American Journal of Epidemiology
Vol. 133, No 7
Printed in U.S.A

Chagas' Disease: Risk Factors for House Infestation by *Triatoma dimidiata*, the Major Vector of *Trypanosoma cruzi* in Costa Rica

Mark D. Starr,[1,2] Julio C. Rojas,[3] Rodrigo Zeledón,[3] David W. Hird,[1] and Tim E. Carpenter[1]

The reduction of domiciliary infestation by insect vectors, the key to controlling Chagas' disease, depends on identification of housing features associated with infestation. In this study, log-linear modeling was used to reanalyze data collected in 1964–1968 from 371 houses on characteristics potentially associated with infestation by the vector *Triatoma dimidiata* in a Costa Rican town with endemic Chagas' disease. A possible increased risk of infestation was observed for houses with a dirt floor (as compared with houses with another floor type) and for houses in poor sanitary condition (as compared with houses in good sanitary condition). A new risk factor for house infestation, the presence of roof tiles, was identified; the odds of infestation for houses with a tile roof were 2.4 times greater than the odds for houses with a galvanized metal roof. This significantly increased risk is probably due to the harboring of *T. dimidiata* in stacks of spare tiles next to house walls rather than to the tile roofs themselves. *Am J Epidemiol* 1991;133:740–7.

epidemiologic methods; housing; insect vectors; risk factors; socioeconomic factors; Triatomidae; *Trypanosoma cruzi*; trypanosomiasis, South American

Chagas' disease (American trypanosomiasis) has been reported from every country in Central and South America, as well as from Mexico, and sporadically from the United States. It adversely affects the health, welfare, and productivity of large groups of people, especially those of low socioeconomic status in agricultural regions (1–3). Recent studies estimate that 19–24 million people are infected with the etiologic agent *Trypanosoma cruzi* and that about 65 million people are currently exposed (1, 4, 5). These represent substantial increases from the 1960 World Health Organization estimates of 7 million and 35 million, respectively (3). This corresponds to a current prevalence of 6–8 percent in Latin America, although prevalence may exceed 40 percent in endemic areas (6, 7).

The parasitic protozoan *T. cruzi* has a

Received for publication July 5, 1989, and in final form October 16, 1990.

Abbreviations: CI, confidence interval; OR, odds ratio

[1] Department of Epidemiology and Preventive Medicine, School of Veterinary Medicine, University of California, Davis, CA.

[2] Current address: Disease Control Branch, Public Health Division, Sacramento County Health Department, Sacramento, CA.

[3] Escuela de Medicina Veterinaria, Universidad Nacional, Heredia, Costa Rica.

Reprint requests to Dr. Mark D. Starr, Disease Control Branch, Public Health Division, Sacramento County Health Department, 3701 Branch Center Road, Sacramento, CA 95827.

This investigation was supported, in part, by Title XII Strengthening Grant funds from the US Agency for International Development (grant AID DAN-1282-G-SS-2111), by the United Nations Development Program/World Bank/World Health Organization Special Programme for Research and Training in Tropical Diseases, and by the Vice-Rector of Research, National University of Costa Rica, Heredia, Costa Rica.

The authors thank the following persons for technical assistance: Marlen Matamoros and Juan Chavarría of the Statistics Department, University of Costa Rica, San José, Costa Rica, Dr. Neil Willits of the Division of Statistics, University of California, Davis; and Dr. Luis Vargas of the School of Veterinary Medicine, National University of Costa Rica.

complex life cycle that involves insect vectors (family Triatomidae, subfamily Triatominae) as the major transmission route between hosts; transfusional and transplacental transmission are infrequent (2, 8). After a relatively mild, sometimes asymptomatic, acute phase of the disease, there is generally a long (years) latent period before affected individuals experience the debilitating symptoms of the chronic phase—chiefly heart disease leading to premature heart failure, but also neurologic and gastrointestinal disorders (2, 8). Chagasic myocarditis occurs in at least 40 percent of those infected and is the most frequent cause of heart disease in some areas of Latin America (6, 8). The physical disability and suffering, medical care, and lost productivity caused by Chagas' disease make it the second most important vector-borne disease (after malaria) in Latin America (5).

