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Human perception towards the association between the domestic rock pigeon and the insect vector of Chagas disease in an urban area of Argentina

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ABSTRACT

This article focuses on identifying risk factors through the knowledge, perceptions, and prevention practices of the population regarding the rock pigeon and the vector of Chagas disease (vinchucas) in an urban area of Argentina. The study used interviews of focal groups, family nuclei with nearby nesting sites and without nearby nesting sites. Among the results, presence of risk factors that contribute to the infestation of vinchucas in houses were identified, such as presence nesting sites of the rock pigeon, and frequency of cleaning the nests and of fumigation. We show that people that kept their houses clean of nests and routinely disinfected their homes had considerably lower probability of finding vinchucas within their houses. We also identify a general lack of knowledge about risk factors of Chagas disease related to the presence of nesting sites in houses, the form of dispersion of the vector and how to act upon encountering a vinchucas. However, respondents who presented nests in their houses associated the encounter of vinchuca with the presence of nesting sites. The respondents showed high levels of support for programs to control the population of the rock pigeon. It is important that the population at risk of contracting Chagas disease can combat this disease through their daily actions. Promoting better knowledge of risk factors would be an important advancement for community compliance and participation in the fight against Chagas disease.

Keywords: *Triatoma infestans*; *Columba livia*; zoonosis; risk factors; urban ecosystems.

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SIGNIFICANCE STATEMENT

The present study provided evidence of pigeon nesting sites as a major risk factor for the infestation of triatomines in urban areas. The study has also identified several factors that decrease the risk of infestation, such as frequency of cleaning the nests and fumigation in houses. We show that people that routinely disinfected their homes and kept houses clean of nests had considerably lower probability of finding vinchucas (*Triatoma infestans*) within their homes. These risk factors shoulde be taken into account to develop simple interventions aimed at reducing triatomine infestation in urban areas, thereby decreasing the incidence of Chagas disease.

INTRODUCTION

Vector-borne diseases such as Chagas disease, dengue, malaria, yellow fever, and encephalitis are infections caused by pathogens that are transmitted by arthropods such as triatomine bugs (vinchucas), mosquitoes, lice, and ticks (Marselle et al. 2019). Vector-borne diseases account for more than 17% of all infectious diseases and disproportionately affect poorer populations, where housing conditions are unfavorable (Wilson et al. 2020). Many vector-borne diseases are classified as neglected tropical diseases, e.g., Chagas disease, dengue, and chikungunya (Feasey et al. 2010). The causal agent of Chagas disease is the flagellated protozoan *Trypanosoma cruzi*, which is transmitted by blood-sucking insects commonly called vinchuca or chinche (Gorla and Noireau 2017); it affects between 18 and 25 million people in Latin America and is currently recognized as the main endemic in the region (WHO 2015). This disease has a complex reality since it is associated with multiple social and environmental factors that require a broad and comprehensive approach (Petana 1976). Chagas disease has traditionally been associated with rural communities, with crudely built houses with adobe walls that provide suitable refuges for *Triatoma infestans* and other domestic vectors (Cecere et al. 2003). However, in recent years this insect has expanded its range from sparsely populated rural and peri-urban areas to densely populated urban areas (Vallvé et al. 1995).

The characteristics of urban landscapes provide unique challenges and opportunities for a species to colonize and proliferate. Added to this, is the fact that Latin America has experienced an overwhelming phenomenon of urbanization, where the proportion of the population living in cities has increased from 41% in 1950 to 80% in 2010, and the urban population is expected to increase to 650 million in 2025 (Butler and Spencer 2010). This rapid urbanization results in proximity between people and pest species, including rodents, birds, and insects, many of which carry pathogens that are transmissible to humans (Barbu et al. 2013). The speed at which these pest species spread through human communities is closely associated with the risk of disease in the human population and with economic loss (Spennemann et al. 2017).

