Prevalence and Seroprevalence of *Trypanosoma cruzi* Infection in a Military Population in Texas

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Abstract. Recent biosurveillance findings at Joint Base San Antonio (JBSA), a large military installation located in south-central Texas, indicate the potential for vector-borne human Chagas disease. A cross-sectional study was conducted to determine the prevalence and seroprevalence of *Trypanosoma cruzi* infection in highest risk subpopulations on the installation, including students and instructors who work and sleep in triatome-endemic field settings. Real-time polymerase chain reaction, enzyme-linked immunosorbent assay, and indirect immunofluorescent antibody assay were performed on enrolled subjects (N = 1,033), none of whom tested positive for *T. cruzi* or anti-*T. cruzi* antibodies. Current countermeasures used during field training on JBSA appear to be sufficient for preventing autochthonous human Chagas disease.

INTRODUCTION

Chagas disease, or American trypanosomiasis, is caused by infection with *Trypanosoma cruzi*. The protozoan parasite is transmitted to humans most commonly through the infected excreta of hematophagous triatomin insects of the family Reduviidae, entering the bloodstream through a wound or mucous membrane.1 Known colloquially as “kissing bugs,” triatomines are found throughout the western hemisphere. Eleven species are endemic to the southern United States, most of which are competent vectors of the parasite.2 In addition to the vector-borne route, *T. cruzi* may be transmitted congenitally, orally in contaminated food or beverages, or directly via blood transfusion or organ and tissue transplantation.3

The majority of human cases are subclinical in both the acute and chronic stages, resulting in lifelong, undiagnosed infection. Cardiac disease, gastrointestinal disease, or both develop in approximately one-third of cases, typically manifesting years or decades after initial infection.4 Chagas disease mortality is usually attributed to heart failure or ventricular arrhythmia,5 but even asymptomatic infection with *T. cruzi* may increase all-cause mortality risk.6

Between 5 and 8 million people globally are infected with *T. cruzi*,1,7 incurring an annual economic burden of 7.2 billion USD.8 Although vectorial transmission is restricted to the Americas,9 human migration from endemic to nonendemic countries—and within endemic countries from rural to urban areas—has broadened the distribution of prevalent Chagas disease.10 Both imported and autochthonous cases occur in the United States, with the former predominating: at least 240 thousand Latin American immigrants are presumably infected,11 whereas fewer than 30 locally acquired infections have ever been reported.12 The dearth of documented autochthonous cases, however, may be more indicative of provider unawareness and suboptimal surveillance than true disease incidence.12,13 Recognizing the potential for vector-borne transmission across a broad swath of the southern United States, the Centers for Disease Control and Prevention (CDC) prioritizes Chagas as one of five neglected parasitic infections14 and urges more research to define autochthonous infection risk.12

In the greater San Antonio metropolitan area and throughout south-central Texas, Chagas disease has been a known but vaguely defined human disease threat since at least the 1960s.15-17 An obligation to elucidate that threat recently emerged from several biosurveillance findings on Joint Base San Antonio (JBSA), one of the largest military training installations in the United States. A 2007 serosurvey of military working dogs, all of which are trained on JBSA, found that 24 (8%) harbored anti-*T. cruzi* antibodies. Multiple military working dogs serving in Iraq required evacuation because of cardiomyopathy, later attributed to Chagas disease.18 A faunal survey was commissioned, which found that 43% (88/205) of collected adult triatomines and 22% (163/736) of nymphs tested positive for *T. cruzi* on polymerase chain reaction (PCR), and blood meal analysis revealed that 33% (43/131) contained human blood in their midgut. Among adults, *Triatoma sanguisuga* (66%) and *Triatoma gerstaeckeri* (30%) were the most common species identified (C. Daniels, unpublished data). This prompted the enforcement of new administrative, technical, and personal protective measures—as well as the reinforcement of existent measures—to protect humans and dogs against vector-borne pathogen exposure during field exercises on JBSA. Because triatomines were collected inside tents and elsewhere near populous training sites, we initiated this study to determine human infection risk.

MATERIALS AND METHODS

This cross-sectional study was designed to establish the prevalence of *T. cruzi* parasitemia and seroprevalence of anti-*T. cruzi* antibodies in five subpopulations most at risk for vector-borne infection while training and working on the installation: students graduating from the US Air Force Security Forces Apprentice course, all of whom had completed a week-long field training exercise on a triatome-endemic site of the installation at least 15 weeks before study enrollment; instructors from the US Air Force Security Forces Apprentice course; instructors from the US Air Force Basic Military Training Field training course; instructors from the Department of Defense Military Working Dog school; and instructors from
the US Air Force Survival, Evasion, Resistance, and Escape course. Given reduced prevalence of triatomines during the winter months,19 and thus reduced likelihood of detecting parasitemia and anti-T. cruzi IgM antibodies, we suspended enrollment from December through March.

