

# Risk factors for triatominae infestation in a municipality of Colombia

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## Abstract

**Background:** Identifying risk factors for Triatominae infestation is essential for the development of vector control interventions.

**Methods:** To determine the intra- and peridomiciliary risk factors associated with triatomine infestation, a cross-sectional analytical study was carried out with random cluster sampling in two stages, which included the identification of risk factors by survey and direct observation, as well as the search and capture of triatomines. The detection of trypanosomes in triatomines was carried out by observing the rectal content and then by conventional polymerase chain reaction (PCR).

**Results:** In 21 of the 207 houses inspected, 13 specimens of *R. colombiensis* and 19 specimens of *P. geniculatus* were found. Entomological indices included: dispersion 36%, infestation 10%, infection 65%, colonization 4.7%, density 15%, and concentration 152%. An association was found between the presence of Triatominae and the existence of branches and fissures in the floors, as well as with the presence of accumulated objects and with knowledge about Chagas disease. The risk of having triatomines in urban homes is 5.7 times higher than the risk in rural areas [confidence interval (CI) 0.508–67.567]; 6.6 times in houses with cracked soil (CI 0.555–81.994), 6 times in houses located near caneyas (CI 0.820–44.781), and 6.16 times with accumulated objects (CI 1.542–39.238).

**Conclusion:** Chagas disease is a complex problem that requires control based on the vector's elimination or surveillance, which implies identifying species and their distribution, generating alerts, knowledge, and awareness in the population. It is necessary to intensify surveillance activities for the event, especially in changing aspects of Chagas diseases' transmission dynamics, such as urbanization and the type of housing associated with the vector's presence.

**Keywords:** Chagas disease, Colombia, epidemiological risk, reduviidae, triatominae

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## Introduction

Chagas disease is a public health problem, especially in Latin American countries; however, due to migration, more and more cases are reported in North America and Europe; as a result, it is now a topic on global health agendas.<sup>1–4</sup>

In Colombia, there have been multiple studies and publications on the subject.<sup>5–26</sup> However, considering the diversity of regions with differentiating environmental, biological, and social factors, transmission, infection, and disease, this should be a source of permanent research, both scientific and operational research, the

latter from the point of view of epidemiology and entomology to carry out effective interventions in public health. On the other hand, the increase in urbanization and the extension of cultivation has meant that humans are in contact with the natural ecotopes of wild triatomines and reservoirs of *Trypanosoma cruzi* (*T. cruzi*)

Chagas disease is a chronic, systemic, parasitic infection caused by the protozoan *T. cruzi*, one of the highest-burden conditions in Latin America, where the burden is between five and ten times greater than malaria.<sup>27</sup>

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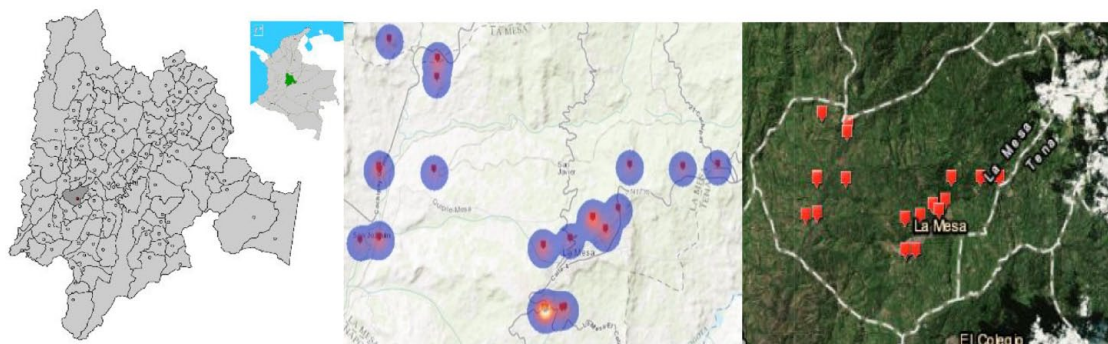
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**Figure 1.** Geographic distribution of sampling sites.