The identification of characteristics that promote colonization and migration to cities allows a mechanistic understanding of the distribution and abundance of species in urban settings (Kareiva 1990). It has been shown that in several Latin American cities there are already triatomines in urban areas such as Buenos Aires and San Juan in Argentina, Heredia in Costa Rica, and Cuernavaca in Mexico (Gajate et al. 2001; Ramsey et al. 2005; Vallvé et al. 1995; Zeledon et al. 2005). Faced with this situation, it has been shown that the domestic rock pigeon (*Columba livia*) builds its nests in the different structures of urban centers (roofs, balconies, air conditioners, palm trees, etc.), and these sites are sometimes used by *T. infestans* to settle and reproduce in cities (Fernández-Maldonado et al. 2017; Vallvé et al. 1995). Although it has not yet been possible to eradicate Chagas disease from endemic countries, control strategies focus on reducing transmission by fast elimination of the vector (WHO 2015). For this, the most effective form of control is to prevent contact between the human being and the vector, curbing opportunities for these insects to settle and reproduce in homes. While housing construction problems are important, practices in and around the home (the peridomicile) also increase the risk of infestation (Cecere et al. 2003; Minoli 2004; Schofield et al. 1999). Previous research indicates that socioeconomic aspects such as extremely poor dwellings, very low incomes and a lower level of education create conditions favorable to the appearance of triatomines (Samartino and Eddi 2010; Sanmartino 1999; Vallvé et al. 1995).

Some of the strongest determinants of triatomine infestation in homes are the number of dogs or cats allowed into the home, the lack cleaning of peridomicile garbage, and the presence of birds' nest nearby (Krystosik et al. 2020; Rodríguez Planes 2018; Ulon et al. 2018). The establishment of pigeon nesting sites on houses or buildings or surrounding areas in urban zones can also increase the risk of infestation because they act as though they were chicken coops in urban areas. Promoting healthier housing practices can create a sustainable solution for triatomine prevention, reducing exposure to Chagas disease in urban areas. To adequately protect the community from this disease, it is necessary to effectively communicate the risk and propose feasible preventive measures, particularly in the control of triatomine vectors (Genero et al. 2018). This vector control requires joint measures such as: national spraying programs in homes, home improvement by reducing the potential sites for the establishment of these insects, and finally and essentially, community participation in the prevention and control of vector-borne diseases (Herdiana et al. 2018). However, community participation entails the development of adequate and effective health education strategies. For this, it is inevitable to understand the community's level of knowledge, its attitudes, and its practices. Studies on knowledge and risk perception of vector-borne diseases such as dengue fever in Mexico revealed that households presented high levels of vulnerability to the disease and an inability to address this risk (Chuc et al. 2013). Nanjesh Kumar et al. (2017) in India revealed that the overall knowledge regarding mosquito-borne diseases was satisfactory and the knowledge about prevention of mosquito-borne diseases was good but still many households did not practice them. Another study in an urban area in India found that the level of knowledge of the populations about vector-borne diseases was low and could be increased through various information, education, and communication campaigns for both the Government and the people (Gorantla et al. 2017).

For this reason, it is necessary to deepen the study of social representations, as well as their cultural characteristics, since in most countries knowledge about vector-borne diseases is low regardless of the level of education (Gorantla et al. 2017; Manrique et al. 2010; Sanmartino and Crocco 2000). To reduce risk factors of Chagas disease, it is important to know the details of the association between the nesting sites of the domestic rock pigeon in the residencies and the vector of the disease. To understand this issue, in this study we had two objectives: 1) to assess the risk factors for Chagas disease in urban nesting areas of the domestic rock pigeon through the knowledge, perceptions and attitudes of the population; and 2) to assess the degree of public support for pigeon population management measures in order to reduce the risk factors for Chagas disease in the community.

MATERIAL AND METHODS

The study area is located in the Tulúm Valley (31°32'16 "S; 68°31'31" W), San Juan province, Argentina (Figure 1), which is characterized by a dry climate, large temperature fluctuations during the day and throughout the year, and annual precipitation normally below 100 mm (Labraga and Villalba 2009; Poblete and Minetti 1999). Greater San Juan has a mainly urban population; 73% of this population is concentrated in a space that represents 2% of the total area of the province. Within the study area, we performed random sampling with restrictions. To collect relevant data, randomized block design was used, 9 blocks with domestic rock pigeon nesting sites and 9 blocks without nesting sites were selected. The blocks (100 x 100 m) were separated from each other by a minimum of 200 m (Figure 1). We then proceeded to visit 10 houses chosen by simple random sampling within each block mentioned above.

