred and taken to the field laboratory where the sand flies were aspirated, counted and recorded for each type of house. Trapping was done for three consecutive nights and this was repeated monthly for three consecutive months. After the trapping period an average catch was calculated for each house.

On construction materials, data was collected on materials used for the walls and roofs. The floor type; whether earthen, concrete, wood or finished in the traditional style of mud mixed with cow dung was noted. Presence of crevices on walls and floor, cracks on doors and windows were recorded. Details on whether walls were complete from base to roof, presence of doors and windows were captured. These factors were used to construct an index of house quality. The social economic status of the household owners was determined using a structured questionnaire. The questionnaire available in English, Kiswahili and the local (Tugen) language was filled by the household head. Those who could not read and write were assisted by members of their family or close neighbors of their choice, who could read and write. Based on this criterion, 36 houses per village were selected for upgrade.

Figure 1 CDC light trap set in a mud-walled house in Marigat.

The houses considered for upgrade were put into two categories based on the materials used to make the walls; the stick-walled houses whose walls were made of closely packed sticks, bound together by rafters leaving space in between (Figure 2), and the walls incomplete and uneven in height. The average sand fly catch from this type of houses was 44.

The mud-walled houses; made from poles and plastered with mud (Figure 3). The wall are so badly cracked that the mud is falling off. The average sand fly catch from this type of houses was 37.All the houses were grass thatched. There were no windows. All had doors but most (80 %) were not lockable and workmanship was poor. They were made from planks of untreated wood, leaving big spaces in between or old pieces of tin nailed on a wooden frame. In addition, they were not complete leaving big spaces above and below. The floors were earthen and cracked but dry since the residents cook from outside. The architecture was poor, (60%) of the structures were not upright. The materials used for construction of the houses were wooden. Wood is easily attacked by termites and the houses selected were already under attack.

The improved houses were made of corrugated iron sheets and timber poles. Each house cost about 500 dollars. The locals participated in the construction by providing labour; they ferried construction materials to the site, helped in fetching water, dug holes into which poles were fixed and those among them who were skilled masons hired to do the construction. The ends of the wooden poles fixed to the ground were treated with used engine oil to prevent attack from termites. Both the walls and roofs were made of corrugated iron sheets. The houses were two roomed with a concrete floor (Figure 4).

They were fitted with lockable wooden windows and doors. The residents were moved in to the new houses, allowed to settle in for one month. For the next three months, three consecutive nights of sand fly trapping were carried each month. At the end of the three month period, an average catch was calculated for each newly improved house and recorded.

Data management and analysis

Data were coded and analyzed using STATA® 12.0 statistical package.

Ethical consideration

This study was carried out after Ethical Clearance from, Scientific Ethical Review Unit (SERU) of Kenya Medical Research Institute (KEMRI). Written informed consent was also sought from the participants after discussing the purpose and methods of the study. The local administration was involved in the construction and relocation of the residents in to the new structures for support and security.

RESULTS AND DISCUSSION

Socio-demographic characteristics of study subjects

This study was carried out for a period of one year starting April 2015 to March 2016. This is because time was required to trap sand flies from the existing houses, pull them down, put up the new structures, allow for settlement and trap again for comparison.

Figure 2 Stick walled, grass-thatched house (Photo by Nzau 2016).

Figure 3 Mud-walled, grass-thatched house (Photo by Nzau 2016).

Figure 4 The new structure of the improved house (Photo by Nzau 2016).

a) Gender and age distribution: A majority of the participants were male (62.7%) which is common among patriarchal communities like those living in the Rift Valley region in Kenya. The 37.3% female who are beneficiaries of the houses is significant in the sense that these are either widows or single-parents that are economically marginalized considering that the culture system in the region does not allow them to own land or property. The average age of the recipients was 58 years with the youngest being 19 years and the oldest being 89 years.

b) The economic status: The majority (55.85%) of the recipients are unemployed with only 9.08% employed, the rest of

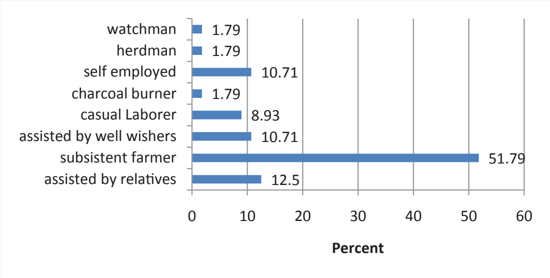

Figure 5 Means of livelihood.

