REVIEW ARTICLE

HYRAXES AND LEISHMANIASIS IN ETHIOPIA

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ABSTRACT

Hyraxes are known in many parts of Ethiopia by the vernacular name 'Shikoko' or 'Osole' and resemble mice. Bush hyraxes (Heterohyrax brucei), rock hyraxes (Procavia capensis) and tree hyraxes (Dendrohyrax dorsalis, Dendrohyrax arboreus, Dendrohyrax validus) are the extant species in the three genera and all of the groups are found in Ethiopia. Dendrohyrax species are not described in Ethiopia and little is known about this genus. Bush and rock hyraxes are the known reservoir hosts of cutaneous leishmaniasis (CL) due to Leishmania aethiopica (L. aethiopica) in highlands of Ethiopia. They are also believed to be the reservoir hosts of Leishmania tropica (L. tropica) and Leishmania killicki (L. killicki). Their role as a reservoir hosts of Leishmania donovani (L. donovani) is not known. The current strategy suggested by World Health Organization (WHO) for Leishmania control is based on treating infected individuals in addition to reservoir host and vector control. In Ethiopia, treating infected individuals has no role in disease control since leishmaniasis is zoonotic in its range. Shooting of hyraxes and/or encouraging predators of hyraxes (biological control), found near heavily infected population with CL, are the only possible ways to control CL based on reservoir control in addition to environmental management. The use of insecticide-treated bed nets to prevent the bites of nocturnally active sandflies is getting attention to prevent both CL and VL. This method could be used in Ethiopia.

Key words: hyraxes; leishmaniasis; control; Ethiopia.

INTRODUCTION

The name hyraxes comes from a Greek word 'hyrak' meaning shrew-mouse. Hyraxes have short legs, a rudimentary tail, and round ears. They are known by the name Shikoko or Osole in many parts of Ethiopia. About 36 million years ago, hyraxes were a dominant browsing and grazing ungulate in Africa, with a size ranging from the present day hyraxes to that of a hippopotamus. These fossil forms are grouped in more than 20 genera (1). The first radiation of bovids around 25 million years ago reduced the diversity of hyraxes and the only hyraxes that live in rocks and trees which were not invaded by bovids persisted (2). Hyraxes are classified under order hyracoidea and family procavidea with in super order pangulata which includes elephants, sea cow, elephant shrew, aardvark and dugongs which are collectively called the Afrotheria (3). Bush hyraxes (*Heterohyrax brucei*), rock hyraxes (*Procavia capensis*) and tree hyraxes (*Dendrohyrax dorsalis*, *Dendrohyrax arboreus*, *Dendrohyrax validus*) are the extant species which are superficially similar in size and appearance (4, 5, 6). Hyraxes are endemic to Africa and the Middle East. The distribution of rock hyraxes extends into the Arabian Peninsula from Lebanon to Saudi Arabia (5, 7). All the three genera of hyraxes are found in Ethiopia. The *Dendrohyrax* species is not described in Ethiopia, as little is known about it. In Ethiopia, *Procavia* and *Heterohyrax* live in rock outcrops, piles of boulders and fractured cliff faces. *Heterohyrax brucei* also live in hollow Ficus and Acacia trees in different parts of Ethiopia (8, 9). Their habitat extends from the Danakil lowlands of Ethiopia (below sea level) to the Bale mountains (South East Ethiopia) (9). In other parts of East Africa, hyraxes can also be found in areas ranging of from the sea level to 3800m (10). They are excellent climbers and jumpers due to the in production of sticky sweat by the glands in the rubbery soles (11). Hyraxes have a low metabolic rate relative to their size and efficient kidneys that concentrate urea in urine and excrete a large amount of undissolved calcium carbonate (1, 5). Urination on vertical rock faces by hyraxes results in the deposition of crystallized calcium carbonate that produces a visible white at colony sites (12). The low metabolic rate and efficient renal concentrating ability permit hyraxes to meet their water requirements by the ingestion of vegetation alone, even under an extreme drought conditions (13).

Hyraxes harbor *Leishmania* in their skin (8) and nematodes in their gut (5). They are susceptible to viral pneumonia and tuberculosis (Sale, as cited in 5). Mange eliminated a colony from one kopje in Serengeti (Tanzania). (14). Different ecto-parasites also infect hyraxes (5, 8).

