SEASONAL VARIATION OF TUNGIASIS IN AN ENDEMIC COMMUNITY

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Abstract. Tungiasis (caused by the sand flea *Tunga penetrans*) is hyperendemic in many resource-poor communities in Brazil. To understand transmission dynamics of this parasitic skin disease in a typical endemic area, a longitudinal study was carried out in a slum in Fortaleza in northeastern Brazil. In a door-to-door survey, the population of a randomly selected area (n = 1,460) was examined on four occasions for the presence of embedded sand fleas. Prevalence rates were 33.6% in March (rainy season), 23.8% in June (end of the rainy season), 54.4% in September (peak of the dry season), and 16.8% in January (begin of the rainy season). Tungiasis was more common in males than in females. The intensity of infestation was correlated with the prevalence. The study shows that prevalence of tungiasis and parasite burden vary significantly during the year with a peak in the dry season. These findings have important consequences for the design of control measures.

INTRODUCTION

Tungiasis is a parasitic skin disease caused by the female sand flea *Tunga penetrans*. Both the male and the female flea are hematophagous, but only the female penetrates into the skin of the host, which results in parasite hypertrophy and egg production.[1] Eventually, the flea dies and is sloughed from the epidermis by tissue repair mechanisms. This process may last up to six weeks.[2] If embedded fleas are not removed appropriately, lesions almost invariably become superinfected.[3]

This ectoparasitosis occurs in many parts of Latin America, the Caribbean, and sub-Saharan Africa. In Brazil, it can be found both in northern and southern regions.[1] The distribution of tungiasis is patchy, and the disease occurs predominantly in impoverished populations.[4–6] In economically disadvantaged communities, the ectoparasitosis is associated with considerable morbidity.[7]

In the few community-based studies performed, a wide range of prevalence rates have been observed. Data available from Nigeria, Trinidad and Tobago, and Brazil suggest that between 16% and 55% of the population may be infested.[8–15]

Tunga penetrans parasitizes a broad spectrum of mammals. Domestic animals such as dogs, cats, and pigs are frequently affected. Peridomestic rodents such as *Rattus rattus* are also important reservoirs.[16] It is not known to which extent the occurrence of different animal reservoirs or behavioral characteristics of the human population contribute to the highly diverging prevalence rates reported in the literature. Similar to other parasitic diseases, such discrepancies may also result if attack rates vary over time and if prevalence rates are determined during different seasons of the year. In fact, in northeastern Brazil, local residents claim that tungiasis becomes a scourge every year during the cashew nut harvest, which coincides with the dry season (September).

To validate these anecdotal observations, we examined a representative sample of the population of a typical endemic area four times during a period of 11 months, namely March (rainy season), June (end of rainy season), September (peak of dry season), and January (beginning of rainy season).

MATERIALS AND METHODS

Study area. The study was performed in Vicente Pinzón II, a typical slum (*favela*) in Fortaleza, the capital of Ceará State

in northeastern Brazil. The area is close to the beach and has a total population of approximately 15,000 inhabitants. Two-thirds of the households have access to piped water. Sixty percent of the population have a monthly family income of less than two minimum wages (1 minimum wage = $80). The adult illiteracy rate is 30% and unemployment rates are high.[17] Many houses are made of recycled materials and do not have cemented floors. Roads and paths are not paved. Waste collection is performed merely at the boundaries of the slum, and garbage of all sorts is scattered throughout the area. There is no public sewage system and hygienic conditions are precarious. There are innumerable stray dogs and cats, and many families keep dogs and cats as companion animals. The study area is comparable to the many other *favelas* in northeastern Brazil.

According to observations of the physicians of the local Primary Health Care Center, three sub-areas of the township (Antônio Carneiro, Luxou, and Morro de Sandra's) are high-risk areas for parasitic skin diseases such as cutaneous larva migrans, scabies, pediculosis, and tungiasis. The sub-area Morro de Sandra's was selected for this study by randomization.

Study design. In March 2001, Morro de Sandra's was inhabited by 1,460 individuals belonging to 327 households (mean = 4.5, range = 1–13 individuals/household). A door-to-door survey was carried out in March 2001, and all households were again visited in June 2001, September 2001, and January 2002. The time schedule was planned such that one survey was performed in the rainy season (March), another at the end of the rainy season (June), the third in the peak of the dry season (September), and the final one in the beginning of the rainy season (January).

To reduce inter-observer bias, all clinical examinations were performed by the same investigator (TW). In case of absent family members, the households were revisited twice. For safety reasons, the examinations were restricted to between 7:00 AM and 5:30 PM, i.e., during full daylight.