The disease affects about 8 million people, of whom 30–40% either have, or will develop, cardiomyopathy, mega digestive syndromes, or both.<sup>28</sup> The cases often occur in poor rural and, increasingly, new urban and peri-urban areas.<sup>29</sup> The World Health Organization (WHO) recognized it as one of the world's 13 most neglected tropical diseases.<sup>30</sup> In Colombia, approximately 5% of the national population is infected, and almost 20% are at risk of transmission.<sup>31</sup>

There are 27 recorded triatomine species in Colombia, of which *Rhodnius prolixus* (*R. prolixus*), *Triatoma dimidiata* (*T. dimidiata*), *Triatoma maculata* (*T. maculata*), and *Triatoma venosa* (*T. venosa*) have been registered in domiciles and peridomiciles.<sup>32</sup> Triatomines of the species *Panstrongylus geniculatus* (*P. geniculatus*), *Rhodnius pallescens* (*R. pallescens*), and *Rhodnius colombiensis* (*R. colombiensis*) have also been occasionally identified. *R. prolixus* is the primary vector, but *T. dimidiata* is also essential in the rural transmission of *T. cruzi* and is considered the second vector in the country.<sup>25,33</sup> The department of Cundinamarca is one of the most endemic for *T. cruzi* infection. Records from 1999 to 2013 have shown 15 triatomine species in the department, distributed in 34 of its 116 municipalities. The municipality of La Mesa reported a critical number of triatomines in this same period. Nevertheless, natural infections with the parasite have not been confirmed.<sup>6</sup>

In Colombia, the risk factors for infestation have been specially studied for *R. prolixus*. Still, it is necessary to know more about the behavior and the factors that favor infestation by other triatomine species.<sup>34</sup>

To better understand the risk of house infestation by triatomines in the municipality of La Mesa, an

entomologic survey was done in 207 houses belonging to 16 localities (9 rural and 7 urban). The identification of risk factors will be fundamental to the development of vector control interventions.

## Materials and methods

### Study area

Fieldwork was carried out from March 2015 to March 2017 in a broad area of the municipality La Mesa, which is located between latitude 4° 37' 59" north and longitude - 74° 28' 1" West (Figures 1 and 2). The predominant Holdridge's life zones are pre-montane wet forest or humid forest pre-montane.<sup>35</sup> The average temperature throughout the year is 24°C (75°F) with 74% humidity and bimodal rainfall. The municipality has characteristics that allow the presence of different species of triatomine vectors of Chagas disease; it is also a population enclave that has both rural and urban areas, but, due to the dense vegetation that surrounds the municipality, it is difficult to establish clear differences between the two environments (Figure 2).

The localities included are rural settlements where people cleared forested areas for raising crops and cattle and some areas of the urban area. The peridomestic areas are characterized by the presence of enclosures for animals, for food and seed conservation, or for storage of tools and materials, in the vicinity of a predominantly mountainous environment with species of fauna and flora that favor the maintenance of the cycle of Chagas disease.

### Sample selection

A cross-sectional survey was carried out at the house level to investigate the role of potential risk factors for house infestation (indoor and outdoor)



**Figure 2.** Photograph of the peri-domicile of houses in urban area of the municipality of La Mesa. The presence of vegetation and other risk factors is observed in the peri-domicile of a house in an urban area a few blocks from the center of the municipality.

by triatomines in a sample of the houses in the urban and rural areas of La Mesa. The dwellings were randomly selected from a pre-existing list of houses obtained from the health office of the municipality; required sample sizes for houses in each area calculated assuming 5% infestation indexes (error 5%; confidence: 95%) determined by previous surveys.<sup>24</sup> Overall, two hundred and seven houses were selected.

#### *Collection of data for risk factor analysis*

The domiciliary unit was divided into two areas: indoor (bedrooms, kitchen, and living area) and the peri-domestic area, including all outbuildings present around the house. Each locality was visited initially to inform residents about the objectives and activities of the study. Each household received educational leaflets describing Chagas' disease signs and symptoms, transmission patterns, and the role of vectors. A questionnaire that identified risk factors for triatomines infestation was completed by interviewing adult residents. Direct observation was made of variables related to housing materials (walls, roof, and floor), domestic animals (presence of dogs, cats, chickens, etc.), outbuildings (overhead storage, chicken coop, grain shed), presence of vegetation (bushes, trees, and palm trees) around the houses, and the domestic use of insecticides.

