Research Article

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Consumer willingness to pay for a hypothetical Chagas disease vaccine in Brazil: a cross-sectional study and the implications

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Aim: Chagas disease is a serious public health problem, endemic in 21 countries in Latin America. A future vaccine can contribute to decreasing the number of cases and its complications. **Methods:** A cross-sectional study was conducted with residents of the northern region of Brazil, on the willingness to pay for a hypothetical vaccine against Chagas disease (effective protection of 80%). **Results:** We interviewed 619 individuals and seven were excluded from the analysis and the value of willingness to pay was US$23.77 (100.00 BRL). **Conclusion:** The Northern region of Brazil is one of the largest markets for this vaccine, due to its epidemiological relevance, so economic studies with this vaccine will be important to assist in the assessment of technologies.

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The disorderly growth of urbanization in Brazil, coupled with environmental conditions such as accelerated deforestation and the climate, have contributed to the emergence and high prevalence of tropical infections including Chagas disease. Tropical diseases occur in 149 countries [1], representing 11.4% of the global burden of disease [2] and affecting one billion people globally [1]. These infections are responsible for causing between 500,000 to 1 million deaths annually [2]. As a result, billions of dollars are typically spent each year on preventive measures and treatment in many developing economies [1,3]. In Brazil, the most prevalent tropical diseases include malaria, dengue, Chagas disease, leishmaniasis, schistosomiasis, tuberculosis and leprosy [4,5].

Chagas disease (American *Trypanosomiasis*) is anthropozoonosis whose causative agent is protozoan, *Trypanosoma cruzi*, transmitted to humans via the feces of infected triatomines (barbers). Other contamination pathways include blood transfusion or organ transplants, congenital, indirect contact (via food ingestion) and breast milk [6]. Chagas disease is an important public health problem, especially in endemic countries such as Brazil, Argentina, Chile

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and Bolivia [7]. According to data from the Pan American Health Organization (PAHO), between six and seven million individuals have been infected and, approximately, 70 million people live in places prone to Chagas infections [7]. Moreover, 30,000 new cases and 14,000 deaths are currently reported per year [8,9]. Overall, Chagas disease represents one of the four major causes of deaths from infectious and parasitic diseases in Brazil [6].

Chagas disease is mainly presented in two phases, acute and chronic. In the acute phase, individuals may present with prolonged fever (more than 7 days), headache, intense weakness, swelling of one eye, swelling and redness at the site of the sting, stomach pain, vomiting and diarrhea. However, in the chronic phase, events related to disturbances in the heart, esophagus and intestine are highlighted [6,10]. There is currently no cure for patients in the chronic phase, and the most serious complication is chronic chagasic cardiopathy, which is highly disabling [11]. This is a concern as currently there appears to be an under diagnosis of Chagas disease [12].

According to the Drugs for Neglected Diseases initiative (DNDi) (2019), this infection is endemic in 21 Latin American countries, causing more deaths than malaria or any other parasitic disease. Further, less than 1% of these patients have access to treatment [9]. In Brazil, approximately 1 million people are estimated to be infected. According to data from the Strategic Management Support Room of the Ministry of Health, 72,084 individuals died between 2001 and 2015, 1187 of which were in the Northern region and 206 in the state of Pará. Besides the Northern region, the Northeast of Brazil is often recognized as one of the other regions in Brazil with the highest number of cases in the country [13].

The Brazilian Unified Health System (SUS) is responsible for providing medicines to treat diseases, which includes benznidazole and nifurtimox for patients with Chagas disease [5]. However, there are concerns with the effectiveness and safety of these medicines, especially, during the chronic phase of the disease limiting their usefulness [10,14]. Consequently, there is a need for effective preventive measures to combat Chagas disease.

Strategies that aim to combat the insect vector (insecticides) in homes in Brazil include the promotion of housing improvement in high-risk areas as well as the encouragement of mosquito nets or wire mesh and individual protection instruments including repellents and long-sleeved clothing. Alongside this, health surveillance and inspections have been intensified at all stages of the food production chain where there is susceptibility to contamination, with special emphasis on places where food is handled [6].

In the last few years, several vaccines against *Trypanosoma cruzi* infection have been developed [15]. These include the immunotherapeutic vaccines, rTSA-1 and rTc24, which are based on TSA-1 and Tc24 antigens, developed by Villanueva-Lizama and collaborators (2018). Previously, positive results were obtained for immune response induction during clinical phase studies involving 39 participants in Mexico [16]. The importance of studies on the development of effective and safe vaccines for the prevention of the disease is important and could represent an effective relevant strategy for combating infections [17]. We are already seeing this with considerable interest and commercial activities surrounding the development of a vaccine against COVID-19.

Some studies published on the research and development scenario of a Chagas disease vaccine have shown promising results. The *TcG2/TcG4* vaccine is an example of such development and protection against several *T. Cruzi* strains has been demonstrated [18,19]. In addition in a study recently conducted by Berry and colleagues (2019), the Tc24 + E6020-SE vaccine showed satisfactory results in model testing of *T. Cruzi*-infected mice in the chronic phase of infection. Additionally, reduction of the inflammatory process and cardiac fibrosis, as well as systemic parasitemia were observed [20]. Other vaccines developed in Mexico, rTSA-1 and rTc24, are being considered as more advanced candidates for Chagas disease vaccine development as they have demonstrated good immune response results in a group of 39 people. This finding also supports the combination of two parasitic proteins (TSA-1 and Tc24) for use as potential vaccine candidates in humans [16].