We administered a questionnaire to all consented participants to gather demographic data, quantify exposure risk, and ascertain the geographic location of infection, should a subject test positive. Demographic data included age, sex, and self-reported race and ethnicity. The questionnaire initially focused on vectorial transmission risk by extracting information regarding military training; permanent residence in and travel to triatomine-endemic areas1,2; camping, hunting,20 and exposure to reservoir wildlife3,17 in triatomine-endemic areas; and bites by triatomines or by unidentified insects that may have been triatomines. We displayed high-resolution photos of T. sanguisuga and T. gerstaeckeri species to facilitate an accurate bite history. After discussing preliminary results with two external consultants, we added questions pertaining to blood transfusion and congenital transmission routes.

We collected whole blood from consented volunteers by peripheral venipuncture. On all subjects from whom we could obtain sufficient aliquots, we performed real-time PCR to determine the prevalence of T. cruzi parasitemia and an enzyme-linked immunosorbent assay (ELISA) and indirect immunofluorescent antibody (IFA) test to determine the seroprevalence of anti-T. cruzi antibodies.

Real-time PCR was conducted in singlicate per CDC published methodology to detect T. cruzi DNA in human samples.21 Briefly, DNA was extracted from buffy coat fractions from EDTA whole blood specimens followed by two multi-target TaqMan real-time PCR assays targeting three highly conserved and repetitive T. cruzi genomic regions: nuclear minisatellite TCZ; kinetoplast DNA; and the small subunit ribosomal RNA (18S rRNA) gene. Internal amplification control was performed with the RNase P human gene from the TaqMan Human RNase P detection reagent (Applied Biosystems, Foster City, CA).22 A blood sample was considered positive if it was PCR-positive for all three T. cruzi targets and equivocal if it was PCR-positive for only two T. cruzi targets. Equivocal results prompted retesting.

The Chagastest ELISA recombinante v.3.0 (Wiener Laboratoríos, Rosario, Argentina) was performed in duplicate, as directed by the manufacturer, for detecting human IgG and IgM anti-T. cruzi antibodies. Collected serum samples were incubated with immobilized antigen, washed, incubated with goat antihuman IgG conjugated to horse radish peroxidase, and washed again. Tetramethylbenzidine and hydrogen peroxide were then added, and the reactions were stopped with 2 N sulfuric acid. The colorimetric readings were taken at 450 nm in a plate reader, using a reference wavelength of 650 nm. Cutoff values were defined, per manufacturer guidance, as the mean negative control readings plus 0.3. The test was considered positive if greater than the cutoff value plus 10%, negative if less than the cutoff value minus 10%, and equivocal if within ±10% of the cutoff value.

Serum was also evaluated for the presence of human IgG antibodies against T. cruzi via IFA technique. A positive control and negative control were validated from the 21-member panel of the Chagas Titer AccuSet™ Performance Panel (SeraCare Life Sciences, Milford, MA). Panel member 1, which had an antibody titer of 1:4,096, was used as a positive control at a 1:200 dilution. Panel member 21, which had a negative titer (<1:128), was used as a negative control, also at a 1:200 dilution. Subject samples were screened at a 1:128 dilution. The dilutions were placed on T. cruzi antigen-coated microscope slides, washed to remove unbound serum antibodies, stained with a fluorescein isothiocyanate–labeled goat anti-human IgG conjugate, and visualized through a fluorescence microscope. A sample was considered positive at a titer equal to or greater than 1:128. IFA testing was conducted in singlicate.

We used descriptive statistics to build demographic and exposure profiles of the enrolled sample, both collectively and stratified by student and instructor status. We compared exposure time between students and instructors with an unpaired t test, using Epi Info v7.0 (CDC, Atlanta, GA). This study was approved by the 59th Medical Wing Institutional Review Board (FWH20140074H). Written informed consent was obtained from all subjects.

RESULTS

A total of 1,033 subjects were enrolled. Consistent with the ratio of students to instructors on the installation, the vast majority of participants (93.1%) were students graduating from the Security Forces Apprentice course (Table 1). During the 16-month study period (April–November 2015 and April–November 2016), we enrolled approximately 15% and 30% of eligible students and instructors, respectively. Most subjects were male (76.9%) and white, non-Hispanic (54.8%). The mean (standard deviation [SD]) age was 21.6 (4.6) years. Three subjects experienced presyncope with venipuncture, all of whom recovered fully without medical intervention. No other adverse events were noted.