The identification of risk factors associated with the presence of triatomines was evaluated by applying surveys prior to a pilot test that allowed

us to verify the validity of the questionnaire before final application. In addition, direct observation of the intra-domiciliary and peri-domiciliary space of each of the 207 dwellings that made up the sample was carried out.

#### *Triatomine collections and processing*

The presence or absence of bugs in each residence was assessed through systematic searches for adult or nymph triatomines. We employed standard methods for sampling bugs in each type of habitat, intradomiciles, and peridomiciles and calculated the infestation, colonization, and infection and dispersion indices.<sup>33</sup> During each house survey visit by a pair of collectors, indoor and outdoor niches were searched for 30 min each. We recorded the presence and site of bugs (inside or outside the house), time of collection, and movement of furniture or outdoor materials for bug searching. A flashlight was used to help see cracks and crevices throughout the buildings' fabric, behind pictures on the walls, furniture, in closets, and especially under bedding material.

From each house, all the bugs collected alive and dead (adults and nymphs) were placed in plastic tubes (separately for intra- and peridomicile samples) numbered with the house code and collection site. Bugs were transported to the laboratory, registered, and identified using taxonomic keys.<sup>36</sup> The numbers, species, and stage(s) of bugs obtained from each house were recorded on laboratory forms (Figures 3–6)



**Figure 3.** Inspection of grooves, holes, and cracks in walls.



**Figure 4.** Preparation and placement of traps with animal bait.



**Figure 5.** Palm inspection.

#### *Detection of T. cruzi infection*

All collected triatomines were analyzed for infection with *T. cruzi* using parasitological and molecular methods. The diagnosis of infection in live triatomines was made by extraction of their intestinal contents, mounting of feces in plates, and microscopic observation to identify movements

compatible with flagellates. Positive samples (with flagellar movement) were fixed and stained with Giemsa to determine infection with *T. cruzi* by morphology. In dead triatomines, a conventional polymerase chain reaction (PCR) was performed from their feces, with amplification of the parasite's kDNA minicircles, using primers S35



**Figure 6.** Packaging of triatomines captured by trapping.

**Table 1.** Summary of entomological indexes for triatomines in La Mesa.

	Entomological indices					
	Infestation %	Dispersion %	Infection %	Colonization %	Density %	Concentration %
Rural region	17 (11/64)	44 (4/9)	66.6 (10/15)	0	23 (15/64)	136 (15/11)
Urban region	6.9 (10/143)	71 (5/7)	64.7 (11/17)	4.7 (1/21)	11.8 (17/143)	170 (17/10)
Total municipality	10 (21/207)	56 (9/16)	65 (21/32)	4.7 (1/21)	15 (32/207)	152 (32/21)

and S36 for this procedure; PCR was also performed on samples in which *T. cruzi* was not evidenced by morphological analysis.

#### Data analysis

To identify the risk factors of home infestation by triatomines, bivariate and multivariate analysis were performed; using Pearson's chi-squared test ( $X^2$ ) and odds ratios, the magnitude of the association with the house infestation was estimated. Statistically significant variables ( $p < 0.05$ ) were then fitted in logistic regression models for multivariable analysis of risk factors. Variables with  $p$ -values of less than 0.1 were retained in the final multivariable model. Statistical analyses were performed using SPSS Statistics version 20.0 from IBM.

## Results

#### General findings

From a total of 207 houses located in 16 localities, the presence of triatomine was investigated

by collecting bugs for 24 months period (urban and rural) (Figures 1 and 2).

All the bugs obtained from searches in and around houses were identified as *P. geniculatus* (19 specimens) and *R. colombiensis* (13 specimens). The proportion of indoor infested housing was 10% (21/207), and the proportion of infested peridomiciles was zero (Figures 3–6). From the collected triatomines, 65.6% were infected with *T. cruzi*. The highest entomological indices were found in the localities of La Vega and Marsella, and the lowest in the localities of El Espino and Baltimore, as shown in Tables 1 and 2. House walls were generally of brick and cement (90.3%), without cracks or crevices (79.2%), and with objects hanging on the walls (94.7%).