Clinical examination and case definition. Each member of the household was examined thoroughly. Since ectopic lesions are easily overlooked, special attention was paid to unusual sites of infestation with *T. penetrans*.[18] The diagnosis of tungiasis was made by clinical inspection of the lesions according to the Fortaleza Classification.[2] Briefly, the diagnosis was based on the presence of a red-brown itching spot with a

diameter of 1–2 mm (early stage), the presence of a yellow-white watch glass–like patch with a diameter of 3–10 mm with a central dark spot (mature stage), and a brown-black crust with or without surrounding necrosis (dead flea = late stage).

Embedded sand fleas with evidence of manipulation by the patient or his or her caretaker with instruments such as needles or thorns was also documented. Such lesions leave a characteristic crater-like sore in the skin.[2]

Data analysis. Data were entered twice into a database using Epi-Info version 6.04d software (Centers for Disease Control and Prevention, Atlanta, GA) and checked for errors that might have occurred during their entry. Ninety-five confidence intervals of prevalence rates were calculated using the respective Epi-Info modules. The chi-square test was used to determine the differences of relative frequencies. Correlations were determined using STATA™ version 7 software (Stata Corporation, College Station, TX). To compare the parasite burden between surveys, the Wilcoxon signed rank test was used.

Monthly precipitation and temperature data for the Fortaleza Municipality were obtained from the Meteorologic Foundation of Ceará State (Fundação Cearense de Meteorologia, Fortaleza, Brazil).

Ethical considerations. Permission to perform the study was obtained from the Health Authority of Fortaleza Municipality. Community associations of the township (*associações dos moradores)* gave their consent to the study. Prior to the study, meetings with community health workers and community leaders were held and the objectives were explained. Informed oral consent was obtained from all adult participants and from the parents or legal guardians of minors. At the end of the study, all participants were treated for tungiasis by standard therapy (removing the embedded flea with a sterile needle and disinfection of the skin lesion). Other parasitic skin diseases diagnosed during the surveys such as scabies, cutaneous larva migrans, and pediculosis were also treated.

RESULTS

During the first door-to-door survey, 1,185 individuals (81.2%) of the total population were examined. They belonged to 301 (92.1%) of the 327 existing households in the study area. The number of individuals examined at each survey, the number of males and females examined, and the number of individuals examined > 15 years old and ≤ 15 years old are shown in Table 1.

Consistently, more females than males and more children than adults participated in the study. The lowest proportions of the target population were examined in September 2001 (58.2%) and January 2002 (60.8%). At the peak of the dry season (September) many inhabitants of the community frequent nearby beaches, and during the holiday season (January) many adults work as hawkers (peddlers) in the tourist areas.

The age-specific prevalence rates are shown in Table 2. In all surveys, children 5–9 years of age had the highest prevalence rates. Tungiasis was more common in males than in females ($P < 0.001$ for March, June and September and $P < 0.05$ for January) (Figure 1). The disease showed considerable seasonal variation, with the prevalence being highest at the peak of the dry season (September, 54.4%) and lowest after the first rain of the rainy season (January, 16.8%). Overall prevalence rates differed significantly between all surveys and for all possible data pairs ($P < 0.001$ in all cases). The seasonal variation was paralleled by similar variation of age-specific prevalence rates.

Figure 2 shows the variation of overall prevalence rates of tungiasis and the monthly precipitation in the study period. The prevalence started to increase with drier weather and peaked when precipitation was zero. Thereafter, the prevalence decreased when it started raining again at the end of the year.

The ratio of non-viable lesions (stage IV of the Fortaleza classification) per total number of lesions per infested individual was calculated because this indicates the proportion of recent infestations. This ratio varied considerably between the four surveys: in March, it was 0.25; in the June survey 0.014, in September 0.0, and in December 0.6.

There was a significant difference in the number of lesions per individual between the different surveys ($P < 0.001$ in all cases) (Table 3). The mean parasite burden was positively correlated with the prevalence ($r = 0.81$, $P = 0.01$) (Figure 3).

The monthly mean temperature varied little from 25.7°C in July to 27.3°C in January/December and showed no association with tungiasis prevalence.