In Brazil, the Medication Market Regulation Chamber (CMED) is responsible for the economic regulation of drugs commercialized in the country. CMED evaluates and establishes the prices of medicines that will be marketed in the country [21]. However, the approval and registration of new medicines including vaccines for commercialization is made by the Health Regulatory Agency (ANVISA) [22]. Consequently, a new technology is only introduced onto the Brazilian market upon compliance with the criteria established by Resolution No. 2 of March 5 2004 guidance [23]. Thereafter, its pricing is defined by CMED. As a vaccine against Chagas disease will be a new product, this technology would be classified as category I. Further, its price cannot be higher than the lowest price of a number of countries including Australia, Canada, France, Greece, Italy, New Zealand, Portugal, Spain and USA [23]. In accordance with the price defined by CMED and for commercialization in the private market, pharmaceutical companies generally submit their new technology to the National Commission for the Incorporation of Technology (CONITEC) for incorporation into the SUS [24].

In the context of limited healthcare resources and growing demand in Brazil [25], it is important to emphasize the importance of undertaking studies in an economic context to support the process of rational decision-making [26,27]. Priority setting is crucial in a country such as Brazil where the public health system caters for over 210 million inhabitants [28]. Accordingly, studies that seek to identify the value of technologies of clinical interest for a given country, such as a vaccine for the prevention of Chagas disease in Brazil, may contribute to future decision-making regarding their pricing.

Willingness to pay (WTP) is a methodology that seeks to estimate the maximum individual value to be allocated to a specific program, medical intervention, or treatment to identify its monetary value. WTP studies enable decision makers to assess a point value, ranges of values, or the positive or negative response to a presented value, contributing to a better perception of an individual's preferences in health decision-making processes [29]. This technique is based on the application of a questionnaire, with prior presentation of the characteristics of the evaluated intervention to the interviewee, in addition to conditions and aspects relevant to the clinical context [30,31]. Importantly, to perform this economic analysis, all participants must receive the same guidance, which requires training for the interviewers [32].

In recent years, this methodological approach has enhanced deliberations regarding the potential value of new vaccines with the first approved dengue vaccine in Brazil [33]. There have also been hypothetical scenarios to help guide future investment and pricing decisions including WTP for a dengue vaccine in countries including the Philippines [34], Indonesia [35], Thailand, Colombia and Vietnam [36], as well as for Ebola [37], HIV [38], malaria [39–42], hepatitis [43], zika [30] and chikungunya [31]. However we are not aware of any studies to date that have evaluated the WTP for a Chagas disease-targeted vaccine. It is important to evaluate the WTP for a hypothetical vaccine for Chagas disease initially by residents of the state of Pará in the Northern region, which comprises seven states including Amazonas, Pará, Acre, Roraima, Rondônia, Amapá and Tocantins, with Pará having the largest number of inhabitants corresponding to 46.68% of the population of this region [44]. The findings from this study may reinforce the need for economic studies to better contribute to the evaluation of new vaccines. Accordingly, methodological approaches, such as WTP may be one of the tools to assist in discussions regarding potential prices for vaccines of relevant infections.

Materials & methods

This study was performed to estimate the WTP of people in Northern Brazil for a hypothetical vaccine to prevent Chagas disease via a contingent valuation analysis. A questionnaire with open and closed questions was used to collect data relevant to individuals who may or may not have had Chagas disease in the past, but were not known to have had the disease at the time of the interview in line with other similar studies [30–33].

Design & study location

The survey was conducted in eleven cities (Belém, Marabá, Parauapebas, Abaetetuba, Rondón do Pará, São Domingos do Araguaia, São João do Araguaia, Baião, Canaã dos Carajás, Jacundá and Itupiranga) in the state of Pará, the ninth most populous state in Brazil. In 2019, this State had 8,602,865 inhabitants, 2,275,032 of which are currently registered in the Metropolitan Region of Belém. Additionally, the Northern region, state of Pará and Brazil are located close to each other and in 2010 had an average Human Development Index (HDI) score of 0.667, 0.646 and 0.737, respectively [45,46].

Despite similar HDI scores, the state of Pará differs from the rest of Brazil in terms of the average *per capita* income and the social demographic characteristics. In 2018, the monthly *per capita* income was US$326.40 (R$1,373.00 BRL) for Brazil and US$205.16 (R$863.00 BRL) for Pará [47]. Additionally, of the 26 states of Brazil, Pará holds the nineteenth position in terms of average *per capita* income of Brazilian cities. However, Pará was responsible for 83% Chagas disease cases in Brazil, making this State highly relevant for this research [6].

The questionnaire (Supplementary Material) used to interview the participants was developed by the research team building on previous publications [30,32–34,36]. Interviews were conducted by undergraduate students in health courses, particularly students with a Bachelor's Degree in Collective Health at the Federal University of Southern and Southeastern Pará (Unifesspa) who were previously trained by the researchers responsible for this study. These researchers applied the methodological approach of WTP, as recommended in previously published studies [30,31,33].