The prevalence of human infection is associated with the degree of adaptation of the vector insects to a domiciliary existence as human habitation has encroached on the insects' ecologic niche (2, 5, 6, 8–10). While *T. cruzi* continues to be maintained in a sylvatic cycle between sylvatic Triatominae and small mammals such as rodents and marsupials, the agricultural practices that have disrupted the sylvatic cycle have also provided rural housing suitable for colonization by the insects and human inhabitants for their blood meals. While nonhuman animal species can still serve as reservoir hosts, the domestic cycle between triatomine insects and people is now the primary mode of infection for humans (2, 6). Of the 114 species of triatomine insects in 13 genera, all of which are considered potential vectors of *T. cruzi*, approximately 12 species are epidemiologically important because of their living, feeding, and defecation behaviors. With a dispersal range of only 10–20 m, only those species that have adapted to rural housing are important. Furthermore, effective vectors are limited to those species that defecate during, or immediately after, feeding, since the insects transmit *T. cruzi* only by defecation (an inefficient mode of transmission thought to require repeated exposures) (6–8). Poor-quality housing and living conditions, such as mud-stick walls, thatched roofs, dirt floors, wood piles, and inferior sanitation, provide daytime hiding places for these insects and have been associated with infestations of dwellings. Regional living habits and local vector species behavior (usually one or two species in a given region) determine which of these factors contribute to the risk of house infestation in a particular area (2, 6, 8, 10–13). Because no effective treatment or vaccine exists or is anticipated in the near future, reducing domiciliary vector infestation is currently the key to controlling this disease (6, 14–17).

In Costa Rica, where *Triatoma dimidiata* is the major vector of *T. cruzi*, extensive surveys of a representative town in a Chagas' disease-endemic area have implicated unsanitary conditions, dirt floors, stored firewood, and possibly domestic animals as risk factors associated with domiciliary infestation by this vector (11, 12). Statistical evaluation of these data was limited to bivariate tests, which can only evaluate the association of each risk factor considered separately with infestation. The authors of these reports recognized this limitation, stating that "it is not easy to separate the effect of each parameter studied, since they are commonly associated (in 76% of our cases)" (12, p. 234). In the present study, log-linear modeling, used in many health-related fields (18–23), was the multivariate technique chosen to complete the data analysis. The purpose of this study was to reexamine the survey data previously collected in Costa Rica by using log-linear modeling to identify significant risk factors for house infestation by *T. dimidiata*.

MATERIALS AND METHODS

Background

The procedures used to collect the original survey data have been described previously (11). In brief, a census was conducted of an entire town, San Rafael de Ojo de Agua, located in a known Chagas' disease-endemic area 22 km northwest of San José, Costa Rica. Information was collected on the characteristics and infestation status of 512 houses (97.8 percent of those in the town) in two complete inspection cycles during the period 1964–1968. These data were coded and entered onto a computer tape. The data were then manipulated for this study on a microcomputer, where all editing and preliminary analysis was conducted using commercially available software packages (Lotus 1-2-3, Lotus Development Corporation, Cambridge, Massachusetts; and Statgraphics, STSC, Software Publishing Group, Rockville, Maryland). The edited data were transferred to a mainframe computer, where the BMDP4F computer program was used to form multiway frequency tables and to carry out the log-linear modeling procedure (24).

Variable selection and definition

Potential risk factors considered as independent variables were first screened for significant associations with the dependent variable, house infestation with *T. dimidiata.* This variable, hereafter called infestation, was defined as evidence of an established colony of *T. dimidiata* based on the presence of nymphal stages or exuviae, not adults only, either inside or immediately adjacent to the house. The independent variables were also tested for independence from each other to evaluate the associations among them.

All of the potential risk factors that were identified were categorical variables and were defined, based on physical and biologic attributes, as follows: sanitary condition of the house—bad, regular, or good (estimated by the general stage of repair and cleanliness); type of floor—dirt (all or part) or other (cement, brick, or wood); type of wall—earthen (adobe or mud-stick) or other (wood or cement); type of roof—tile (all or part) or galvanized metal; and firewood in the house—present or absent.

In addition to the chi-square test for independence, unadjusted relative odds of infestation and their 95 percent confidence intervals were computed from 2-by-2 contingency tables to compare the apparent risk of infestation between categories for each risk factor (25, 26). Each of these was then compared with the corresponding adjusted relative odds of infestation obtained from the log-linear model.

Selection of log-linear model

A multiway frequency table was formed with the observed number of houses for each cross-classification in the appropriate cell. A log-linear model was then selected that summarized the structure of the data set by significant associations among these cross-classified variables (24, 27, 28). Interactions that we wished to study because of a substantive prior interest were not included in this model but were included in the final model (29–31). The parameters estimated by the final model were used to calculate the relative odds of infestation and the 95 percent confidence intervals for each category of each risk factor, as well as for combinations of risk factors (32).