The information was compiled using a closed interview in which one person from the family unit over 18 years old was questioned. This survey was conducted in September 2016, in conjunction the beginning of the transmission season of vector of Chagas disease. The surveys included questions related to people's perceptions of pigeons, their nesting sites, vector identification, and the disease they transmit, and to their actions when they encounter *T. infestans*. In addition, we asked whether they associated pigeons with the vector of Chagas disease, and any prevention and/or control measures of the pigeon population they would agree with. An university student was trained to administer the questionnaires together with the first author of this article. People were personally contacted in their homes during the day from Monday to Friday. Then we requested their consent orally to respond to the questionnaire, according to the International Society of Ethnobiology Code of Ethics (International Society of Ethnobiology 2006). A pilot study was carried out to identify any deficits and to correct them accordingly. This project was evaluated and approved by the ethics committee of the National University of San Juan (Act No. 02-115-18).

Data analysis

General Linear models (GLMs) with binomial distribution of errors (binary) were used to relate the finding of vinchucas within the homes, with two predictor variables (the frequency of cleaning pigeon nests and the frequency of fumigation of the housing). Model selection was based on information-theoretic procedures (Burnham Anderson 2003). Akaike's information criterion (AIC) was calculated for each model (Burnham Anderson 2003). Due to small sample size, the models were evaluated using AIC corrected for small sample size (AICc) (Burnham and Anderson 2003; Garamszegi 2011). Model comparisons were made with AIC, which is the difference between the lowest AIC value (i.e. best of suitable models) and AIC from all other models (Burnham and Anderson 2003). The weight of the Akaike (wi) of each model and the relative importance (RI) of the explanatory variables were evaluated (Burnham and Anderson 2003). The software used was R 3.3.2. (the R- Project for Statistical Computing; http://www.R-project.org) and the specific package used was MuMIn to streamline the information-theoretic model selection (Barton 2020).

RESULTS

This study shows the observations received from 180 respondents in 18 blocks of the study area (Bernard 2017). Among those surveyed, 45.55% were men and 54.44% were women. Only 50.5% of respondents perceived the pigeons as a problem; this perception was regardless of whether or not nesting sites were present nearby. Of these, 79.4% reported that the problem was the birds' nest in houses or buildings. In addition, we asked about the reason for finding T. infestans in or around the home. More than half (53.3%) of respondents were unaware of the reason for T. infestans being found in the city, while 25.6% recognized nesting sites as an ecotope of T. infestans