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Understanding the reservoir system is important in designing *Leishmania* rational control (15). WHO (16) has also suggested *Leishmania* control based on reservoir host and vector control. In Ethiopian highlands, where the CL is endemic and the vectors such as *Phlebotomus longipes* (*P. longipes*) and *Phlebotomus pedifer* (*P. pedifer*) exist, the ecological and behavioral requirements of hyraxes make them perfect reservoir hosts of *L. aethiopica* (8, 9). However, Mammalogists in Ethiopia have done little in studying hyraxes and parasitologists often encounter problems, particularly in relation to the systematics of hyraxes for extrapolating information gathered about leishmaniasis with the proper species of hyraxes. The aim of this review is, therefore, to provide adequate information about hyraxes and their role in leishmaniasis in Ethiopia with possible suggestions on *Leishmania* control strategies.

METHODS

This review is developed after data (knowledge) about the subject has been gathered during epidemiological investigations of leishmaniasis in different areas of Ethiopia (Addis Ababa, Merabete, Awash Sebat Killo and Silti) from January 2005 to June 2006 together with the information gathered from literature found mainly on the Enterz-PubMed site.

Reproduction and behavior: Rock and bush hyraxes live in cohesive and stable family groups (colonies) consisting of 3-7 related adult females, one adult territorial male, dispersing males, and juveniles of both sexes. The territorial male repels all introducing males (17). Male offspring disperse usually between 12 and 30 months after becoming adolescent (18). Members of a colony can be as many as 50 individuals (15). Females become receptive about once a year and a peak in births seems to coincide with the rainy season (17, 19). Unlike the two breeding seasons suggested in tropical areas where two rainy seasons occur (17), in southeastern Addis Ababa only one breeding season was found that coincided with the summer rainy season (unpub. data). Gestation is about 7.5 months and the number of young per female bush and tree hyraxes ranges from 1-3 and in rock hyraxes from 1-4 and weaning up to 5 months. Reproductive maturity is generally attained at an age of 16 – 24 months (17) and they can live longer than 11 years (19).

In hyraxes, there is a gland found dorsally which disseminates scent that is used for communication among individuals in a colony (20). Larger hairs, mostly colored yellow or brown or black, surround the dorsal gland forming the dorsal spot. During courtship or aggression, males erect these hairs. The hairs also provide tactile feedback to the hyrax during exploration and use of their underground living quarters (21). Hyraxes have a poor ability to regulate their body temperature. They are dependent on shelter (boulders and tree cavities) that provide relatively constant temperature and humidity (5, 22). During cold conditions at night, members of a colony huddle and stack together in their holes to keep themselves warm (23). In the morning and at dusk, hyraxes bask in the sun and shelter at midday in their holes and shades (11). Hyraxes' behaviors are also related to risk of predation (5). Sympatric *H. brucei* and *P. capensis*, sometimes occupying the same habitat and their separation in field could be difficult. They share common holes and latrines (7, 19, 23). Communal existence increases the chance of signaling predators (5). Synchronous annual birth, gestation period, and reproductive seasons of the two genera were also reported to be the same (24). Due to different reproductive anatomy and sexual behaviors, they do not interbreed (14). Interspecific competition is avoided by differential feeding habits. Rock hyraxes feed mainly on grass while bush and tree hyraxes feed on vegetables (25, 26). Eagles and carnivores (Mongoose, Genet cat etc.) are the main predators. After the destruction of carnivorous predators by man in South Africa, hyraxes have become pests (15). The hyrax population size is controlled by predators (18).

Classification of hyraxes:Although there is a dispute over the classification of hyraxes, they are generally classified into 5 species in 3 genera such as *Procavia*, *Heterohyrax* and *Dendrohyrax* (4, 5, 6). Restriction fragment length polymorphisms of mitochondrial DNA show *Heterohyrax* and *Procavia* are closely related and *Dendrohyrax* is basal within the family *Procavidea* (5). All the 3 genera are found in Ethiopia. *Dendrohyrax* species is common in the Bale Mountains above 3000m(9). But, this species is undescribed so far and its role as a reservoir host of leishmaniasis is also unknown. Further investigations are required.