Data collection instrument

The WTP technique involves the application of a questionnaire, with prior presentation to the interviewee of the characteristics of the disease, the intervention required for decision-making process, and the conditions and important aspects of the clinical context of the disease. To use the WTP technique, all interviewees must receive the same information [32]. Consequently, training of the interviewers involved in the survey was required and was conducted prior to the applications in June 2019 at Unifesspa.

The questionnaire comprised the following five sections: questions to test participants' knowledge regarding Chagas disease; information on the disease, intervention and alternatives for preventing the disease; questions to assess their understanding of the information provided; Discrete Choice, Bidding Game and Open-Ended Questions [34] including questions to identify whether individuals would pay US$14.26 (R$60.00 BRL) for a single dose of the hypothetical Chagas disease vaccine and questions to estimate the range of values that respondents would pay for the technology; and a socioeconomic questionnaire.

For the discrete choice technique, the value of US$14.26 (R$60.00 BRL) was established for a single dose of Chagas disease vaccine. This choice was derived based on the Brazilian market involving single-dose vaccines, in consultation with the Price List of the Drug Market Regulation Chamber (CMED) and through the factory price (FP) of vaccines in Brazil [48].

The efficacy of vaccine protection (80%), as well as the possibility of local events (e.g., swelling at the site of application and pain) and information on the disease, epidemiological data and criteria for vaccination were included in the initial stage of the interview. Difficulties associated with questions related to the research context and the socioeconomic questionnaire were explained by the interviewers. An illustration was also used to exemplify and facilitate an understanding of the percentage of protection from the hypothetical vaccine for Chagas disease.

Sampling & selection criteria

The selection of the interviewees was performed in a random manner. Briefly, individuals from high circulation areas, such as squares, parks, markets and fairs, were invited to participate and if they agreed, completed the questionnaire.

If there is a greater uncertainty that 50% of the respondents would agree to pay US$14.26 (R$60.00 BRL; a margin of global error of 4 percentage points at a 95% confidence level), a minimum of 600 respondents would be required in this survey. The number of individuals to be interviewed in each of the eleven cities was defined according to the population size of each of these municipalities [46].

As described, interviewees may or may not have a history of Chagas disease; however, at the time of the interview, they were excluded if they had symptoms or were diagnosed with the disease. As a criterion for participation, individuals had to possess and declare an income, with individuals under 18 years of age and those without income being excluded. Individuals who would not use the vaccine or would not use it even if it were free and those who were willing to pay more than twice their declared monthly income were excluded from the sample, as established for this approach [32] and observed in similar studies [30,31,33,36].

Data analysis

The WTP for a Chagas disease vaccine was estimated from the maximum median value declared by individuals who were willing to pay any amount greater than or equal to zero. The median of the maximum WTP among the groups defined by the covariates was compared using the Mann–Whitney test (two groups) or the Kruskal–Wallis test (three or more groups). The level of significance was 5%. All socioeconomic variables were evaluated and the median ratio of the maximum WTP for the hypothetical Chagas disease vaccine, such as education and *per capita* family income, were included. To evaluate the median of the maximum disposable value to pay and the *per capita* family income, the individuals were organized into groups and stratified by *per capita* wage income (number of minimum wages) into '<0–0.25,' '0.25–0.50,' '0.50–0.75' and '0.75–7.5' groups, with each containing 25% of the sample data. For the correlation involving disposition and schooling, the respondents were stratified by level of schooling: 'never studied or did not complete primary education,' 'completed primary education,' 'completed secondary education' and 'completed higher education or more.'

The frequency of participants who had private health insurance or were without insurance at the time of the interview was assessed. According to the National Supplementary Health Agency (ANS), which regulates private health insurance in Brazil, private health insurance coverage in Pará comprised 10.3% of its population until March

2019, with 807,453 beneficiaries in the state as of June 2019. However, the national profile was 24.2% of the population (47,053,184 people) in March 2019 [49].

Additionally, the WTP of the interviewees was evaluated controlling for variables including history with the disease, health plan and gender. As a tool for statistical analysis, Microsoft Excel 2010 and Minitab 17 were used. For comparative purposes, the conversion value provided by the Brazilian Central Bank (2020: US$1 = R$4.2064 BRL/Brazilian real) [50] was adopted.

Ethics statement

All interviews were conducted after reading and signing an informed consent form. In addition, all researchers of the project signed a confidentiality agreement prior to the interviews. This study was approved by the Ethics and Research Committee of the Federal University of Pará (UFPA), under CAAE registration number 12943619.5.0000.8607.

Results

Population characteristics

A total of 619 interviews were conducted with individuals aged between 18 and 84 who agreed to participate and answer the questionnaire. Table 1 describes the characteristics of the individuals including in the study. The average age of the interviewees was approximately 36 years; 43.9% [619] of the population were males, 96.8% worked at the time of the interview, 38.1% were self-employed, 3.6% reported being retired and 17.6% had completed higher education or more.

Table 1. Characteristics of respondents (n = 619).