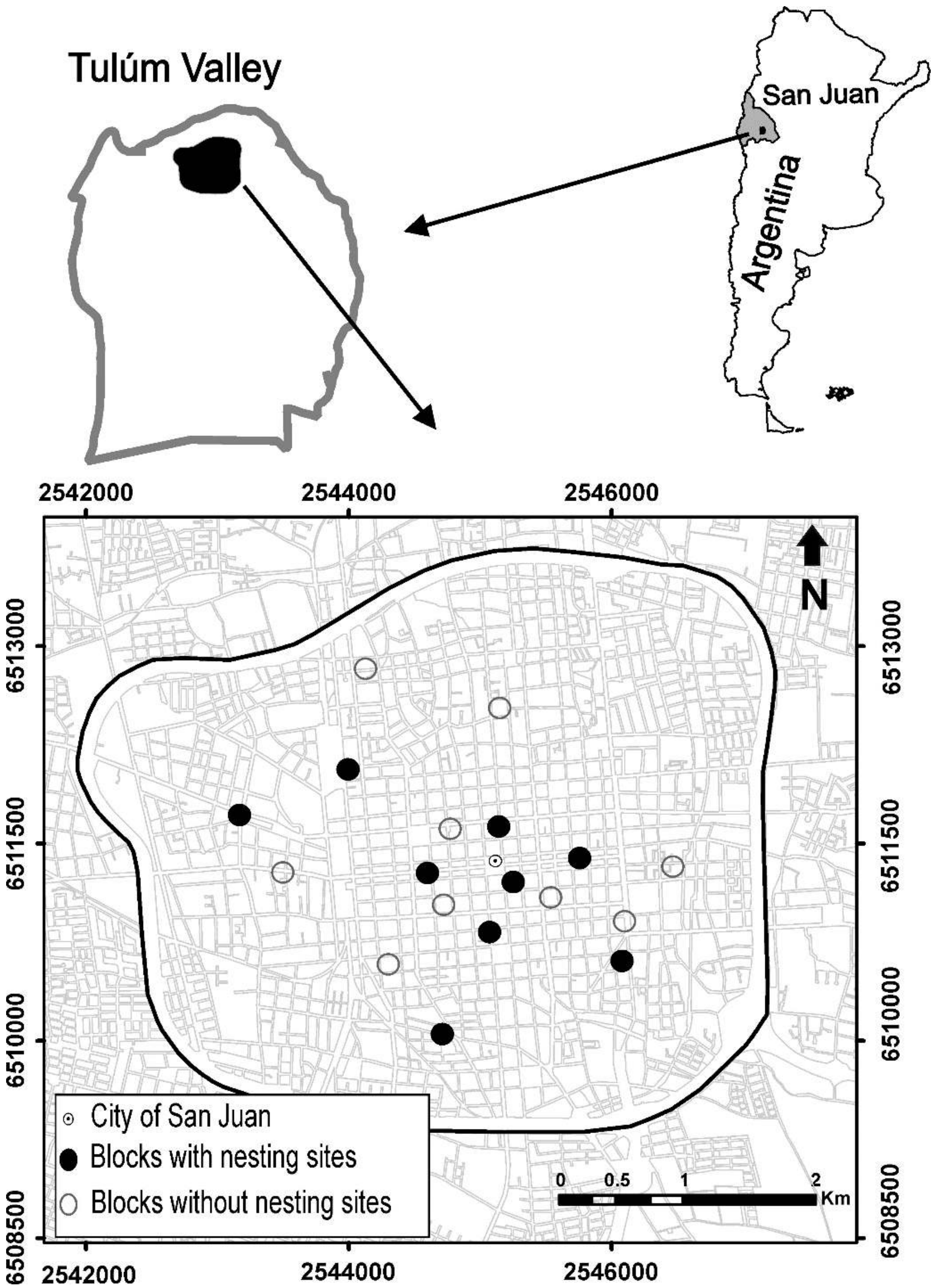

Figure 1. Presence-absence of domestic rock pigeon nesting sites in city of San Juan. The circles indicate the sites selected to carry out the surveys.

in urban areas for reproduction and dispersal. Only a few (2.2%) mentioned the existence of chicken coops,

Table 1. Perceptions about the reason for finding T. infestans in homes or surroundings.

Answer: reason for finding *T. infestans* in the city	Respondents (n = 180) (%)
Do not know	96 (53.33)
Nesting sites	46 (25.56)
Other animals (bats, dogs, chicken coops)	4 (2.22)
Wasteland/garbage dump/building material/neighbor/wind	34 (18.89)
Total	180 (100)

bats and dogs in the city as other causes of the presence of the vector (Table 1).

As for transmitted Chagas disease, 93.88% were able to identify the vector (T. infestans) and the disease it transmits, while only 6.11% of the respondents failed to recognize either the vector or the disease transmitted. When the respondent found T. infestans, we asked what they did with the vector insect. Almost half (49.44%) of the people did not respond, 30% responded that they killed it, while only 10.5% of the people indicated that they took it to be tested for the T. cruzi parasite. The remaining responses were: it was already dead, nothing, or that they kept it in storage (Table 2).

Regarding disease prevention and/or control measures through house fumigation, most people fumigate their homes once a year (50.55%), around 23% every 6 months, and 17% never. When asked about cleaning roofs and balconies to eliminate pigeon nests and thus reduce the encounter of *T. infestans*, of the 90 respondents with nesting sites, 73.33% of the respondents never removed the nests from the site, and only 12.22% of the respondents cleaned up the site once a year.

To run the GLMs, all surveys with nesting sites that responded not having pigeon nests were discarded (n = 33). However, 7 surveys were incorporated from the block without nesting sites where they answered having eliminated pigeon nests. In total, 64 surveys were used to perform the models. The best model showed a relationship between the probability of finding vinchucas within the homes and the following explanatory variables: frequency of cleaning pigeon nests and frequency of fumigation of the housing (AICc= 81.77, Akaike weight 0.64), with a relative importance of 0.85 and 0.78 for the variables, respectively. The probability of finding vinchucas within the homes decreased as the frequency of cleaning pigeon nests increased. Also, the probability of finding vinchucas within the homes decreased as the frequency of fumigation of the housing increased (Figure 2).

Finally, the respondents were asked about measures to control the pigeon population. Seventy-six point five percent of the people stated that the State should be responsible for managing the pigeon population, and 67% of the respondents agreed with the elimination of nesting in homes. In addition, 50% of the population agreed to replace the city's palm trees with another type of ornamental tree on which pigeon do not nest.