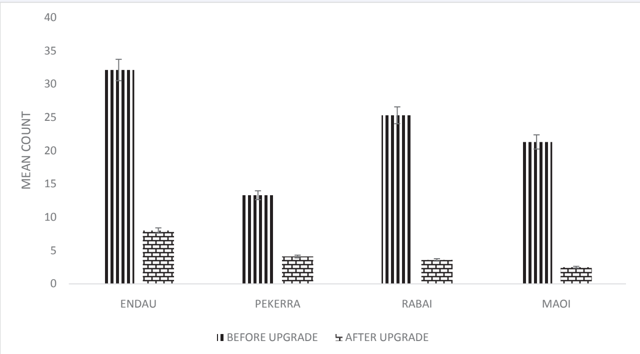

Figure 6 Comparison of average sand fly catches before and after house improvement.

the recipients are self-employed. The hardest hit group in terms of employment is females with 64% unemployed compared to 46% of unemployed males. While 13.78% of the men are employed, only 4.48% of the women are employed.

c) Means of livelihood: A significant proportion of the recipients depend on well-wishers (10.71%) and relatives (12.5%). A majority of the recipients are subsistent farmers (51.8%) keeping goat and cows at subsistent level (Figure 5), goats that cannot be sold to meet the daily needs of the family as they are held as the source of wealth by the male household heads. The only farming occurs at the Perkerra irrigation scheme that is held in trust by the national government and mainly used to grow seeds for distribution to other parts of the country, leaving the locals impoverished.

d) Monthly expenditure of the household heads: The average monthly expenditure per household is 49 dollars (4,950 Kenya shillings) with a huge variance of 26 dollars. A majority (53.7%) have a monthly expenditure of 10-50 dollars. Given that the average household size was found to be 5 people, the figures indicate that the majority live on less than a dollar per day. This would pose a challenge in affording or even seeking for treatment when infected or affected by visceral Leishmaniasis. This also explains the poor housing which is a major risk of exposure to the VL vector, the sand fly.

The value of the improved housing structure to the locals

The improved houses were made of corrugated iron sheets and timber poles. Each house cost about 500 dollars as the local participated in the construction by providing labour. The ends of the wooden poles fixed to the ground were treated with used engine oil to prevent attack from termites. Both the walls and roof were made of corrugated iron sheets. The houses were two roomed with a concrete floor. They were fitted with lockable wooden windows and doors. Other than protecting the occupants from the sand fly bites, the houses provide protection from elements such as rains and wind. Other benefits of the improved houses include separation of sleeping space for the children and parents, an important cultural aspect, children can seat and do their school work in a protected area and during rains people will be able to collect rain water; water is a scarce commodity in the area.

Comparison between sand fly densities before and after housing improvement

The improved house structures proved effective in reducing the numbers of sand flies getting in to rest indoors. The reduction in the number of sand flies trapped indoors before and after house improvement was significant as shown in Figure 6.

Paired Student t- test was used to compare prevalence before and after the house upgrade The finding indicated that there were statistically significant differences in terms of sand-fly prevalence ($p < 0.05$) between “before house upgrade” and “after house upgrade” in all the villages. This implies that upgrading houses significantly reduced the number of sand flies in the four villages. This would point to reduced human- sand fly contact.

DISCUSSION

The modification or improvement of houses and/or their surrounding environment either by filling in cracks or crevices in walls and floors is commonly referred to as environmental modification (EVM) [14]. This method targets endophilic sand flies by denying them favorable resting and breeding sites. EVM is a method that has not been studied much world over and in Kenya this study reports the findings of what may be the first study to the best of our knowledge on EVM.

The study was done in Marigat, a VL endemic area and the socio-demographic data clearly points to the fact that leishmaniasis is a poverty related disease. 60% of houses in the area were in deplorable state and favorable to habitation by sand flies. On economic status only 9.08% are employed and most of the residents live below a dollar per day. Interestingly, most female beneficiaries were either widowed or single parents and 32% of the beneficiaries had a family member affected by VL. The destitute houses were typically made of either mud or sticks and grass thatched with earthen floors. They were small in size and characterized by cracks and crevices.

This study targeted the vector with the view to reducing the vector-human contact. The new approach of upgrading housing was hinged on making dwellings unfavorable resting sites for the VL vector. The *P.martini* which is the vector for VL in Baringo is endophagic [21]. The study was complemented by earlier works which indicated that these types of houses provide ideal resting and breeding sites for sand flies in Kenya [16,22]. The stick-walled had higher catches than the mud walled. This is because the sticks are loosely packed leaving spaces in between that offer the sand flies easy indoor access. Further, some of the sticks were cracked providing favorable resting sites. On the other hand, the mud walls were extensively cracked both from the inside of the wall and outside. This offers suitable breeding site for *P. martini* which breeds in cracks on walls and floors [23]. The walls were generally low with big open spaces between the walls and roof which allowed easy indoor access by sand flies. The area is characterized by strong winds especially in the evening, time when sand flies come out to feed; the air currents easily carry the flies [24,25] over the low walls and wide space between the wall and roof into the house.