Variable	n	(%)
Age in years (mean [SD])	36.5	5.9
Man	272	43.9
Has children	380	61.4
Education level		
– Had never attended school	5	0.8
– Completed elementary school	120	19.4
– Completed high school	381	61.6
– Completed college or more	109	17.6
Currently working	599	96.8
Have private health insurance	213	34.4
Had Chagas disease	2	0.3
Reported that other people in the household had Chagas disease	6	1
Family income (number of minimal wages†)		
– <1		20.0
– 1–2		22.5
– 2–3		7.4
– 3–5		8.7
– 5–10		3.6
– 10–20		1.1
– >20		0.0

†32.3% of the respondents refused to respond to questions regarding family income. 4.4% do not know their family income. The difference to reach 100% for all questions is due to answers such as "*don't know*" and "*don't want to answer*" Brazilian minimum wage in 2019 was 998.00 BRL (US$237.25) per month.

Only 0.3% of the participants reported having Chagas disease in the past and 1% reported having an individual with the disease in their home. The profile of respondents with health insurance and *per capita* family income below five to ten minimum wages was 34.4% and 58.6%, respectively, as shown in Table 1.

WTP for a hypothetical Chagas disease vaccine

Of the 619 study participants, 0.6% said they would not be vaccinated even if the hypothetical vaccine was free. The main reasons were efficacy (25%), safety (50%) and opposition to vaccine use (25%). After descriptive analysis

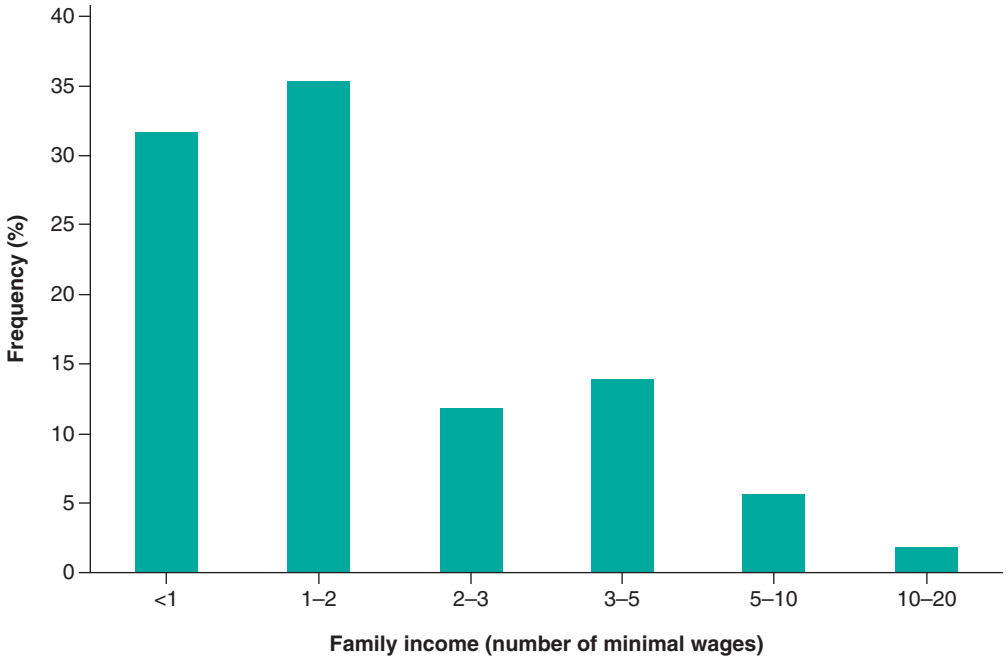

Figure 1. Family income of respondents included in analysis of the willingness to pay for a hypothetical Chagas disease vaccine.

of the data, seven individuals did not meet the eligibility criteria, with four opposed to vaccine use, even if available free of charge, and three individuals reporting a disposition value to pay twice their monthly family income. As a result, 612 interviewees were finally eligible to participate in the WTP study.

Among the 612 respondents, 43.4% were men, 61.9% had completed high school, 61.5% had children, 97.3% were working at the time of the interview, 3.6% were retired, 35.3% had health insurance and 0.3% already had Chagas disease. The percentage of participants who reported having *per capita* family income of up to two minimum wages was 35.2% (Figure 1).

From the application of the discrete choice technique, 91.8% of the interviewees were identified to be willing to pay some amount for the vaccine, with 69.4% of the participants willing to pay US$14.26 (R$60.00 BRL) for a single dose of this hypothetical vaccine. Of the 377 respondents who had children, 332 (54.2%) were willing to pay US$14.26 (R$60.00 BRL) to vaccinate their children. The questionnaires revealed that the percentage of respondents who were willing to pay between US$7.13 (R$30.00 BRL) and US$28.52 (R$120.00 BRL) was 43.8%. The minimum and maximum WTP for the hypothetical vaccine was US$0.00 (R$0.00 BRL) and US$475.46 (R$2,000.00 BRL).

The WTP of respondents for the hypothetical Chagas disease vaccine was estimated to be an average of US$23.77 (R$100.00 BRL). Consequently, 50% of the interviewees reported a maximum WTP of US$23.77 or less (Figure 2).