DISCUSSION

Tungiasis has been a common disease in many parts of Latin America and the Caribbean for many years. This is reflected by the innumerable popular names for the ectoparasitosis, such as *nigua* (Argentina, Venezuela, and the Caribbean), *kuti*, *suthi-pique* (Bolivia), *ogri eye* (Surinam), *bicho de pé*, *bicho de porco* (Brazil), *chica* (Colombia and Venezuela), *sikka* (Guyana), *pique* (Argentina, Chile, Uruguay, and Paraguay), *piqui* (*quéchua*), and *tü* (*tupí guaraní*).[1,19] It remains unclear whether socioeconomic changes have led to a decrease of occurrence of the ectoparasitosis since the 1970s, or whether it became neglected as a disease entity associated with extreme poverty.[1] In Brazil, infestation by *T. penetrans* is still common in economically disadvantaged communities, ur-

TABLE 1
Samples of the target population examined during the four surveys*

Study period	Total (n = 1,460)	Males (n = 686)	Females (n = 774)	≤ 15 years old (n = 650)	> 15 years old (n = 810)
March 2001	1185 (81.2%)	523 (76.2%)	662 (85.5%)	593 (91.2%)	592 (73.1%)
June 2001	1185 (81.2%)	544 (79.3%)	641 (82.8%)	570 (87.7%)	615 (75.9%)
September 2001	849 (58.2%)	371 (54.1%)	478 (61.8%)	448 (68.9%)	401 (49.5%)
January 2002	888 (60.8%)	387 (56.4%)	501 (64.7%)	432 (66.5%)	456 (56.3%)

* Data in parentheses indicate percentages of individuals examined in the respective sub-group.

TABLE 2
Age-specific point prevalences of tungiasis at the four surveys and 95% confidence intervals (CIs)

Age group (years)	March 2001 Prevalence (95% CI)	June 2001 Prevalence (95% CI)	September 2001 Prevalence (95% CI)	January 2002 Prevalence (95% CI)
0–4	40.7% (34.6–47.1)	33.8% (27.6–40.4)	67.8% (60.4–74.5)	32.6% (25.6–40.1)
5–9	56.5% (48.7–64.2)	41.3% (33.8–49.0)	72.8% (64.5–80.1)	31.4% (23.9–39.8)
10–14	44.6% (37.2–52.3)	31.2% (24.4–38.7)	64.4% (55.6–72.5)	21.7% (14.7–30.1)
15–19	23.0% (16.0–31.4)	16.3% (12.0–37.3)	43.9% (33.0–55.3)	7.5% (2.8–15.6)
20–39	16.5% (12.6–21.2)	9.5% (6.7–13.2)	34.4% (28.1–41.2)	2.9% (1.2–5.8)
40–59	23.7% (16.2–32.6)	16.2% (10.1–24.2)	41.8% (30.8–53.4)	6.2% (2.3–13.0)
≥ 60	38.1% (23.6–54.4)	27.0% (13.8–44.1)	52.0% (31.3–72.2)	11.4% (3.2–26.7)
Total	33.6% (30.9–36.4)	23.8% (21.4–26.3)	54.4% (51.0–57.8)	16.8% (14.4–19.4)

ban centers, and the rural hinterland.[10,11,14] This is of concern since in impoverished populations tungiasis is associated with considerable morbidity.[7,11,14]

Control measures for tungiasis can only be developed if transmission dynamics are well understood. However, valid epidemiologic data on tungiasis are almost nonexistent. For example, it remains enigmatic why a minority of individuals show an extremely high parasite load and therefore disproportionately contributes to the propagation of the parasite in the environment. Similarly, the factors determining the characteristic age distribution with highest prevalence rates in children and the elderly are not known. As a first step in the process of understanding local transmission dynamics of *T. penetrans* in an endemic area, we determined disease occurrence and intensity of infestation at different times of the year.

The results of this longitudinal study show that the occurrence of tungiasis varies throughout the year and seems to follow local precipitation patterns. Maximum and minimum prevalence rates differed by more than a factor of three. The peculiar variation occurred irrespective of age; age-specific prevalence rates varied in a similar way over the year, as overall infestation did. The overlap of precipitation patterns and prevalence suggests that attack rates started to increase sharply as soon as the rain stopped (July) and reached a peak when precipitation was zero (September). When it started raining again in December, assumably decreasing attack rates were followed by a dramatic decrease of prevalence in January. The ratio of non-viable/total number of lesions per patient corroborates these assumptions. Since most embedded fleas die 4–6 weeks after penetration, a ratio of nearly zero in

September, when highest prevalence rates were found just after the rains have diminished, indicates that most infestations were recent. The same holds true for the June survey. In contrast, temperature does not seem to have an impact on the occurrence of tungiasis in this area.