Five subjects (0.5%) reported a triatomine bite and 131 (12.7%) reported a bite from an unidentified insect that may have been a triatomine. Subjects experienced 8,130 weeks of total exposure time in the triatomine-endemic field environment of JBSA, for a mean (SD) of 7.7 (18.0) weeks. Instructors (47.0 [45.6] weeks) had a greater mean exposure time than students (4.0 [4.0] weeks) \( P < 0.001 \). Details on demography, binary risk factors, and time residing and conducting higher risk activities in triatomine-endemic areas are provided in Table 1.

All PCR \((N = 1017)\), ELISA \((N = 1023)\), and IFA \((N = 1023)\) tests were negative, with the exception of one equivocal ELISA result. The enrollment total exceeds laboratory result figures because adequate blood specimens could not be obtained on every subject. The indeterminate ELISA result \((0.279 \text{ IV} \text{ [equivocal range: } 0.27–0.33 \text{ IV}])\) belonged to a student of Hispanic ethnicity, who was born and lived in Central America for 2 years before emigration to the United States. He then lived in the southwest United States for 19 years before arrival at JBSA. During training, he experienced three bites that may have been from triatomines, although he could not definitively classify the insect. Repeat ELISA testing was also equivocal, and his PCR and IFA testing were negative. He was advised to visit his health care provider for further discussion and workup.

DISCUSSION

Of 1,033 enrolled subjects, none tested positive for either T. cruzi parasites or anti-T. cruzi antibodies, suggesting that
Chagas disease is currently a low threat for military personnel on JBSA. One subject, who tested negative on PCR and IFA, had an equivocal ELISA result. Even if he were truly infected, his case could not be conclusively categorized either as autochthonous, because of his early childhood spent in Latin America, or as vectorial, given the possibility of vertical transmission.

The apparent mismatch between these reassuring findings and the troubling biosurveillance signals—i.e., cases of canine Chagas cardiomyopathy and a high volume of T. cruzi infection in south-central United States,12 despite a high prevalence of T. cruzi vectors in South America,2,3 the sylvatic species indigenous to the southern United States are less likely to defecate while taking a blood meal,28,29 and to colonize domestic and peri-domestic settings.2 These biologic and ecologic dynamics may partially explain why autochthonous human Chagas disease appears to be of relatively low risk in the United States, despite a high prevalence of T. cruzi vectors in South America,2,3 the sylvatic species indigenous to the southern United States are less likely to defecate while taking a blood meal,28,29 and to colonize domestic and peri-domestic settings.2 These biologic and ecologic dynamics may partially explain why autochthonous human Chagas disease appears to be of relatively low risk in the United States,12 despite a high prevalence of T. cruzi infection in triatomine vectors18,19,34 and substantial evidence for triatomine feeding on humans.34,37,38 Risk for autochthonous human infection is associated with increased age, Hispanic ethnicity, and living in rural or poverty-stricken areas near the United States–Mexico border.29,42

TABLE 1
Demographic and risk factor profile of study subjects

<table>
<thead>
<tr>
<th></th>
<th>Students, N = 962</th>
<th>Instructors, N = 71</th>
<th>Total, N = 1,033</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Security forces apprentice students</td>
<td>962 (100%)</td>
<td>–</td>
<td>962 (93.1%)</td>
</tr>
<tr>
<td>Security forces apprentice instructors</td>
<td>–</td>
<td>2 (2.8%)</td>
<td>2 (0.2%)</td>
</tr>
<tr>
<td>Basic military training field training instructors</td>
<td>–</td>
<td>36 (50.7%)</td>
<td>36 (3.5%)</td>
</tr>
<tr>
<td>Military working dog school instructors</td>
<td>–</td>
<td>23 (32.4%)</td>
<td>23 (2.2%)</td>
</tr>
<tr>
<td>Survival, evasion, resistance, and escape instructors</td>
<td>–</td>
<td>10 (14.1%)</td>
<td>10 (1.0%)</td>
</tr>
<tr>
<td>Age, mean (SD)</td>
<td>20.9 (3.6)</td>
<td>31.6 (3.0)</td>
<td>21.6 (4.6)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>735 (76.4%)</td>
<td>59 (83.1%)</td>
<td>794 (76.9%)</td>
</tr>
<tr>
<td>Female</td>
<td>227 (23.6%)</td>
<td>12 (16.9%)</td>
<td>239 (23.1%)</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White, non-Hispanic</td>
<td>515 (53.5%)</td>
<td>51 (71.8%)</td>
<td>566 (54.8%)</td>
</tr>
<tr>
<td>Black, non-Hispanic</td>
<td>121 (12.6%)</td>
<td>7 (9.9%)</td>
<td>128 (12.4%)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>221 (23.0%)</td>
<td>8 (11.3%)</td>
<td>229 (22.2%)</td>
</tr>
<tr>
<td>Other</td>
<td>105 (10.9%)</td>
<td>5 (7.0%)</td>
<td>110 (10.6%)</td>
</tr>
<tr>
<td>Potential exposures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Known triatomine bite</td>
<td>4 (0.4%)</td>
<td>1 (1.4%)</td>
<td>5 (0.5%)</td>
</tr>
<tr>
<td>Unidentified insect bite</td>
<td>102 (10.6%)</td>
<td>29 (40.8%)</td>
<td>131 (12.7%)</td>
</tr>
<tr>
<td>Received blood products in the United States†</td>
<td>7 (0.8%)</td>
<td>3 (5.9%)</td>
<td>10 (1.1%)</td>
</tr>
<tr>
<td>Received blood products outside the United States†</td>
<td>3 (0.3%)</td>
<td>0</td>
<td>3 (0.3%)</td>
</tr>
<tr>
<td>Mother from endemic country*</td>
<td>90 (10.2%)</td>
<td>4 (7.8%)</td>
<td>94 (10.1%)</td>
</tr>
<tr>
<td>Weeks in triatomine-endemic area, mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field environment at JBSA-Lackland</td>
<td>4.0 (0.4)†</td>
<td>47.0 (45.6)</td>
<td>7.7 (18.0)</td>
</tr>
<tr>
<td>Camping/hunting in Latin America or southwest United States‡</td>
<td>30.8 (125)</td>
<td>75.8 (284)</td>
<td>35.2 (147)</td>
</tr>
<tr>
<td>Wildlife exposure in Latin America or southwest United States‡</td>
<td>110.2 (281)</td>
<td>246.1 (514)</td>
<td>126.7 (320)</td>
</tr>
<tr>
<td>Living/traveling in Latin America</td>
<td>78.0 (230)</td>
<td>80.9 (225)</td>
<td>82.1 (212)</td>
</tr>
<tr>
<td>Living/traveling in southwest United States‡</td>
<td>430.4 (486)</td>
<td>235.9 (578)</td>
<td>380.9 (474)</td>
</tr>
</tbody>
</table>