The following three variables presented a statistically significant relationship with the maximum value of WTP ($p < 0.05$): monthly per *capita* family income ($p < 0.001$), gender ($p = 0.003$) and education level ($p < 0.001$). No statistically significant relationships ($p > 0.05$) with the maximum WTP (i.e., health plan, age and history) for Chagas disease identified for the remaining variables (Table 2).

Males (US$28.52/R$120.00 BRL) were more willing to pay for the vaccine than females (US$23.77/R$100.00 BRL), with a value $p = 0.003$. Additionally, individuals who declared a higher monthly *per capita* household income reported higher WTP values, with median values for each stratification group of US$14.26 (R$60.00 BRL), US$23.77 (R$100.00 BRL) and US$28.52 (R$120.00 BRL; Figure 3).

As shown in Figure 4, individuals with higher educational levels declared a higher WTP for the hypothetical Chagas vaccine ($p < 0.001$).

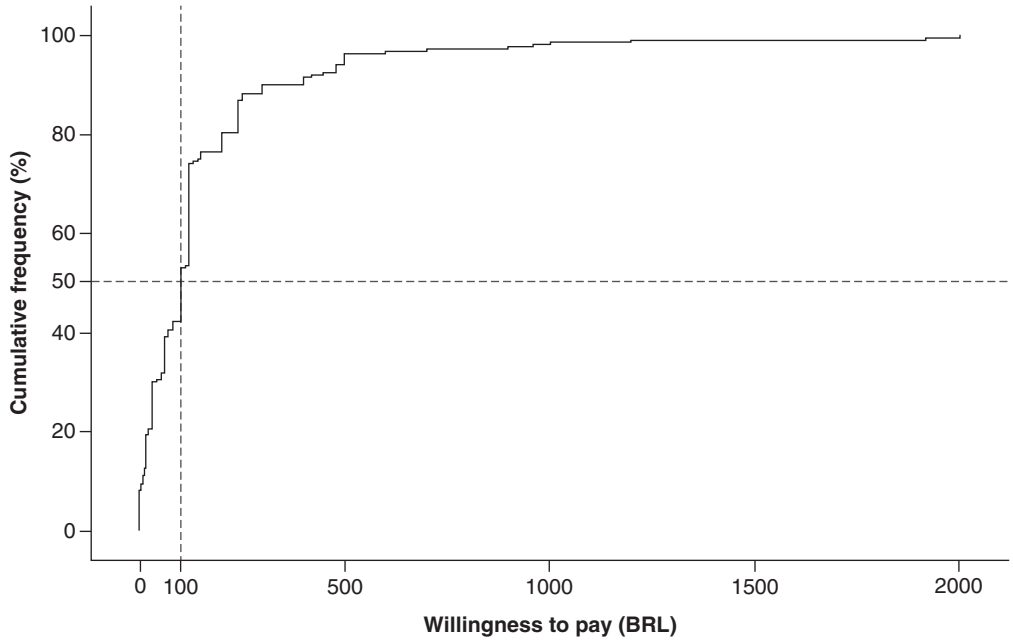

Figure 2. Cumulative percentage of the willingness to pay for a hypothetical Chagas disease vaccine according to the reported maximum values.
BRL: Brazillian real.

Table 2. Willingness to pay associated with each variable.

Variable	WTP (US$)	WTP (BRL)	p-value
Gender	28.52	120.00	0.003
Individuals who had children	23.77	100.00	0.551
Education level	28.52	120.00	0.000
Per capita household income	28.52	120.00	0.000
Insurance health	23.77	100.00	0.245
Working at the moment of the interview	23.77	100.00	0.991

2020: US$1 = R$4.2064 BRL [50].
BRL: Brazillian real; WTP: Willingness to pay.

Discussion

This study sought to estimate the willingness of consumers in Northern Brazil to pay for a hypothetical Chagas disease vaccine. Whilst there is currently no licensed vaccine for Chagas disease; we believe in view of ongoing efforts to develop vaccines to prevent this disease, it is important to examine the WTP for a hypothetical Chagas disease vaccine to provide benchmark WTP data to help guide future decision making. A hypothetical efficacy of 80% was based on effectiveness levels of vaccines already incorporated and made available to the Brazilian population by SUS. Previous studies performed by our research group in Brazil also considered a hypothetical scenario of 80% efficacy for a vaccine to prevent chikungunya [31] and zika [30] infections. Some characteristics of the study population that are similar to the profile of the Brazilian population include the high percentage of women (51.9%), low percentage of individuals who have never studied (7.6%), and the close percentage of individuals with complete higher education (16.5%). In addition, 61.9% of the participants had completed high school resembling the largest group (complete high school or equivalent) identified in the National Household Sample Survey conducted by the Brazilian Institute of Geography and Statistics (IBGE) for the state of Pará (22.9%), Northern region (24%) and Brazil (25.2%) [51].