Heterohyrax is less heavily built than *Procavia* (18), and has a narrow muzzle, (26) smaller size and rarely greater than 48cm. body length (7). *Heterohyrax* has reddish or grayish brown hairs while *Procavia* is covered with yellowish to reddish or grayish-brown hairs (5). *Dendrohyrax*, on the other hand, has long, wooly, grey or brown hairs

(6, 27). In *Heterohyrax*, the ventral color is white or creamy, in distinct contrast to the rest of the pelage unlike the light brown or yellowish venter in *Procavia* (5, 7). A small dorsal gland is surrounded by cream to rust orange to dirty white erectile hairs that form a dorsal spot in *Heterohyrax* as opposed to yellow or black based yellow and black hairs in *Procavia* (7). The discrete white to creamy eyebrows of *Heterohyrax* can be recognized from a considerable distance, unlike the more diffused yellowish color in *Procavia* (5). Browsing *Heterohyrax* and *Dendrohyrax* consume soft food and have brachydont dentition (short crowned and with relatively long root), whereas *Procavia* feeds mainly on grass, a relatively coarse food and therefore has hypsodont dentition (high crown with relatively short roots) (23, 25). The combined length of the upper molars in *Dendrohyrax* and *Heterohyrax* is greater than or equal to the combined length of molars, unlike *Procavia* which has the combined length of upper premolars less than the combined length of upper molars (7). The cranium is flat dorsally in *Heterohyrax* and *Procavia*, but dorsally concave in *Dendrohyrax* (6, 27).

***Procavia in Ethiopia*:**The Procavia capensis has 17 subspecies (4) which can be divided into northern and southern species. The northern subspecies like *P. c. ruficeps* (Sudan), *P.c.johanstoni* (Kenya, Tanzania) and *P. c. syriacus* (The Middle East, North Africa) have first lower premolar (P_1) and a dental formula: I 1/2C0/0P4/4M3/3, total 34 like *H. brucei*. P_1 is absent in southern species as in the case of *P. c. capensis* (South Africa) and *P. c. welwitscii* (Angola and Namibia) (26). In Ethiopia, *P. c. habessinica* (North West Ethiopia) and *P. c. scioana* (central Ethiopia) have black dorsal flash and are scarcely distinguished from *P. c. capensis* from South Africa. They only differ by the usual presence of P_1. On the other hand, *P. c. pallida* (Ogaden/ North Somali or lowland form) with black based yellow dorsal spot is often confused with yellow spot of *P. c. syriacus* (7, 28) and *P. c. welwitschii*. The retention of $P_{1,}$ at least until the eruption of third molars (M3), in *P. c. syriacus* and *P. c. pallida* makes them different from *P. c. welwitschii* which lose P_1 very early. *P.c. capillosa* (Southeastern – Ethiopia) has unique convergent upper incisors. The *P. c. erlangeri* (Central and Eastern Ethiopia) has a very distinctive form such as a black head, yellow body color and the virtual absence of dorsal flash (7, 9). The Southern Ethiopian Rift Valley forms are *P.c. jacksoni* and with a prominent dorsal yellow spot (7).

***Heterohyrax in Ethiopa*:**The genus *Heterohyrax* contains only one extant species, *H. brucei*, with 25 sub species (5). The genus *Heterohyrax* was first described by Gray in 1868 using the yellow spotted hyraxes from central Ethiopia. There was a taxonomic confusion due to the association of the name yellow spotted hyraxes only to *Heterohyrax* species. The yellow spotted *P. capensis* (*P. c. syriacus* and others) were grouped as *Heterohyrax* until Thomas (1892) separated yellow – spotted hyraxes as yellow spotted dassie (*P.c. syriacus* in Sinai/Lebanon, Isreal and Syria) and yellow spotted *H. brucei* of Gray (1968) as a name for any *Heterohyrax* in Africa. The *H. brucei* found in Ethiopia other than *H. b. brucei* are *H. b. thomasi* (Kaffa, Gimirra and Omo Basin in South and Southwest Ethiopia). *H. b. rudolfi* (Borena in Southern Ethiopia), *H. b. princes* (North of Abaya Lake in Central Ethiopia) and *H. b. somalicus* (Southeastern Ethiopia) (5, 28). Most probably, the *H. b. pumilus* found in Somaliland (5) may also occur in Ethiopia.