JBSA = Joint Base San Antonio; SD = standard deviation.
† In addition to the 1-week field training exercise, sleeping in tents, at least 15 weeks before enrollment, most had recently completed 3 weeks of daytime field training, during which they slept in barracks.
‡ Southwest United States was defined as Arizona, California, Colorado, Nevada, New Mexico, Oklahoma, Texas, and Utah.
§ Wildlife exposure was defined as either hunting or living in a dwelling infested by woodrats, raccoons, opossums, skunks, wild hogs, coyotes, or deer.

Another explanation, albeit a study limitation and not a causative factor, is the possibility of false-negative testing. According to a recent meta-analysis, the Weiner ELISA has a sensitivity of 93.7% (95% confidence interval: 87.7%, 96.9%) for detecting human antibodies against T. cruzi.43 IFA testing is approximately 90% sensitive, although substantial heterogeneity exists across studies.44 This may be due to methodological differences, particularly with titer dilution cutoffs used.
to determine positive results. Our 1:128 dilution screening was
designed to maximize overall test accuracy, but other labo-
raries may demarcate a positive result at a titer of 1:80,45
thus concealing some specificity for improved sensitivity. PCR
is rarely used in isolation to rule out disease. Although it has
some diagnostic value during the parasitic acute stage of
disease,4 its sensitivity for detecting chronic infection in adults
is below 50%.43 However, by using three tests in parallel and
analyzing more than a thousand subjects, imperfect sensitivity
for any one test does not undermine conclusions drawn this
study.

The lack of molecular and serologic evidence of T. cruzi
infection in our study sample, although encouraging, should
not be misapplied. First, our findings should not be used to
exclude Chagas disease from the differential diagnosis list
when evaluating service members who trained or worked on
triatomine-endemic field sites of JBSA. Although we selected
populations with the highest risk of exposure, we only tested a
sample thereof, and many had a short duration of exposure.
Our results, therefore, may not be generalizable to populations
with prolonged exposures or who trained on the installation
before aggressive countermeasures were deployed. Second,
our findings should not be used to establish countermeasure
success. In the absence of a control group not employing
these measures, our study was not designed to verify their
effectiveness. Current countermeasures appear sufficient but
categorically necessary in preventing autochthonous hu-
man Chagas disease on JBSA.

Despite an abundance of T. cruzi–infected triatomine vec-
tors, some of which evidently feed on humans, Chagas dis-
ease is currently not a major infectious disease threat for
military students and instructors on JBSA. Even if parasite
transmissibility is intrinsically unlikely due to biochemical
factors, primary preventive measures reducing exposure to
T. cruzi and other vector-borne pathogens should continue.
To stage realistic military field training exercises while max-
imizing the health of humans, animals, and the environment,
we urge holistic One Health approaches built on collaboration
between military training leadership, civil engineers, and
medical, veterinary, and public health personnel.

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