RESULTS

Only 16.4 percent of the 495 houses for which information on infestation status was available were infested. Houses without a complete data set for all variables were excluded from the multivariate analysis, limiting it to 371 houses (72.5 percent). The number and percentage of houses corresponding to each risk factor category for both the original and the restricted data sets are shown in table 1. The percentages of houses in each category that were infested are also shown for both data sets. The restriction of data resulted in no significant changes in the proportion of houses in each risk factor category or in the proportion infested for each category ($p > 0.7$), indicating that data were not missing in a systematic manner. Examination of the unadjusted relative odds of infestation for both data sets (table 2) also indicates that no significant changes were introduced by the removal of houses without complete information.

The "best-fit" log-linear model chosen from the six-way frequency table showed

TABLE 1. Characteristics of houses in the original sample* and the restricted sample† and rates of house infestation with *Triatoma dimidiata*, by selected house risk factors, Costa Rica, 1964–1968

House risk factor	Original data set			Restricted data set		
	No. of houses	% of houses‡, §	% infested‡, §	No. of houses	% of houses§	% infested§
Total	512	100.0	16.4	371	100.0	15.9
Sanitary condition of house						
Good	105	20.8	6.7	77	20.7	6.5
Regular	292	58.0	16.2	211	56.9	16.6
Bad	107	21.2	26.9	83	22.4	22.9
Missing data	8					
Floor type						
Other	153	35.3	8.0	134	36.1	8.2
Dirt	281	64.7	19.6	237	63.9	20.3
Missing data	78					
Wall type						
Other	306	73.7	13.8			
Earthen	109	26.3	21.0	—‖		
Missing data	97					
Roof type						
Galvanized metal	150	36.1	6.8	139	37.5	7.2
Tile	265	63.9	20.9	232	62.5	21.1
Missing data	97					
Firewood indoors						
Absent	95	20.2	10.8	77	20.8	13.0
Present	376	79.8	17.9	294	79.2	16.7
Missing data	41					

* Data on 97.8 percent of the houses in San Rafael de Ojo de Agua, Costa Rica, collected by census in 1964–1968.
† The original sample excluding houses without complete data for all variables.
‡ Percentage was calculated after subtracting missing data for that category.
§ For each category, no significant difference existed between the proportions of houses or the proportions infested before and after exclusion of missing data ($p > 0.7$).
‖ Wall type was not included as a risk factor in the final log-linear model.

that wall type was not a significant component of the model. Since this variable was also not significant in previous work with this vector (11), we excluded it (27, 29). We could have similarly omitted the variable "firewood in the house" but chose to keep it in the model since its potential biologic role as a risk factor has been reported from Costa Rica (11, 12). When we used the remaining variables to form a five-way frequency table, the final model fitted the tabular data well ($n = 371$, $G^2 = 28.77$, 29 df; $p = 0.48$) and contained the five main effects—sanitary condition, firewood indoors, type of floor, type of roof, and infestation—as well as several interaction effects among the main effects.

Comparison of the proportions of houses with infestation (table 1) and the unadjusted relative odds of infestation (table 2) for the risk factor categories suggests that all five independent variables might be considered potential risk factors for infestation. However, consideration of all possible two-way interactions between independent variables demonstrated a significant association ($p < 0.05$, chi-square tests for independence) between every pair of variables, with the exception of the association between type of wall and firewood in the house. For each risk factor, the adjusted relative odds of infestation (table 2) represent a substantial decrease from the unadjusted relative odds. Most notably, dirt floor and bad sanitary condition each dropped from unadjusted relative odds with 95 percent confidence intervals that excluded 1.0 (unadjusted relative odds = 2.8 and 4.3, respectively) to much smaller adjusted relative odds with 95 percent confidence intervals that included

TABLE 2. Relative odds of house infestation by *Triatoma dimidiata* in a Costa Rican town, by selected house risk factors for infestation, 1964–1968

House risk factor	Categories compared*	Relative odds of infestation (95% confidence interval)		
		Unadjusted (n = 495)†	Unadjusted (n = 371)‡	Adjusted (n = 371)‡
Sanitary condition of house	Bad/good	5.1 (2.1–12.3)	4.3 (1.5–12.1)	1.9 (0.5–7.1)
Floor type	Dirt/other	2.8 (1.5–5.5)	2.8 (1.4–5.7)	1.7 (0.8–3.8)
Wall type	Earthen/other	1.7 (0.9–3.0)	1.6 (0.8–2.9)	—§
Roof type	Tile/galvanized metal	3.6 (1.8–7.3)	3.5 (1.7–7.1)	2.4 (1.1–5.4)
Firewood indoors	Present/absent	1.8 (0.9–3.7)	1.3 (0.7–2.8)	1.0 (0.4–2.1)

* We compared the first category listed with the second category (the reference category) to calculate the relative odds.