Further, employment was identified as the main form of financial income (72.4%), with the number of retirees being the lowest percentage (20.5%) [52]. Previous studies of WTP for hypothetical vaccines against zika [30] and chikungunya [31] in the country also reported a higher percentage of women (58.2 and 57.3%) and a reduced

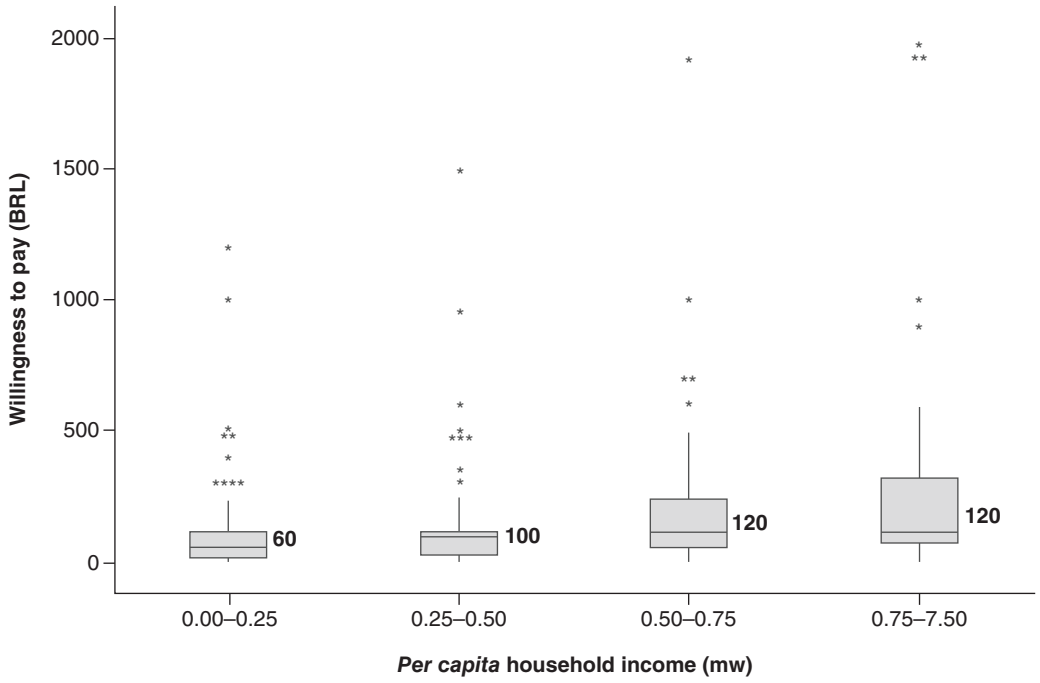

Figure 3. Box plots indicating willingness to pay for a hypothetical vaccine for Chagas according to *per capita* household income range.
BRL: Brazillian real; mw: Minimum wage.

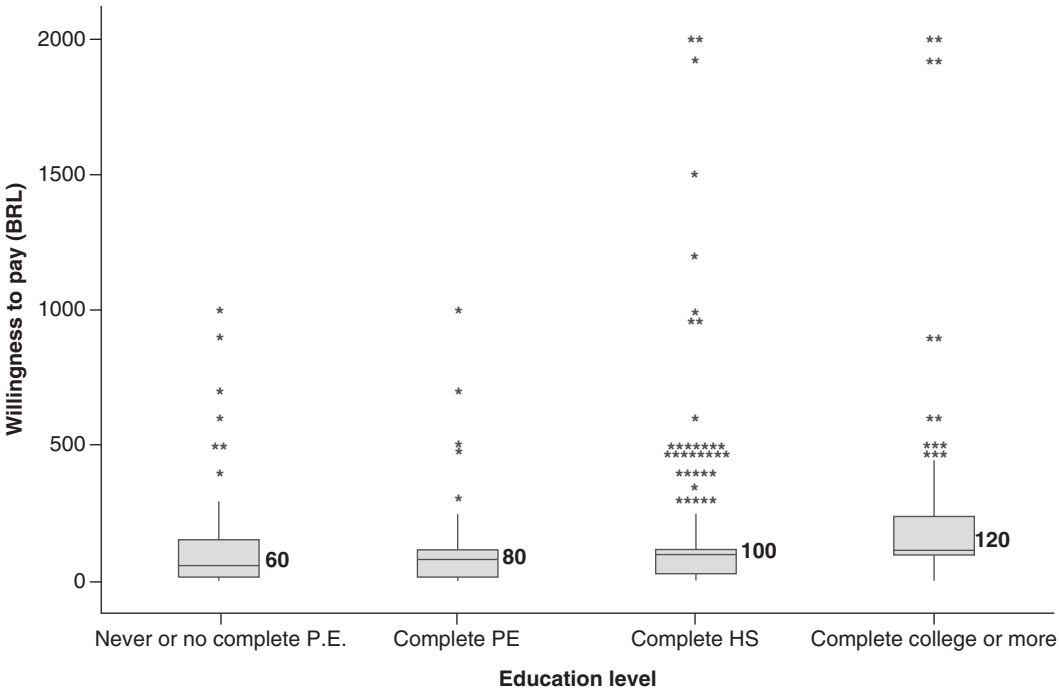

Figure 4. Box plots indicating willingness to pay for hypothetical vaccine for Chagas according to education level.
BRL: Brazillian real; HS: High school; PE: Primary education.

percentage of individuals who never studied (0.6 and 0.2%). Employment was also the main form of income (71.2 and 87.9%) and the lowest participation of interviewees who reported *per capita* income of 10 to 20 minimum wages (BRL) (4.3 and 8.9%) or more (0.6 and 1.8%).