Roofs were made of straw, palm leaves, or similar fibers in 4.8% of houses. The floors of the houses were made of cement (71.3%), earth (8.2%), or a combination (20.5%), and 25% of the houses had pens or sheds nearby.

**Table 2.** Entomological indexes for triatomines in La Mesa.

Rural region	N	Entomological indices					
		Infestation %	Dispersion %	Infection %	Colonization %	Density %	Concentration %
La Vega	5	60 (3/5)	NA	80 (4/5)	0	100 (5/5)	166 (5/3)
El Espino	5	20 (1/5)	NA	0	0	20 (1/5)	100 (1/1)
Baltimore	2	50 (1/2)	NA	0	0	50 (1/2)	100 (1/1)
Hungría	5	60 (3/5)	NA	66.6 (2/3)	0	60 (3/5)	100 (3/3)
Zapata	16	6 (1/16)	NA	100 (2/2)	0	12 (2/16)	200 (2/1)
Hospicio	3	66.6 (2/3)	NA	66.6 (2/3)	0	100 (3/3)	150 (3/2)
El Palmar	20	0	NA	0	0	0	0
Cápata	5	0	NA	0	0	0	0
San Martín	3	0	NA	0	0	0	0
Total rural	64	17 (11/64)	44 (4/9)	66.6 (10/15)	0	23 (15/64)	136 (15/11)
Urban region	N	Infestation %	Dispersion %	Infection %	Colonization %	Density %	Concentration %
Marsella	8	12 (1/8)	NA	60 (3/5)	12 (1/8)	62 (5/8)	62 (5/8)
Toledo	40	5 (2/40)	NA	0	0	5 (2/40)	5 (2/40)
Villas del Nuevo Siglo	29	6.8 (2/29)	NA	100 (3/3)	0	10 (3/29)	10 (3/29)
Santa Bárbara	17	0	NA	0	0	0	0
La Perla	24	8 (2/24)	NA	50 (1/2)	0	8 (2/24)	12 (3/24)
La Perlita	10	10 (1/10)	NA	100 (3/3)	0	30 (3/10)	30 (3/10)
Las Ceibas	15	13 (2/15)	NA	50 (1/2)	0	13 (2/15)	13 (2/15)
Total urban	143	6.9 (10/143)	71 (5/7)	64.7 (11/17)	4.7 (1/21)	11.8 (17/143)	170 (17/10)
Total in the municipality	207	10 (21/207)	56 (9/16)	65 (21/32)	4.7 (1/21)	15 (32/207)	152 (32/21)

Domestic animals were found in 60.4% of houses, while 85.5% of the houses had shrubs and trees, including palms.

#### *Awareness and understanding of risk factors for Chagas disease*

On the awareness of Chagas disease, 39% had heard about Chagas disease, 67% did not know about the existence of a treatment, 63% knew how the disease is transmitted, and 33% knew the symptoms.

Faced with the knowledge of triatomines, 63% of those surveyed claimed to have heard about triatomines and of those who answered this question, approximately 60% knew where they live and what they feed on. 44% affirmed that they know how to control them; 39 people (29%) have seen triatomines inside their home, and 43 (33%) have seen them outside the home. 6.9% reported having been bitten (or some other occupant of the home) by a triatomine. In addition, it was identified in 99.2% of the responses that the recognition of the fecal matter of these insects is not usual.