† There were 495 houses with information on infestation status. For each variable, the number of houses (with information on infestation status and that variable) was: sanitary condition, 492, floor, 420; wall, 403; roof, 401; and firewood, 462.

‡ There were 371 houses in the restricted data set (those with complete data for all variables studied).

§ Wall type was not included as a risk factor in the final log-linear model.

1.0 (adjusted relative odds = 1.7 and 1.9, respectively). For tile roof, the adjusted relative odds were 2.4 and remained significant (95 percent confidence interval 1.1–5.4), while for the presence of firewood, the adjusted relative odds were equal to 1.0.

Comparison of houses with combinations of the high-risk categories with houses with lower-risk combinations suggests a greater risk of infestation when multiple risk factors are present (table 3). For example, houses with a tile roof, a dirt floor, firewood indoors, and a bad sanitary condition have adjusted relative odds of infestation of 7.7 when compared with houses having the opposite profile. Table 3 highlights the usefulness of multivariate analysis—the relation of the adjusted relative odds between categories of any risk factor remains consistent, regardless of the combinations of other risk factors. For example, there are only trivial differences throughout the table between the relative odds of infestation associated with the presence of firewood.

DISCUSSION

In this study, the exclusion of approximately one fourth of the original data set because of missing data could be a potentially large source of bias. If there was any pattern of data collection, house inspection procedures, resident cooperation, etc., that accounted for the missing data, the differential proportion of missing values by risk factor and/or infestation could have resulted in systematic biases in the multivariate analysis. We examined the distribution of houses by risk factor category, the proportion of houses infested by risk factor category, and the unadjusted relative odds of infestation for each risk factor in both the original and restricted data sets and found no evidence that data were missing in a systematic manner (tables 1 and 2).

Two previously identified risk factors, the presence of a dirt floor and bad sanitary condition, each had adjusted relative odds of infestation that approached 2.0. Although the 95 percent confidence interval for each includes 1.0, these two factors should still be considered potentially important risks for house infestation on the basis of the magnitude of their relative odds and the biology of *T. dimidiata*. Dirt floors provide the insects with the opportunity to cover themselves with dirt (instinctive camouflage behavior in this species), while the poor state of repair and cleanliness of a house in bad sanitary condition provides numerous hiding places where the insects have been observed (11, 12).

TABLE 3. Adjusted relative odds of house infestation by *Triatoma dimidiata* in a Costa Rican town, 1964–1968, for each combination of major risk factor categories

Roof type	Floor type	Firewood indoors	Sanitary condition of house	Adjusted relative odds*
Galvanized metal	Other	Absent	Good	1.0
			Regular	1.5
			Bad	1.9
		Present	Good	1.0
			Regular	1.4
			Bad	1.9
	Dirt	Absent	Good	1.7
			Regular	2.5
			Bad	3.3
		Present	Good	1.7
			Regular	2.4
			Bad	3.2
Tile	Other	Absent	Good	2.4
			Regular	3.6
			Bad	4.7
		Present	Good	2.4
			Regular	3.5
			Bad	4.5
	Dirt	Absent	Good	4.1
			Regular	6.0
			Bad	7.9
		Present	Good	4.0
			Regular	5.9
			Bad	7.7

* Adjusted for the effects of the other risk factors in this table.

A previously unidentified risk factor, the presence of a tile roof, was discovered in this study (adjusted relative odds = 2.4). Roof type was a risk factor not previously investigated in these data, since *T. dimidiata* is rarely found more than 1 m above the ground in Costa Rica (11). Even though tile roofs were relatively cheap and were common among poorer houses at the time of the survey, it is still difficult to imagine how the roof itself could influence house infestation by such a vector. However, a review of the original data cards and recent interviews with residents present during the original study revealed a possible explanation: Spare roof tiles were commonly stored in stacks against outside walls of houses, and occasional reports of finding vector insects in these piles appear on the original data cards. We recently visited a house from the study area that was still infested and found nymphal stages of the vector under tiles in such a stack. We suggest that these stacks of tiles, and not the tile roof, provided an excellent refuge for the insects that was still close to their human hosts located indoors. It is known that *T. dimidiata* living close to outside walls often enter the house for human blood meals (33).