DISCUSSION

We were able to detect a lack of general knowledge and a lack of interest among the community in taking preventive measures against the infestation of homes by triatomines. Furthermore, our study identified important risk factors for domestic triatomine infestation in an urban area of the city of San Juan. These factors were nesting sites of *domestic rock pigeon* as new ecotopes for *T. infestans* for reproduction and dispersion, frequency in the use of domestic insecticides, and the cleaning frequency of roofs and balconies, all these were relevant in preventing infestation by triatomine in highly urbanized areas.

It is a fact that community participation is essential for the control of vector-borne diseases. This study showed that most of the respondents agreed the domestic rock pigeon was a problem in urban areas, but only 25.6% of the respondents interpreted pigeon nesting sites as being new ecotopes of *T. infestans* for their reproduction and dispersal. 53.3% of the respondents do not know the reason for finding *T. infestans* in their homes. This shows a general lack of knowledge about risk factors for Chagas disease, mainly related to the presence of nesting sites near homes. One study reported that the presence of nesting sites near houses increased *T. infestans* infestation in homes, leading to higher densities of triatomine populations in urban areas (Bar et al. 1993).

Most part of the people interviewed was able to correctly identify *T. infestans* as a vector for Chagas disease, However, we were able to detect a general lack of basic knowledge of how to act when faced with *T. infestans* at home or near it. Only 10.5% of the interviewees mentioned that they took the insect for their analysis of the *T. cruzi* parasite; most respondents, however, seem to not know that triatomines can be analyzed, and thus quickly detecting whether the person bitten may have the disease. This lack

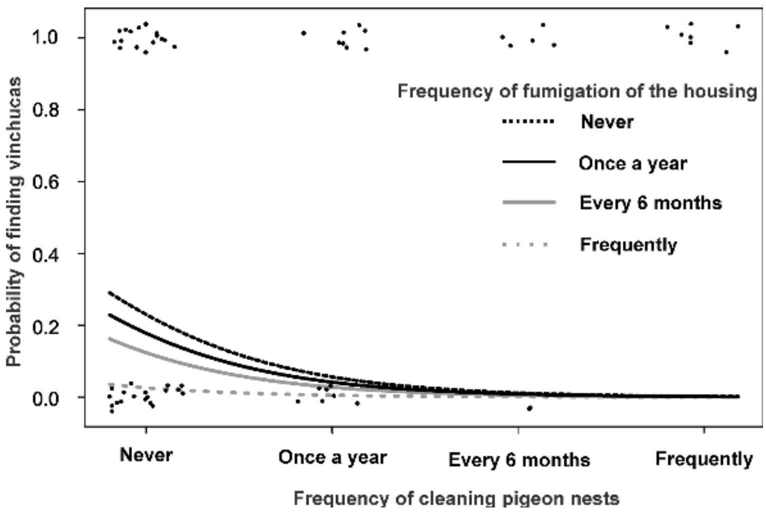

Figure 2. Generalized linear model (global model) explaining the variation in the probability of finding vinchucas within the homes depending on the frequency of cleaning pigeon nests and frequency of fumigation of the housing.

of information indicates a limited knowledge of the transmission of Chagas disease, its relationship with triatomines and the specific consequences for health. This result is similar to what has been observed in other countries and communities (Aguilar 2012; Sanmartino and Crocco 2000). This lack of knowledge and awareness about Chagas disease and its relationship to triatomines can be considered a major barrier to vector control, as the community may be relatively noncommittal about eliminating triatomines. This can be seen in several other cases with vector insects such as mosquitoes transmitting infectious diseases like malaria, dengue, Japanese encephalitis and lymphatic filariasis, or the sandfly which transmits leishmaniasis (Alizadeh et al. 2021; Patel et al. 2011).

There is therefore an important need for education on these aspects. It has been shown that the best vigilance strategy against domiciliary triatomine infestation is through inhabitants reporting suspected vectors, one of the most accurate and economically proven detection techniques to date (Abad-Franch et al. 2011). Regarding prevention and/or control measures through the fumigation of houses, most people fumigate once a year (49.44%). This yearly outlay is based on the motivation to control insects in general, not specifically triatomines. However, many households would become involved in more vector control efforts targeting triatomines if they recognized them

Table 2. Knowledge of respondents about the identification of *T. infestans* and the disease it transmits and their actions when encountering an individual of this insect.