In this study, the percentage of respondents who had a health plan was 35.3%, a percentage higher than the national health coverage rate (24.2%), but similar to the health coverage rate in the Metropolitan Region of the capital of Brazil (Brasília) (35.6%) [49]. According to the National Supplementary Health Agency (ANS) (2019), the number of beneficiaries of health care plans in Brazil fell by 1% in the first quarter of 2019 (47.1%) compared with the second quarter of 2018 (47.2%), with variations among regions of the country; this is because the North is responsible for 10.6% of the public of beneficiaries [49]. Notably, the private health market functions as a supplement to the Brazilian public health system while the SUS, created in 1988, is responsible for guaranteeing full, universal and free access for the Brazilian population [53].

According to data from the Notifiable Diseases Information System (SINAN), 2060 cases of Chagas disease were reported from 2008 to 2017 in the North of Brazil, including 65 in the Northeast, 29 in the Center-West, seven in the Southeast and four in the South [54]. Although, cases of Chagas disease have been identified throughout the country, the high epidemiological burden of this infection has been confirmed in the North (95%). Among the states of the region, Pará is the most affected, with, as mentioned, 83% of the national cases [6]. Based on data from 2018, approximately, 361 new cases were reported to be associated with this infection, with Pará having 275 cases [55]. Such a high number of related cases in the state is linked to the occurrence of oral transmission outbreaks [6]. This is because this region has a high consumption of regional foods such as açaí, sugarcane juice and bacaba [56–59]. Based on these findings, we believe it is important to evaluate the WTP for a hypothetical vaccine for Chagas disease initially by residents of the state of Pará in the Northern region, which comprises seven states including Amazonas, Pará, Acre, Roraima, Rondônia, Amapá and Tocantins, with Pará having the largest number of inhabitants (8,602,865) corresponding to 46.68% of the population of this region [44].

The median value of WTP for the hypothetical Chagas disease vaccine was US$23.77 (R$100.00 BRL) for a single dose. The WTP value was defined from the median of the maximum values presented by the interviewees. Notably, this criterion, which has been established in literature [30–33], is intended to avoid discrepant values from the population profile scenario of a study. As recommended in the methodological approach and adopted in our study, interviewees who presented a value of WTP twice as high as their monthly family income *per capita* (outliers) were excluded from our analysis, as these suggested WTP values were deemed infeasible [26].

Muniz and collaborators (2018), who employed the WTP approach as a paid strategy in Brazil, reported R$100.00 BRL/US$31.34 as the cost for a hypothetical vaccine for zika virus (80% efficacy) [30], similar to our study. Overall, compared with studies conducted for the first vaccine approved for dengue [33] (60% efficacy) and the hypothetical vaccine for the prevention of chikungunya (80% efficacy) [31], a slightly higher value of R$120.00 BRL was obtained in our study. Interestingly in a study conducted in Nigeria for three hypothetical vaccines against malaria, protozoan infection and Chagas disease [60], Udezi *et al.* (2010) [41] identified a WTP of US$6.77 for vaccine A (75% efficacy), $6.70 for vaccine B (85% efficacy) and US$5.06 for vaccine C (95% efficacy). Notably, WTP studies were conducted with the following scenarios: hypothetical or actual, number of doses, protection and region used. However, WTP estimates may well vary according to the income characteristics of the population [36]. Nevertheless, studies such as Lucas *et al.* (2007) revealed that lower WTP values of a product or service are observed when participants have more time to evaluate the product/service and this product/service is within their budget constraints [61].

Individuals with a higher *per capita* household income reported higher WTP (Figure 2), a result similar to that found for the WTP of hepatitis B vaccine by Sardar *et al.* (2018). In this study, people with higher income levels were willing to pay more for the hepatitis B vaccine in Pakistan. Such findings indicate a direct relationship between the WTP and increased income [43,62]. Based on gender, males in our study were found to be willing to pay more than females (US$28.52/R$120.00 BRL vs US$23.77/R$100.00 BRL). This is similar to the study by Sardar *et al.* (2018) [43] where males were also more willing to pay more than females. This may reflect the fact that wages of males are typically higher females in Brazil [63,64]. Based on these findings, the higher the income, the greater the WTP mirroring previous studies in Brazil [30,31,33]. Historically, the wage of males has been generally superior to that of females in Brazil, thereby showing a clear difference in income between genders [63,64].

Additionally, individuals with higher educational levels had a higher WTP value for the Chagas disease vaccine (Figure 3) reflecting perhaps greater knowledge about Chagas disease and its implications. This is similar to the findings of Sardar *et al.* (2018) [43] for a hepatitis B vaccine where there was also a higher level of schooling among the interviewees, which may contributed to their willingness to independently investigate the threats related to hepatitis B and its effects.