The lack of association of infestation with the presence of firewood indoors (adjusted relative odds = 1.0) was unexpected, since firewood's biologic role of carrying and harboring the insects was directly observed in the original survey (11, 12). However, the location of *stored* firewood was probably the key risk—not just its presence indoors, which may be temporary. In some houses, the firewood was stored indoors or against a wall outdoors (allowing the harbored insects access to human blood meals), while in other houses the firewood was stored outdoors away from the house and was only brought indoors in small amounts when needed. An evaluation of the effect of stored firewood on infestation will require the availability of more specific data. Many other potential risk factors for house infestation in endemic areas of Costa Rica and other parts of Latin America have been suggested. These include family size (i.e., host density), house age, hygiene, and the presence of domestic or peridomestic animals (8, 17, 34). As larger data sets become available, the effects of additional risk factors can be investigated.

The three major strategies currently being applied to the control of Chagas' disease vectors are insecticide use (a short-term strategy), housing improvements, and health education and community participation (2, 6, 15, 17, 35, 36). Long-term control of this disease requires the identification, for the epidemiologic situation in each locale, of the most economical, effective, and culturally acceptable methods of reducing or eliminating domiciliary infestation by the insect vectors (6, 17, 35). This in turn requires accurate identification of socioeconomic factors, specifically housing characteristics, that are risk factors for house infestation. The biology of domestic Triatominae makes them especially vulnerable to control; there are no real technical barriers, but control must be integrated into regional development and land management. While there is little incentive for investment in new housing or extensive modernization, appropriately directed housing improvement yields long-term effectiveness for a low overall cost and is safe, with minimal environmental impact (6, 16, 35).

The application of multivariate analysis in this study allowed more accurate characterization of the relative contribution of each risk factor to house infestation, including the discovery of the presence of a tile roof as a newly identified risk factor and the confirmation of increased risk due to dirt floors or bad sanitary conditions. With the advent of microcomputer applications for multivariate techniques (37, 38), the ability to discover new information in previously collected and analyzed data increases and has great potential in the study of tropical diseases.

REFERENCES

1. Walsh JA. Estimating the burden of illness in the tropics. In: Warren KS, Mahmoud AAF, eds. Tropical and geographical medicine. New York: McGraw-Hill Company, 1984:1073–85.
2. Nogueira N, Coura JR. American trypanosomiasis (Chagas' disease). In: Warren KS, Mahmoud AAF, eds. Tropical and geographical medicine. New York: McGraw-Hill Company, 1984:253–69.
3. World Health Organization. Chagas' disease: report of a study group. Geneva: World Health Organization, 1960. (WHO Technical Report Series no. 202).
4. Special Programme for Research and Training in Tropical Diseases. Advances in research on Chagas' disease: five years of progress. Trop Dis Res Newsl 1983;20:6–7.
5. Schofield CJ, Apt W, Miles MA. The ecology of Chagas' disease in Chile. Ecol Dis 1985;1:117–29.
6. Schofield CJ. Control of Chagas' disease vectors. Br Med Bull 1985;41:187–94.
7. Acha PN, Szyfres B. Zoonoses and communicable diseases common to man and animals. Washington, DC: Pan-American Health Organization, 1980. (PAHO Scientific Publication no. 354).
8. Zeledón R. Epidemiology, modes of transmission, and reservoir hosts of Chagas' disease. In: Trypanosomiasis and leishmaniasis, with special reference to Chagas' disease. Ciba Foundation Symposium 20 (new series). Amsterdam: Associated Scientific Publishers, 1974:51–85.
9. Piesman J, Sherlock IA, Mota E, et al. Association between household triatomine density and incidence of *Trypanosoma cruzi* infection during a nine-year study in Castro Alves, Bahia, Brazil. Am J Trop Med Hyg 1985;34:866–9.
10. Mott KE, Muniz TM, Lehman JS, et al. House construction, triatomine distribution, and household distribution of seroreactivity to *Trypanosoma cruzi* in a rural community in northeast Brazil. Am J Trop Med Hyg 1978;27:1116–22.
11. Zeledón R, Solano G, Burstin L, et al. Epidemiological pattern of Chagas' disease in an endemic area of Costa Rica. Am J Trop Med Hyg 1975;24: 214–25.
12. Zeledón R, Vargas LG. The role of dirt floors and of firewood in rural dwellings in the epidemiology of Chagas' disease in Costa Rica. Am J Trop Med Hyg 1984;33:232–5.
13. Wilton DP, Cedillos RA. Domestic triatomines (Reduviidae) and insect trypanosome infections in El Salvador, C. A. Bull Pan Am Health Organ 1978;12:116–23.
14. Brener Z. Present status of chemotherapy and chemoprophylaxis of human trypanosomiasis in the Western Hemisphere. Pharmacol Ther 1979;7: 71–90.
15. Pan-American Health Organization. Report of a study group on Chagas' disease. Washington, DC: Pan-American Health Organization, 1970. (PAHO Scientific Publication no. 195).
16. World Health Organization. Environmental management for vector control: Fourth report of the WHO Expert Committee on Vector Biology and Control. Geneva: World Health Organization, 1980. (WHO Technical Report Series no. 649.)