***Hyraxes as reservoir hosts of leishmaniasis in Ethiopia*:**Most leishmaniasis are zoonotic diseases with one or more reservoir hosts maintaining the disease. A host is by definition a habitat for a parasite at least temporarily. A mammalian host responsible for the long term maintenance of a population of an infectious agent is a reservoir host. Other than reservoir hosts, there are incidental hosts that are irrelevant to long term persistence (blind end). Occasionally, these incidental hosts may be responsible for transmission and are regarded as secondary reservoir hosts. According to Ashford (1996) (15), reservoir hosts fulfill the following criteria: (1) abundance or gregariousness (2) long-lived or survive at least during a non-transmission season of the parasite (3) remain infected for a long time without acute diseases and (4) present the parasite in their skin or circulation for sandfly bite. The only reservoir hosts of CL in the old world that fulfill these criteria are hyraxes. The behavioral and ecological requirements of hyraxes in *L. aethiopica* endemic areas (Ethiopia and Kenya) make them good reservoir hosts of leishmaniasis. They are long-lived, gregarious, and share a habitat with *Phelobotomus* species and enhance the environment by the accumulation of organic matter in their latrine for sandfly breeding (8). Both the mammals and the vectors are infected at least seasonally (9). The intense outbreaks of *L. aethiopica* infections of man are usually due to exposure to an area where a parasite is maintained by hyraxes (8). This is a typical example of zoonotic transmission.

Reports on zoonotic cutaneous leishmaniasis (ZCL) due to *L. tropica*, however, are scarce and the search for reservoir hosts is intensive. The dogs and rats so far described are not true reservoir hosts, but incidental hosts. Dogs in some areas were victims like humans (15). The only suspected animal, where more than one specimen has shown some suggestion of being a reservoir host, is the hyrax. Both in Kenya and Israel, hyraxes have been found infected (29, 30, 31). The search for more infected hyraxes with *L. tropica* in the zoonotic foci would confirm whether this animal is the only sole reservoir host of this parasite. After the discovery of *L. tropica* from a patient (32) and sandflies (33) in lowland of Ethiopia, hyraxes are also believed to be the reservoir hosts of *L. tropica* in Ethiopia (32, 33). Hyraxes have been found infected with *L. killickii*, a closely related group to *L. tropica* in Kenya and Namibia (29, 30), which has been reported as an agent of anthroponotic cutaneous leishmaniasis in Tunisia (34). *L. tropica* and *L. killickii* were believed to have originated in the hyrax system in the zoonotic settings in Africa and might have later evolved into anthroponotic forms elsewhere (32).

There is no report of hyrax infection by *L. major* in Ethiopia or elsewhere, however, it is identified from an *Arvicanthis* species and sandflies (*P. duboscqi*) in the lowlands (Southern Ethiopia) (35, 36, 37). Totally, four host-parasite ecosystems have been described for *L. major* based on the principal hosts in different endemic areas, namely *Psammomys*, *Meriones*, *Rhombomys* and *Arvicanthi*s and *Phlebotomus* sandfly vectors (15, 38, 39). The animals, which satisfy the criteria for reservoir hosts, are the great gerbils (*Rhombomys opimus*) (15).

Apart from anthroponotic transmission in India, *L. donovani* is zoonotic throughout its ranges (40). In East Africa, the reservoir hosts of visceral leishmaniasis are unknown. Dogs are the principal domestic reservoir hosts while wild canids (foxes, Jackals, and Wolves) serve as the major sylvatic reservoirs of *L. infantum* (agent of VL in the Mediterranean Region). Rodents, carnivores and dogs in VL endemic areas were screened for *L. donovani* in East Africa, but a reservoir host(s) has not been known (43, 44, 45, 46). *Felis serval*, *Mongoose* and *Genetta genetta* (carnivores) and rodents found infected with *L. donovani* in rare occasions in Sudan (43, 44) that might be incidental hosts and might have acquired the infection from the animals they feed-on. These carnivores were found in significant numbers and were important predators of hyraxes in Merabete lowlands (around Wonchit river, about 1400m a.s.l) where VL infected patients were found (Hailu, unpub. data) and in Awash Sebat Killo (Awash Valley) in Ethiopia. In VL endemic area, where hyraxes are common, the role of hyraxes as a reservoir host of VL should not be ruled out. Further investigation is required.