**Table 3.** Selected results of bivariable analyses of associations between infestation and exposure variables.

Variable	N		Triatomines (%)		OR (95% CI)	X <sup>2</sup> (p-value)
			Yes	No		
Location	207	Rural	11 (17.2)	53 (82.8)	2.8 (1.1–6.8)	0.025
		Urban*	10 (7.0)	133 (93.0)	1	
Knowledge	206	Yes	17 (20.9)	64 (79.0)	0.09 (0.026–0.32)	0.000
		No*	3 (2.4)	122 (97.6)	1	
See triatomines inside the house	132	Yes	12 (30.7)	27 (69.23)	6.44 (2.2–18.8)	0.000
		No*	6 (64.5)	87 (9.3)	1	
Walls with cracks and crevices	207	Yes	8 (18.6)	35 (81.3)	2.65 (1.02–6.8)	0.039
		No*	13 (7.92)	151 (92.07)	1	
Floors with cracks and crevices	207	Yes	5 (2.94)	12 (70.58)	4.5 (1.41–14.48)	0.006
		No*	16 (0.84)	174 (91.57)	1	
Domestic animals	207	Yes	17 (13.6)	108 (86.4)	3.06 (1.7–9.47)	0.004
		No*	4 (3.2)	78 (62.4)	1	
Accumulated objects	207	Yes	13 (19.11)	55 (80.88)	3.8 (1.5–9.8)	0.003
		No*	8 (5.75)	131 (94.24)	1	

\*Reference category.  
CI, confidence interval; OR, odds ratio.

Regarding the identification of risk factors in homes and peridomicile, the survey shows the following results. Only 10% of the homes had ceilings and walls made of vegetable fibers or dirt floors, 20% report cracks or cracks in the floor, 72% use angeos on doors and windows, and 94% report having objects hanging on the walls of their homes.

60% of the dwellings had domestic animals, 48% reported wild animals close to the home, and 25% of the dwellings were close to corrals or sheds. 85% of the houses were surrounded by trees (including palms) and 73% had arches or similar constructions attached to the house.

#### Bivariate analysis

The bivariate analysis showed that the intra-domiciliary presence of triatomines is associated with the location of the dwelling [odds ratio (OR) 2.8, 95% confidence interval (CI): 1.1–6.8, *p*-value

0.025], cracks and crevices in walls (OR 2.65, 95% CI: 1.0–6.8, *p*-value 0.039) and in flats (OR 4.5, 95% CI: 1.4–14.8, *p*-value 0.006), the presence of domestic animals (OR 3.06, 95% CI: 1.7–9.47, *p*-value 0.004), the accumulation of objects inside or outside the house (OR 3.8, 95% CI: 1.5–9.8, *p*-value 0.003), and see triatominae inside the house (OR 6.44, 95% CI: 2.2–18.8, *p*-value 0.000). Knowledge about Chagas disease and its vector behaved as a protection factor (OR 0.09, 95% CI: 0.026–0.32, *p*-value 0.000) (Table 3).

#### Multivariate analysis

In the multivariate analysis (Table 4), using the value of the adjusted OR, it was determined that the probability of having houses infested with triatomines in an urban area is 5.7 times the probability of the rural area (95% CI: 1.542–39,238, *p*-value 0.035), the probability of infestation in houses with floors with cracks is 6.6 times the probability of dwellings without this condition

**Table 4.** OR (95% CI) of risk factors associated with the infestation in multivariable analysis.

Variable	OR crude*	p-value	OR adjusted**	OR (95% CI)	
				Lower limit	Upper limit
Location_Urban <sup>a</sup>	1742	0.035	5708	1542	39,238
Knowledge about Chagas disease <sup>a</sup>	-4083	0.001	0.017	0.001	0.524
Floor has cracks or cervices	1897	0.0033	6668	2.6	81,994
Enramadas outside the house <sup>a</sup>	1802	0.0078	6059	2.3	44,781
Accumulated objects inside or outside the house <sup>a</sup>	1818	0.0021	6162	3.58	67,567

<sup>a</sup>Reference category; \* $\beta$  value; \*\* $\beta$  exponential. CI, confidence interval; OR, odds ratio.

(95% CI: 6.555–81.994,  $p$ -value 0.003), the probability of finding triatomines in a dwelling located near carney is 6.0 times the probability of homes away from this type of construction (95% CI: 6.820–44.781,  $p$ -value 0.0078), and, in houses with the accumulation of objects the probability of infestation is 6.1 times the probability of those dwellings without this characteristic (CI: 2.508–67.567,  $p$ -value 0.002). Infestation with triatomines is lower in homes with owners with knowledge about Chagas disease. Therefore, this variable was a protection factor (OR 0.017, 95% CI: 0.001–0.524,  $p$ -value 0.001).