17. Marsden PD. Selective primary health care: strategies for control of disease in the developing world. XVI. Chagas' disease. Rev Infect Dis 1984;6:855–65.
18. Tompkins ME, Alexander GR, Jackson KL, et al. The risk of low birth weight: alternative models of neonatal mortality. Am J Epidemiol 1985;122:1067–79.
19. Miholic J, Hiertz H, Hudec M, et al. Fever, leukocytosis, and infection after open heart surgery: a log-linear regression analysis of 115 cases. Thorac Cardiovasc Surg 1984;32:45–8.
20. Mackowiak PA, Browne RH, Southern PM, et al. Polymicrobial sepsis: an analysis of 184 cases using log-linear models. Am J Med Sci 1980;280:73–80.
21. Oler J, Bentley JM. Log-linear model selections in a rural dental health study. Stat Med 1983;2:59–69.
22. Kass PH, Strombeck DR, Farver TB, et al. Application of the log-linear model in the prediction of the antinuclear antibody test in the dog. Am J Vet Res 1985;46:2336–9.
23. Thorburn MA, Carpenter TE, Jasper DE, et al. The use of the log-linear model to evaluate the effects of three herd factors on *Streptococcus agalactiae* mastitis occurrence in California, 1977. Prev Vet Med 1983;1:243–56.
24. Brown MB. Frequency tables. In: Dixon WJ, ed. BMDP statistical software. Berkeley, CA: University of California Press, 1985:145–206.
25. Schwabe CW, Riemann HP, Franti CE. Epidemiology in veterinary practice. Philadelphia, PA: Lea and Febiger, 1977.
26. Fleiss JL. Statistical methods for rates and proportions. 2nd ed. New York: John Wiley and Sons, Inc, Publishers, 1981.
27. Freeman DH, Jekel JF. Table selection and log-linear models. J Chronic Dis 1980;33:513–24.
28. Fienberg SE. The analysis of cross-classified categorical data. 2nd ed. Cambridge, MA: The MIT Press, 1980.
29. Bishop YMM, Fienberg SE, Holland PW. Discrete multivariate analysis: theory and practice. Cambridge, MA: The MIT Press, 1975.
30. Brown MB. Screening effects in multi-dimensional contingency tables. Appl Stat 1976;25:37–46.
31. Benedetti JK, Brown MB. Strategies for the selection of log-linear models. Biometrics 1978;34:680–6.
32. Holt D. Log-linear models for contingency table analysis: on the interpretation of parameters. Sociol Methods Res 1979;7:330–6.
33. Zeledón R, Solano G, Zúñiga A, et al. Biology and ethology of *Triatoma dimidiata* (Latreille, 1811). III. Habitat and blood sources. J Med Entomol 1973;10:363–70.
34. Piesman J, Sherlock IA, Christensen HA. Host availability limits population density of *Panstrongylus megistus*. Am J Trop Med Hyg 1983;32:1445–50.
35. DeRaadt P. Improvement of rural housing as a means of control of Chagas' disease. In: New approaches in American trypanosomiasis research. Washington, DC: Pan-American Health Organization, 1976:323–5. (PAHO Scientific Publication no. 318).
36. Petana WB. Educational approach in the control of Chagas' disease. Bull Pan Am Health Organ 1975;9:300–5.
37. Koepsell TD. Loglinear modeling with inexpensive computing equipment. Am J Epidemiol 1984;120:777–87.
38. McGee DL. A program for logistic regression on the IBM PC. Am J Epidemiol 1986;124:702–5.