Answer	**Respondents (n = 180) (%)**
Identification of the vector and the disease	
- Yes	169 (93.88)
- Not	11 (6.11)
Measures to be taken with the vector	
- Does not know	89 (49.44)
- Killed the insect vector	54 (30)
- Analyze	19 (10.55)
- It was dead/ nothing/saved	18 (10)
Total	180 (100)

as serious threats. Communities do not recognize most vector-borne diseases as a threat on account of lack of information about them (Nava-Doctor et al. 2021).

Many of respondents did not associate roof and balcony cleaning with triatomine infestation inside the houses. These results are similar to those found by Gregorio et al. (2019) for the Zika Virus Disease in the Philippines, where 16% of the respondents did not know about or provided no response to the practice of cleaning water containers to remove potential mosquito breeding sites. These limitations can be overcome using more efficient community education campaigns.

Moreover, our model showed that those sites that were kept clean of nests and were frequently fumigated considerably decreased the probability of finding *T. infestans* within them. This finding is crucial since pigeon nests are potential *T. infestans* breeding sites which can give rise to vector-borne epidemics such as Chagas disease. These factors, the frequency of use of domestic insecticides and cleaning frequency of roofs and balconies, were relevant in preventing infestation by triatomine in highly urbanized areas. The results also uphold the conclusion that the attitudes and practices of the heads of household exert important effects on domestic infestation with triatomines (Gaspe et al. 2015). These results can be compared with field studies that indicate that a clean patio, in this case roofs and balconies, can result in a 50% reduction in house infestation by triatomines (Dumonteil et al. 2013; Rosecrans et al. 2014).

Most respondents considered that it is the government's and not the community's responsibility to control pigeon nests, by eliminating pigeon nests from houses and replacing the city's palm trees for another type of ornamental tree in which the pigeon does not nest. This shows the extent to which the community is noncommittal about taking preventive measures against infestation by triatomines. This is not surprising given the epidemiology of Chagas disease in Argentina. Over the last decade, our study area has been ranked among the 5 provinces at higher risk of vector transmission (Spillmann 2014). These results differ from those found by Desjardins et al. (2020) in Colombia for dengue, chikungunya, and Zika diseases, where the community believed that they are generally more responsible for preventing vector-borne diseases than the government. Community-based educational interventions are essential and effective strategies to increase understanding and active participation of the community in the prevention and control of vector-borne diseases in cities of Argentina and other urban areas in Latin America (Yevstigneyeva et al. 2014).

CONCLUSION

In conclusion, we were able to detect risk factors for Chagas disease in cities, where domestic rock pigeon nesting sites have become a new ecotope for *T. infestans*, allowing it to reproduce and disperse in highly urbanized areas. The frequency of use of household insecticides and the frequency of cleaning of roofs and balconies were relevant to prevent infestation by triatomines. These factors allowed us to explain some of the risk factors in infestation within houses in urban areas. We recommend that interventions should target these factors to reduce infestation and provide sustainable vector control. Vector-borne disease control programs should emphasize the importance of reducing vector sources, methods for controlling the reproduction of *T. infestans* in urban areas, and urban Chagas prevention activities. We emphasize that the nesting sites are suitable refuges for the breeding of *T. infestans*, and this information should be communicated to the community for better participation in efforts to control the vector. Efforts need to be intensified to create public awareness and mobilize the community about the preventive measures they should take. Overall, we believe that, through community participation and experience, the impact of current interventions should translate into practice changes and full community involvement in vector-borne disease control. Our main recommendations are as follow:

Recommendations

- Disease control programs should emphasize the importance of improving the cleaning of homes as an effective measure, which does not represent any further cost to the community or the government, while also promoting community involvement. However, time and effort constitute barriers to cleaning roofs and balconies. One effective way would be to design educational messages indicating that house cleaning also contributes to controlling mosquitos, thus combining efforts against dengue and Chagas disease vectors.

- Interventions and messages of preventive behavior should be spread in materials that are both decorative and useful, such as calendars. In addition, the use of mobile health apps technology can be efficient tools to disseminate information about Chagas and other health issues, and to record the presence of the vector in certain areas of the cities.

- Development of health education and workshops on community-based disease and vector surveillance, control, and treatment may also help with increasing awareness and compliance from the community.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived the presented idea: VNFM, CEB.
Carried out the experiment: VNFM.
Carried out the data analysis: VNFM.
Wrote the first draft of the manuscript: VNFM.
Review and final writing of the manuscript: VNFM, CEB.
Supervision: CEB.

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