The improved houses were made of corrugated iron sheets both the walls and the roof. The choice of this material was guided by a number of factors; (i) the iron sheets are smooth/ crevice free hence depriving the vector of its resting and breeding site, (ii) iron is a good conductor of heat and given the high temperatures typical of the region would be unfavorable for the sand fly since phlebotomine sand flies prefer to rest in cool dark places and humid habitats [26]. Further, as common practice in the area, residents do not rest indoors during the day, preferring to rest under shade outdoors therefore, would not be affected by the hot conditions inside the houses during day time (iii) the more decent houses in the area were made of this material hence it was assumed would be more acceptable to the residents, (iv) the material does not retain moisture yet sand flies thrive in moist conditions. The floor was plastered with cement as opposed to the previous ones that were earthen. Female sand flies are known to deposit eggs in cracks and holes in the ground and floor of buildings [13]. The cement floor is easy to clean and keeps dry most of the time and has no cracks. This denies female sand flies suitable breeding sites as opposed to the earthen floor that had many cracks. The improved houses were two roomed, this eased congestion which is a risk factor for VL in this region. The houses had windows which allow natural light and free movement of air in and out. The dark conditions in the destitute houses favor the habitation of sand flies compared to the lighted conditions in the improved ones [27]. This further reduced the vector- human contact. The destitute houses were small, on average 5 ft. x 7ft. This small living space with an average of 5 people is highly congested forcing the residents to rest outside in the evening and only going inside to sleep at night. This habit exposes them to sand flies which are known to feed more at dusk and at night when temperatures fall [28]. In addition, the congested conditions enhance transmission in case a member of the family is infected. On the other hand, the improved houses are spacious; 12 ft. by 16 ft. with cooking area separated from sleeping area. The residents can rest indoors in the evening hence reduce chances of contact with the sand flies.

The improved houses also offer many added advantages. They provide privacy which was hitherto lacking in the destitute houses, improved hygiene since the concrete floor is easy to clean and boosted self-esteem. In addition, the construction materials were bought from local businessmen and the residents provided labor. This served to boost their income and encourage community participation which is an important factor in the sustainability of any control program. Further, the distribution of kerosene or fire wood lighting is better in the improved houses so the school going children can do their school work in the evening. During the short erratic rains, the residents can harvest rain water from the roof tops for domestic uses as well as getting protection from weather elements.

The results indicated significant difference in sand fly densities inside the houses before and after upgrade ($p < 0.05$). This means that, there was reduced vector – human contact and hence reduced transmission of the parasite. Research shows that *Leishmania* parasite can optimize its transmission through behavioral manipulation of the infected fly. The infected fly becomes more tenacious, returning to feed more readily and delivering more bites than uninfected flies [29], improved housing greatly reduces this interaction.

From the foregoing, it is clear that, the fight against VL by targeting the vector remains feasible; however there is need for control strategies to be tailored to the risk factors in the region. In Marigat Sub-County, destitute housing is a major risk factor [6] and therefore improving finishing on walls or improving the structures is an environmentally friendly and sustainable approach in the control of VL in the area. However owing to the diversity of the sand fly vector and it's breeding and resting sites, there is not one single method that fits all. Therefore from the findings of this study, improving housing, when integrated with other methods can provide sustainable control of VL in Marigat Sub-County.

CONCLUSION

The findings indicated that there was a relationship between the house type/structure and the density of sand flies indoors, as indicated by the size or number of the sand flies trapped. There were more sand flies trapped in the stick-walled houses than in the mud-walled houses. The house type influenced the accessibility to the indoors by the sand flies for resting and feeding. This in turn influences the contact between this vector of leishmaniasis and its human host, influencing the transmission of the visceral leishmaniasis. The results indicated that by improving the house structure from mud and stick wall to corrugated iron sheet walls and roof, the density of sand flies indoors decreased significantly. This means by improving the house, one is able to separate the vector and the human host hence reducing bites by the infected sand flies and considerably cutting the transmission chain. The method of controlling or reducing possible leishmaniasis transmission by improving housing is long term, sustainable and has many added advantages that further help improve the daily lives of these poor people. Used together with other method of intervention the method of improving housing would stop disease transmission by a considerable margin.

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