#### Entomological indexes

The highest entomological indexes were found in the rural region of the municipality, except for the dispersion (71%), concentration (170%), and colonization (4.7%) indexes, which were higher in the urban region (Tables 1 and 2).

#### Discussion

This study shows that a low percentage of the population has a basic knowledge of Chagas disease and its transmission mechanisms; only 39.1% knew about the disease, 13% knew the symptoms, and although 63.3% had heard of the triatomine vector, they did not know about it directly (44.4%) and did not know that it participates in the transmission cycle of the illness. Mundaray *et al.*<sup>37</sup> in 2013 in the State of Carabobo, Venezuela. presented higher percentages of knowledge of the disease and its symptoms (60%) as well as a high percentage of response to the recognition of the vectors (72%).

The two studies coincide in the deficient knowledge of transmission mechanisms and reservoirs and are reinforced by the investigations of Hurtado *et al.*<sup>38</sup> and Hernández, *et al.*,<sup>39</sup> showing that the challenge is to teach people the risk factors so that from home they avoid practices that favor arrival or contact with the vector and its excreta.

One aspect that influences the greater exposure to the vector and infection is the education of the inhabitants of the affected areas. High illiteracy rates, low levels of education, and even high school dropouts lead to a low ability to elucidate the importance of disease care and the need to control risk factors.<sup>40</sup> In La Mesa, a characteristic that should be used in favor of promotion and prevention activities is the high proportion of schooling in all age groups, with a very low percentage of respondents who reported not having received formal education (0.5%).

The type of construction materials of the houses appears as a risk factor for the transmission of Chagas disease.<sup>7,41,42</sup> Castillo and Wolff's article<sup>40</sup> showed a relationship between the presence of triatomines and the precariousness of the houses evaluated by the construction materials of walls, floors, and ceilings. In addition, it indicates that the areas with greater exposure to endemic infections are characterized due to conditions of poverty, reflected in homes built with natural and not very resistant materials, and low levels of sanitation. The same scenario in another study for Colombia reveals the vulnerability of the indigenous communities of Valledupar<sup>23</sup> with poorly constructed homes and in precarious



socioeconomic conditions, which unfortunately occurs in most of the country's indigenous communities, since their traditions, customs, and ways of life differ from what has been considered as a protective factor for Chagas disease.

The research by Campbell-Lendrum<sup>24</sup> identified the risk of Chagas transmission in homes with wooden walls (OR 0.46), fully plastered walls (OR 0.78), tile roofs (OR 0.51), and tile floors (OR 0.57). In La Mesa, most of the dwellings that make up the sample have adequate construction conditions (which have been identified in most studies as protection factors) such as the use of materials such as brick or concrete (90.3%, tiles (95.2%), with finishes (90.3%), free of cracks or fissures (79.2%).

Regarding the factors related to the presence of animals, Mundaray *et al.*<sup>37</sup> obtained a high percentage of domestic and wild animals in the intra- and peridomicile (74%), according to the reports of Herrera<sup>29,43-45</sup> and Bonfante-Cabarcas *et al.*<sup>46</sup> on the presence of animal reservoirs such as dogs, goats, and chickens, among other birds. The study carried out in Oaxaca by Villalobos *et al.*<sup>47</sup> explains the frequent presence of chicken coops in the peridomicile, being spaces of easy colonization and chickens one of the most important transmitters. Campbell-Lendrum *et al.*,<sup>24</sup> with a sample of 41,971 households in 15 Colombian departments, found a high correlation between the presence of triatomines and the presence of cats (OR 1.27) and pigs (OR 1.16), in addition to having a space of storage at home (OR 1.16) or a grain storage shed (OR 1.25). In the present study, only 26.6% of the dwellings have areas attached storage.