Encouragingly, 91.8% of the respondents agreed to pay to be vaccinated, demonstrating high acceptability. This is similar to Ughasoro *et al.* (2015) [37] who found that 87.5% of the respondents were willing to pay for an Ebola vaccine in Nigeria. In another study conducted by Abdulkadir *et al.* (2015) [65] for a malaria vaccine in Nigeria, high acceptability was also demonstrated, with 87% of the participants willing to accept the vaccine. Technologies such as vaccines are generally well accepted by the population. Accordingly, efforts and incentives applied to the development of vaccines for disease control are indispensable for public health, thereby requiring investments [66,67]. The National Immunization Program in Brazil, which is considered to be one of the largest programs in the world, is a strategy of the SUS that aims to protect the population from communicable diseases through vaccination of all age groups via annual campaigns [67].

Overall, the development of an effective vaccine against Chagas disease will be important for controlling this infection [17]. Lee *et al.* (2010) employed a social perspective to investigate the potential economic value of a *Trypanosoma cruzi* vaccine in Latin America to determine the vaccine's cost–effectiveness. The authors demonstrated that vaccination is very cost-effective in terms of price, effectiveness and risk of infection, ultimately providing cost savings and health benefits, even with a low risk of infection and vaccine efficacy. Such findings ultimately support the development of a human vaccine for Chagas disease. We believe the establishment of economic models prior to the development of a Chagas disease vaccine is advantageous and can help in the decision-making process to derive the potential health and economic benefits. Economic analysis studies help to guide investments as well as the development and implementation of potential vaccines [68].

We are aware this study had limitations. These include some interviewees' inability to understand all the information initially explained (disease, epidemiology, transmission, treatment), which could arise despite efforts to remove all doubts of the participants and ensure prior training of the interviewers. Furthermore, the hypothetical nature of the vaccine's efficacy was stressed and may not reflect reality when a new vaccine becomes available. In addition, since the socioeconomic profile of the Northern region, which is currently considered to have the greatest prevalence of Chagas disease in Brazil, differs from other regions in Brazil, this may also affect the generalizability of the findings. Despite these limitations, we believe this study has provided information that will be of benefit to both the pharmaceutical industry and the Government especially given the high prevalence rates of Chagas disease in the chosen region contributing to future discussions on prices once a vaccine is licensed.

Conclusion

Whilst the number of cases of Chagas has declined in Brazil, it remains an important public health problem in Brazil and other countries. The present study revealed the monetary value of a hypothetical Chagas vaccine at US$23.77 (R$100.00 BRL). As efforts continue in pursuit of developing vaccines against Chagas disease, economic studies with this vaccine will be important to inform future pricing and funding decisions.

Future perspective

Chagas disease will continue to pose an important challenge to health systems in endemic areas since despite efforts to control the disease through vector control. This has not been helped by accelerated urbanization and low adhesion among the population to control measures, which is likely to continue. In addition, it can be said that, although the cases of this infection have reduced in Brazil, Chagas disease remains an important public health problem with records of serious manifestations and deaths not only in Brazil but in other endemic countries, especially, in Latin America. Chagas disease affects, in general, individuals in situations of social vulnerability, such as poverty and lack adequate housing, such conditions that will still remain. This has not been helped by the invisibility of the vast majority of patients given the lack of opportunity for diagnosis, negatively impacting on the chances to success with treatment. In this scenario, the search for a safe, effective and cost-effective Chagas disease vaccines continue to represent an important strategy to control this infection. It is anticipated that during the next 5 years, more advances will be made with vaccine development building on those of Villanueva-Lizama and collaborators [16]. Concerns with the impact of Chagas disease on cardiomyopathy leading to events such as heart failure, arrhythmias, thromboembolism, stroke and sudden death, reinforce the need for vaccines with adequate safety and efficacy. In this context, we recommend that the search for a vaccine and a price based on the profile of consumers continue. In this respect, we continue to support more efforts and government investments from the most affected countries and companies to encourage the development of medicines and vaccines for Chagas disease. This is the first study conducted in the context of the WTP for a hypothetical Chagas disease vaccine, and

can contribute to decision-making about potential prices for a future vaccine once it becomes available in Brazil, as well in the discussions in other endemic countries.

Executive summary

- Chagas disease is a serious public health problem, with around 70 million people at risk of developing the infection worldwide.
- Endemic in 21 countries in Latin America. It represents one of the four leading causes of death from infectious and parasitic diseases in Brazil.
- Currently there is no effective vaccine against Chagas disease; however, this could represent an important strategy for controlling the disease.
- This study cross-sectional estimated the willingness to pay (WTP) of Brazilian respondents for a hypothetical Chagas disease vaccine using a contingent valuation method.
- A total of 50% of the interviewees, residents in the Northern of Brazil, were willing to pay US$23.77 (100.00 BRL) for a hypothetical vaccine against Chagas disease.
- The continued occurrence of Chagas disease infection in endemic regions, reinforces the need research into the development of effective and safe vaccines, as well economic studies to contribute to subsequent discussions regarding potential pricing and funding for new vaccines associated to its prevention.
- Overall, this study can contribute to decision-making about potential prices for a Chagas disease vaccine once it becomes available in Brazil.

Supplementary data

To view the supplementary data that accompany this paper please visit the journal website at: www.futuremedicine.com/doi/suppl/10.2217/cer-2020-0241

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Ethical conduct of research

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

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