It may be speculated that in the population studied exposure-related behavior had changed according to the seasons of the year. Lower prevalence rates would then reflect less exposure per unit of time rather than reduced attack rates due to intrinsic changes in the flea population. However, several arguments point against this hypothesis. First, there is evidence that infestation takes place inside the houses as well as in the local environment (Muehlen M and others, unpublished data). Second, in the semi-arid climate of northeastern Brazil, domestic and leisure activities carried out in and outside the houses do not vary much during the year. Rain does not last more than a couple of hours and are considered a pleasure rather than a nuisance. Therefore, it does not have much influence on behavior that might put the individual at risk for the infestation with sand fleas. Third, although more adults may stay outside the endemic area for a prolonged period of the day during the holiday season (because there are more jobs available in the tourist districts), this does not hold true for children 5–14 years old and the elderly, the two most vulnerable groups in the population. When schools are closed during the national holiday season (December and January), children spend even more hours per day in the endemic area playing on the compounds or roaming around. Nonetheless, age-specific prevalence rates decreased significantly during this period of the year and showed the lowest value of the four surveys. Finally, seasonal variation of preva-
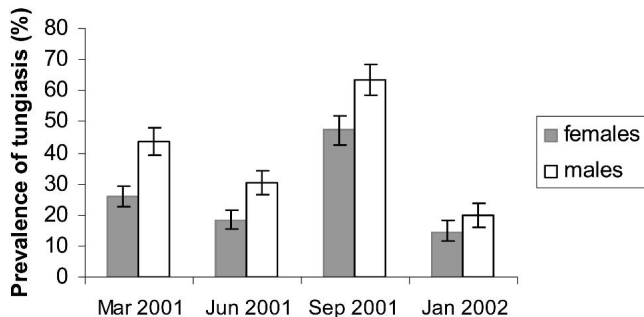

FIGURE 1. Point prevalence rates of tungiasis in an endemic area in northeastern Brazil stratified by sex. Error bars show 95% confidence intervals.
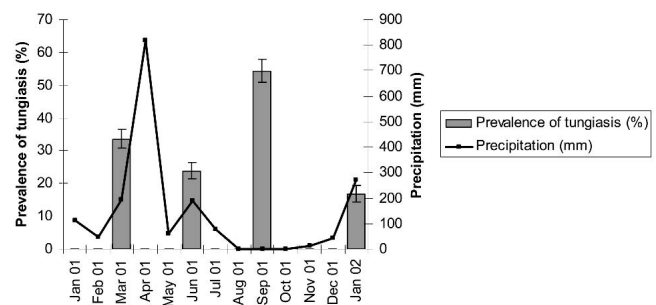

FIGURE 2. Seasonal variation of the prevalence of tungiasis and monthly precipitation from January 2001 to January 2002 in Fortaleza, northeastern Brazil. Error bars show 95% confidence intervals.

TABLE 3
Age-specific parasite burden at the four study periods

Age group (years)	March 2001 Number of lesions: mean, median, range	June 2001 Number of lesions: mean, median, range	September 2001 Number of lesions: mean, median, range	January 2002 Number of lesions: mean, median, range
0–4	7.2 4 1–67	5.1 2 1–47	7.3 4 1–48	3.8 2 1–17
5–9	6.8 5 1–33	4.5 2 1–42	8.0 4 1–65	3.7 3 1–13
10–14	6.7 3 1–58	5.3 2 1–50	8.8 5 1–76	4.0 2 1–38
15–19	5.4 3 1–26	3.8 2 1–18	6.4 3 1–34	3.7 1 1–14
20–39	7.8 2 1–158	4.1 2 1–24	3.9 2 1–69	2.1 1 1–6
40–59	14.5 2.5 1–127	3.4 2 1–14	10.7 3 1–115	6.3 1.5 1–20
≥60	16.1 3.5 1–101	13.1 5.5 1–50	7.8 7 1–24	3.5 2 1–8
Total	7.8 3 1–158	4.9 2 1–50	7.4 3 1–115	3.8 2 1–38