The study carried out in the Mexican municipality of Metztlán<sup>42</sup> showed that the presence of rodents near the home is risky. Likewise, the study by Manrique *et al.*<sup>48</sup> associates positive cases in humans with the presence of dogs and chickens at home; in the findings of Cortés *et al.*<sup>49</sup> infection in children is correlated with the number of infected triatomines, and the presence of chickens is related to home infestation. An association between Chagas seropositivity and the presence of armadillos in homes located in jungle environments has also been described. The role dogs in the transmission and as sentinels of *T. cruzi* infection has been explored in the programs of control.<sup>50,51</sup>

In La Mesa, possession of domestic animals (dogs, cats, parrots, chickens, among others) was recorded in 60.4% of the homes, and the proximity of the homes to wild animals (rodents, borugos, armadillos, possums, etc.) in 48.3%, with less frequency of facilities dedicated to animal exploitation, such as corrals or sheds (25.1%).

In reference to another risk factors for triatomine infestation, Mundaray *et al.*<sup>37</sup> reported abundant vegetation (82%) in the vicinity of the houses, and Villalobos,<sup>47</sup> explains that the location of the houses is an important risk factor, since the houses located on the peripheries are more likely to have vectors, especially if they are near palm trees, in addition to the fact of using palm fibers and other materials of plant origin for the manufacture of roofs.<sup>38</sup> In the municipality of La Mesa, 85% of the homes observed have trees in their vicinity.

The study by Villalobos *et al.*<sup>47</sup> for *Triatoma phyllosoma* concluded that there are very low levels of genetic variation between species; the insect survives in places other than its natural habitat, and its living conditions are flexible, this allows them to survive and colonize domestic environments quickly and reduces the possibility to find an infection-free environment. Vectors can change from wild to rural environments and then to urban environments,<sup>8,52</sup> also pointed out by Guzmán-Marín in Campeche to explain the wide adaptability of *T. dimidiata*, which does not have a homogeneous distribution pattern and its wide dispersal makes it difficult to control.<sup>53,54</sup>

In this regard, in the study carried out in Venezuela by García *et al.*,<sup>55</sup> there are very worrying data, the high rate of colonization by the vector in non-endemic areas, thus expressing the reproductive success of triatomines that maintain their biological chain by adapting to different types of ecosystems. It was evidenced that higher rates of infestation occur in regions where man has intervened the most, characterized by being a mountain area; in comparison with lower indices in regions with plain areas and few wooded extensions that also have control programs with the use of insecticides.

The studies by Guhl *et al.*<sup>13</sup> and Guzmán-Marín *et al.*<sup>53</sup> conclude that the high number of microclimates allows the wide geographic distribution of the insect in all territories and show that

the vegetation index and five climatic factors are sufficient to predict the distribution of the vector: the wind speed, the rate of precipitation, the type of vegetation, humidity, and temperature, resulting in the most influential in the abundance of vectors, the wind speed. Although these factors were not evaluated in the present study, they constitute the basis for generating new research in the municipality of La Mesa.

According to Mordini, “an attempt is made to highlight the two instances of the disease today: rural and urban Chagas”<sup>56</sup> and to guide research to observe the behavior of the vector in the urban environment, and not only to observe the expression of globalization of disease because of migration. Other studies have explored changes in the urban/rural distribution: Náquira explains that the presence of vectors is directly related to the informal urbanization that favors the environment for the establishment of triatomines; progressively, and as the city expands, the vectors expand and Zeledón *et al.*, identified the presence of triatoma adults and nymphs in a well-built house very close to the urban area of San José, Costa Rica.<sup>11,41,57–61</sup> Regarding the domiciliation of the vector, it is worth mentioning the studies by Cantillo-Barraza *et al.*<sup>22</sup> and Parra-Henao<sup>15</sup> that demonstrate the intra-domiciliary presence and colonization of *T. dimidiata*, with the potential risk of transmitting the disease due to the high rates of natural infection that this vector presents and its short defecation time. In La Mesa, it was found that the risk of having triatomines in urban homes is 5.7 times the risk in rural areas. Furthermore, the presence of nymphs in a house in an urban area was identified.

*T. dimidiata* is the most widely distributed vector of the infectious agent responsible for Chagas disease;<sup>62</sup> it has been reported in Guatemala and Mexico; in Colombia, it has a wide distribution in the Andean, Caribbean, Llanos Orientales, and Alto Magdalena regions,<sup>7,17–19,25,26,32,53,63–66</sup> so it is of great importance despite being considered a secondary species in the transmission of *T. cruzi*.