Leishmania control strategy in Ethiopia:The current strategy suggested by the World Health Organization (WHO)(16) for *Leishmania* control is based on reservoir and vector control in addition to treating infected individuals. In Ethiopia, both visceral leishmaniasis (VL) and CL are zoonotic diseases and the *Leishmania* parasite cycle is maintained in the wild (47). Although the treatment of active human cases of zoonotic VL or CL can cure the disease, it has no role in the prevention of the incidence of new cases because humans are usually dead-end hosts. Culling or treatment of infected dogs (reservoir hosts), as was implemented in Brazil (48), cannot be practical in Ethiopia (East Africa) since nothing definite is known about reservoir hosts of VL. On the other hand, the reservoir hosts of CL (hyraxes) live mostly in crevices of basalt rocks in the gorges and tree cavities in forests (8, 9) and trapping, diagnosis and culling or treating infected hyraxes is almost impossible. In addition, it is not possible to control the zoonotic cutaneous leishmaniasis due to *L. aethiopica* by destroying the habitats of hyraxes in the wild as it was done for *L. major* by ploughing the holes of the rodent reservoir hosts in the Middle East (15). However, it might be possible to control CL due to *L. aethiopica* by shooting on hyraxes close to a heavily infected villages or by encouraging specific predators such as the eagle, mongoose, genet cat, etc. (biological control) as it was suggested by Ashford (15). Another option could be environmental management. For example, the construction of a bridge on a gorge that bisects a "*Silti*" town in Southern Ethiopia has created an ideal environment for sandflies and hyraxes to reproduce underneath. This resulted in a rapid population growth of sandflies and hyraxes and in the emergence of CL in the area (unpub. data). In a situation like this, where human-made environmental change results in increased risks for leishmaniasis, contractions should be made by taking into account the possible epidemics of leishmaniasis.

In Ethiopia, *Leishmania* control strategy had better depend more on vector control other than spraying insecticides. There are two reasons for not using spraying insecticide in the Ethiopian context: (1) the vectors are not endophilic (do not rest mostly indoor after feeding) (2) resting sites of sandflies are in wild and applying insecticide in a wild setup is not cost effective and practical. Thus, *Leishmania* control strategy may depend on methods that protect sandfly bites: use of bed nets and chemical repellants.

Bed nets: Bed nets, especially when treated with pyrethroids, provide considerable protection against leishmaniasis. The effectiveness of this method is determined by local sandfly behavior. Bed nets are effective particularly for endophagic (mainly feeding indoors) and those most active when people are asleep (49). A study in Kenya and Uganda has shown that use of insecticide-treated mosquito nets which was associated with low risk of VL (50). *Leishmania* control strategy in Ethiopia may involve the use of insecticide-treated bed nets for protection against leishmaniasis. In Ethiopia, highland CL is associated with the presence of hyraxes, and vectors living in crevices of basalt rock in the gorges or tree cavities in the forest, while VL is associated with the existence of unknown reservoir host (s) and vectors in cracking black clay soil of Acacia- Balanites woodlands (in North West Ethiopia) and in termite mounds (in the South and Southwestern Ethiopia). Most of these sandfly vectors of both CL and VL are active at night and visit human dwellings where they bite sleeping people (8, 16, 47, 51, 52), and it is most likely that insecticide treated bed nets could help in minimizing the risk of leishmaniasis. *P. orientalis* and *P. martini*, the main vectors of VL in Ethiopia, are reported to prefer rest and bite in the wild (53). In that case, the usefulness of insecticide-treated bed nets is questionable. The use of insect repellents applied to the skin and/ or insecticide–treated clothing could be an alternative in such circumstances. So far, insecticide-treated bed nets have not been used as a *Leishmania* control programs except in Eastern Sudan, where about 300,000 insecticide-treated bed nets were provided to local people (49). The effectiveness of these bed nets, however, has not been evaluated. In Afganistan and Pakistan, on the other hand, CL patients were provided with bed nets that were primarily aimed to avoid anthroponotic CL due *L. tropica* transmission from infected patients.

In conclusion**,** in Ethiopia, knowledge about the transmission of leishmaniasis is far from complete. Although all of the agents of leishmaniasis in the old world are reported in the country, almost nothing is known about reservoir hosts of *L. donovani*, *L. tropica* and *L. major*. The later two were identified only from a patient, sandflies and an Arvicathis species in a lowland. Further research activities in the area are highly required. Although hyraxes are the reservoir hosts of CL due to *L. aethiopica*, their role as reservoir hosts of *L.* donovani, *L. tropica* and *L. major* is not known. More knowledge about the behavior and ecology of hyraxes and sandflies is important in designing a control strategy at least for CL in the highlands. More research is necessary in this area, too. Evidence suggests that insecticide-treated bed nets could have an important role in the prevention of leishmaniasis. The use of insecticide-treated bed nets in a *Leishmania* control program is recommended in Ethiopia followed by the evaluation of the outcome.

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