lence rate in the human population is accompanied by similar changes of disease occurrence in dogs, cats, and experimentally exposed sentinel animals (Heukelbach J and others, unpublished data).
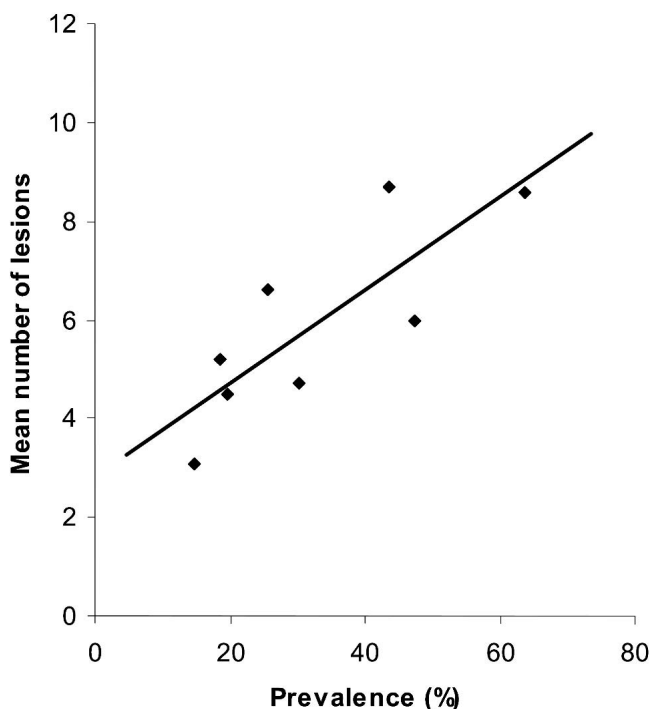

FIGURE 3. Correlation of mean number of lesions per patient and prevalence of tungiasis at the four survey periods. Male and female sex are shown as separate data points (r = 0.81, P = 0.01).

We therefore suggest that seasonal variation of prevalence and infestation intensity indicates changes in the dynamics of the flea population that are related to climatic variables. Conceivably, high humidity in the soil impairs the development of free-living stages of *T. penetrans*. Furthermore, heavy rains may simply wash away eggs, larvae, pupae, nymphs, and adults. Interestingly, in rural communities in Ceará, the local population irrigates the soil of their compounds to reduce attack rates.

We cannot rule out that bias due to non-participation, especially in the September and January surveys when only 58% and 61% of the target population were examined, contributed to differences in prevalence. Since adult males, the subgroup with the lowest prevalence of tungiasis, were consistently under-represented (many male adults are absent from the *favela* during daytime, and for safety reasons the examination were not carried out during darkness), the true population prevalence might actually be lower than reported.

The varying attack rates of *T. penetrans* during the year help to explain the highly diverging prevalence rates observed in previous studies. In fact, a closer look into the studies published confirmed that they were performed at different seasons of the year over a prolonged period of time, and that period rather than point prevalence rates were assessed.[8–15,20,21] Obviously, if one aims to determine the occurrence of a disease that is subject to seasonal variation, cross-sectional studies do not allow conclusions to be made on the health impact of the respective disease in the area.

Variation of prevalence correlated significantly with infestation intensity. Since the parasite load is directly responsible for the degree of tungiasis-associated morbidity, assumably morbidity will also vary during the year. Control measures aimed at reducing morbidity should then be scheduled to be in place before the attack rate increases, i.e., at the beginning of the dry season, and focused on the most vulnerable population groups, namely children and the elderly.

An ancillary finding of our study is the observation that tungiasis was consistently more common in males. This confirms less convincing data from previous studies and indicates different exposure of males and females to *T. penetrans*.[9,10,12,22]

Recently, a second sand flea species from Ecuador (*Tunga trimamillata*) parasitizing humans has been identified.[23,24] Epidemiologic features of this new species are unknown, and it cannot be excluded that this species is also endemic in northeast Brazil.

In summary, we have performed the first longitudinal study on tungiasis and have shown for the first time that infestation follows a characteristic seasonal variation. Prevalence was highest in the dry season, decreased dramatically with the start of the rainy season, and was related to infestation intensity. The data suggest scheduling intervention measures at the beginning of the dry season to prevent severe morbidity.

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REFERENCES

1. Heukelbach J, de Oliveira FA, Hesse G, Feldmeier H, 2001. Tungiasis: a neglected health problem of poor communities. *Trop Med Int Health 6:* 267–272.

2. Eisele M, Heukelbach J, van Marck E, Mehlhorn H, Meckes O, Franck S, Feldmeier H, 2003. Investigations on the biology, epidemiology, pathology and control of *Tunga penetrans* in Brazil: I. Natural history of tungiasis in man. *Parasitol Res 90:* 87–99.

3. Feldmeier H, Heukelbach J, Eisele M, Sousa AQ, Barbosa LM, Carvalho CB, 2002. Bacterial superinfection in human tungiasis. *Trop Med Int Health 7:* 559–564.