In the present study, no specimens of *T. dimidiata* were found, but some of the entomological indicators calculated for *P. geniculatus* and *R. colombiensis* are striking, with respect to similar studies:<sup>14,22,53,55,67–70</sup> The colonization index (4.7%) is lower compared to other reports in the region. The dispersion (36%) is exceeded in the

reports from Yucatán (95%), Campeche, and Provincia del Chaco (100%). The infestation rate of this study (10%) exceeds the record of Sucre (3.65%), Arica (1.69%), Goiás (3.44%), and Isla Margarita (5%). The concentration (152%) is lower than that of Chiquimula (565%), Isla Margarita (4121%), and Yucatán (379%), and is higher at the national level than that reported for the Sierra Nevada de Santa Marta (129%).

*R. colombiensis* is a wild species distributed mainly in the departments of Cundinamarca and Tolima. In turn, *R. prolixus* is domiciled in this same region. The natural habitat of *R. colombiensis* in some municipalities of these departments has been intervened and replaced by crops, which has led to the adaptation of insects to the peridomestic area of human dwellings. This pattern has also been observed with other species considered exclusively wild, such as *P. geniculatus*.

The contagion rate (65%) exceeds some national reports: Capitanejo (20.6%), Macaravita (50%), Soatá (10%), Valledupar (4%), Tipacoque (20%), Sierra Nevada (20%), Mompo (48%), and is lower than the index calculated for Isla Margarita (75.40%). Compared with other studies in the region, it exceeds the estimates of Yucatán (16%), Campeche (38%), Arica (19.20%), Chiquimula (52, 30%), Provincia del Chaco (53.20%), and the Sucre state in Venezuela (1.72%), whose figure is the lowest in the region.<sup>14,21,22,53,55,67,68,70</sup>

## Conclusions

This study in the municipality of La Mesa evidenced the presence of triatomines and an active cycle of Chagas disease in the region. The entomological indices of colonization, dispersion, and concentration were higher in the urban area of the municipality, the infestation rates and density were higher in the rural region, and the natural infection was similar in the two areas. The study provides important information for control programs, specifically in terms of identifying homes at risk for triatomine infestation.

The results identify relationships between some characteristics of the dwellings and the probability of domestic and peridomestic infestation. The identified risk factors are consistent with other studies and add evidence for the specific intervention.

This study has implications for maximizing surveillance efficiency, which is likely to become increasingly important if control interventions succeed in reducing infestation rates.

Although everything seems to be known in the dynamics of the disease, the issue of determinants and social determination cannot be ignored, which involves economic development, the organization of the State and power relations to understand, what characteristics beyond the socioeconomic or environmental conditions explain the presence of the vector in affected populations, expanding the analysis of the health-disease process, and the possibilities for comprehensive intervention.

It is necessary to instill self-care as part of promotion and prevention activities. Education must be made at school, at home, at work, and in all spaces for community use, about the key elements in the transmission of Chagas disease and the basic sanitation rules aimed at maintaining spaces free of attractants for vectors triatomines and reservoirs of *T. cruzi*.

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### Author Contributions

GPH: Concept of the manuscript, collected data, wrote manuscript, reviewed and approved final version of the manuscript; SGJ: Concept of the manuscript, collected data, wrote manuscript, reviewed and approved final version of the manuscript; YBR: collected data, wrote manuscript, reviewed and approved final version of the manuscript; MJO: Concept of the manuscript, wrote manuscript, reviewed and approved final version of the manuscript; MS: collected data, wrote manuscript, reviewed and approved final version of the manuscript; OATG: Concept of the manuscript, collected data, wrote manuscript, reviewed and approved final version of the manuscript

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The authors declare that there is no conflict of interest.

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### Ethical statement

The study, including specimens capture, and management were performed according to VI and VII principles of The International Guiding Principles for Biomedical Research Involving Animals and Colombian law 84 of 1989 Decrees 1376 of 2013 and Resolution No. 8430 of 1993 under the previous approval of the Ethical Committee of the Antonio Nariño University – 115-05- 2013 and ANLA permit 2016046238-1.000. Participants provided verbal informed consent to participate in the study.

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