4. Heukelbach J, van Haeff E, Rump B, Wilcke T, Moura RC, Feldmeier H, 2003. Parasitic skin diseases: health care-seeking in a slum in north-east Brazil. *Trop Med Int Health 8:* 368–373.

5. Heukelbach J, Oliveira FAS, Feldmeier H, 2003. Ectoparasitoses e saúde pública no Brasil: desafios para controle. *Cad Saude Publica 19:* 1535–1540.

6. Heukelbach J, Mencke N, Feldmeier H, 2002. Cutaneous larva migrans and tungiasis: the challenge to control zoonotic ectoparasitoses associated with poverty. *Trop Med Int Health 7:* 907–910.

7. Feldmeier H, Eisele M, Saboia-Moura RC, Heukelbach J, 2003. Severe tungiasis in underprivileged communities: case series from Brazil. *Emerg Infect Dis 9:* 949–955.

8. Chadee DD, 1994. Distribution patterns of *Tunga penetrans* within a community in Trinidad, West Indies. *J Trop Med Hyg 97:* 167–170.

9. Chadee DD, 1998. Tungiasis among five communities in southwestern Trinidad, West Indies. *Ann Trop Med Parasitol 92:* 107–113.

10. Wilcke T, Heukelbach J, Cesar Saboia MR, Regina SK-P, Feldmeier H, 2002. High prevalence of tungiasis in a poor neighbourhood in Fortaleza, northeast Brazil. *Acta Trop 83:* 255–258.

11. Muehlen M, Heukelbach J, Wilcke T, Winter B, Mehlhorn H, Feldmeier H, 2003. Investigations on the biology, epidemiology, pathology and control of *Tunga penetrans* in Brazil II. Prevalence, parasite load and topographic distribution of lesions in the population of a traditional fishing village. *Parasitol Res 90:* 449–455.

12. Ade-Serrano MA, Ejezie GC, 1981. Prevalence of tungiasis in Oto-Ijanikin village, Badagry, Lagos State, Nigeria. *Ann Trop Med Parasitol 75:* 471–472.

13. Nte AR, Eke FU, 1995. Jigger infestation in children in a rural area of Rivers State of Nigeria. *West Afr J Med 14:* 56–58.

14. Carvalho RW, Almeida AB, Barbosa-Silva SC, Amorim M, Ribeiro PC, Serra-Freire NM, 2003. The patterns of tungiasis in Araruama township, state of Rio de Janeiro, Brazil. *Mem Inst Oswaldo Cruz 98:* 31–36.

15. Ejezie GC, 1981. The parasitic diseases of school children in Lagos State, Nigeria. *Acta Trop 38:* 79–84.

16. Heukelbach J, Costa ALM, Wilcke T, Mencke N, Feldmeier H, 2004. The animal reservoir of *Tunga penetrans* in poor communities in northeast Brazil. *Med Vet Entomol 18:* (in press).

17. Family Health Program, Unidades Básicas de Saúde da Família, 1999. *Aída Santos e Silva. Relatório de Territorialização.* Fortaleza, Brazil: Minicipal Health Council of Fortaleza.

18. Heukelbach J, Wilcke T, Eisele M, Feldmeier H, 2002. Ectopic localization of tungiasis. *Am J Trop Med Hyg 67:* 214–216.

19. Soria MF, Capri JJ, 1953. Tetanos y "piques". *La Prensa Med Argentina 40:* 4–11.

20. Matias RS, 1989. Epidemia de tungíase no Rio Grande do Sul. *Rev Soc Bras Med Trop 22:* 137–142.

21. Chadee DD, Furlonge E, Naraynsingh C, Le Maitre A, 1991. Distribution and prevalence of *Tunga penetrans* in coastal south Trinidad, West Indies. *Trans R Soc Trop Med Hyg 85:* 549.

22. Arene FO, 1984. The prevalence of sand flea (*Tunga penetrans*) among primary and post-primary school pupils in Choba area of the Niger Delta. *Public Health 98:* 282–283.

23. Fioravanti ML, Pampiglione S, Trentini M, 2003. A second species of *Tunga* (Insecta, Siphonaptera) infecting man: *Tunga trimamillata. Parasite 10:* 282–283.

24. Pampiglione S, Trentini M, Fioravanti ML, Onore G, Rivasi F, 2003. Additional description of a new species of *Tunga* (Siphonaptera) from Ecuador. *Parasite 10:* 9–15.