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Barriers and facilitators for preventing mother-to-child transmission of *Trypanosoma cruzi* and hepatitis B in the Gran Chaco region: a qualitative analysis using the consolidated framework for implementation research (CFIR)

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Abstract

Background Mother-to-child transmission (MTCT) of *Trypanosoma cruzi* and hepatitis B virus (HBV) increases morbidity and disability in Latin America and the Caribbean. The tailormade comprehensive antenatal care based on the Framework for the elimination of MTCT of HIV, syphilis, hepatitis B virus (HBV), and Chagas disease (EMTCT Plus) has been implemented in the region since 2018 through a private-public partnership. This study aimed to estimate the effectiveness of the intervention in preparing MTCT of *T. cruzi* and hepatitis B. The study further attempted to identify the barriers to and facilitators for preventing MTCT of *T. cruzi* and HBV in the Gran Chaco region of Argentina and Paraguay.

Methods Data on *T. cruzi* and HBV screening and treatment among pregnant women and infants were collected from antenatal care (ANC) registries between June 2018 and December 2022. A cascade-of-care analysis was applied to assess the intervention's effectiveness and identify bottlenecks. Additionally, key informant interviews were conducted for both implementors and service recipients to identify barriers to and facilitators for accessing screening and treatment using the Consolidated Framework for Implementation Research.

Results A total of 1,658 pregnant women were recruited, achieving 100% antenatal care coverage and screening for *T. cruzi* and HBV. The prevalence of *T. cruzi* among pregnant women was 3.3% (95%CI: 2.4-4.1%), while in newborns it was 14.0% (95% CI: 6.0–25.0). Treatment coverage for newborns infected with *T. cruzi* was 100%, whereas post-delivery treatment coverage among mothers was 67.3%. This achievement was likely attributed to strong community engagement, contributing to 100% ANC coverage. However, barriers such as a fragile local health system, long-term follow-up requirements, high mobile populations, cultural beliefs, and social trauma were identified in target areas.

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Conclusion Implementing the EMTCT Plus Framework improved access to quality ANC in the study area. Nevertheless, continuous follow-up for *T. cruzi* screening and treatment for post-delivery remains challenging. To improve access to healthcare and ensure the sustainability of the intervention, an intercultural approach that empowers the community, alongside efforts to strengthen the local health system, is recommended.

Keywords *Trypanosoma cruzi*, Chagas disease, Hepatitis B, Mother-to-child transmission, Gran Chaco, Pregnant women, EMTCT plus

Background

Chagas disease (ChD) is a neglected tropical disease (NTD) caused by the parasite *Trypanosoma cruzi* [1]. In individuals with chronic infections, the disease can progress to severe heart failure in about 30% of cases and to megacolon, or both, in approximately 10% of infected individuals. Transmission of *T. cruzi* occurs via vector transmission, oral transmission, blood transfusion, organ transplantation, and vertical transmission [1]. The Pan American Health Organization (PAHO) estimates that around seven million people are infected with *T. cruzi*, most of whom are living in Latin America and the Caribbean (LAC) [2]. Of these, 1.13 million women of reproductive age are estimated to be infected in LAC, with most infections considered chronic occurring before pregnancy [3, 4]. Vertical transmission of *T. cruzi* in LAC results in at least 15,000 new cases annually [4].

Hepatitis B virus (HBV) affects liver function and can cause cirrhosis and life-threatening complications. An estimated 2.8 million people are infected in LAC, of which approximately 9,000 are children under five years of age [4]. Vertical transmission is the primary route of infection in birth and early childhood [5].

Mother-to-child transmission (MTCT) is a leading cause of new infections for both diseases. A systematic review revealed that the pooled congenital *T. cruzi* transmission rate is estimated to be 4.7% in LAC (95% CI: 3.9–5.6% [6]. Concerning HBV, approximately 10,000 new chronic HBV infections were reported in 2016, of which 56% were considered perinatal transmission, with the remainder occurring through horizontal transmission in childhood [7].

In 2017, PAHO announced the Framework for the Elimination of Mother-to-Child Transmission Plus (EMTCT Plus) to accelerate the elimination of MTCT of human immunodeficiency virus (HIV), syphilis, ChD, and HBV in LAC [4]. The key elements include 1) a strong political commitment at the highest levels associated with robust inter-programmatic planning and implementation of the national plan for dual elimination; 2) integration of EMTCT into Maternal and Child Health (MCH) services; 3) quality follow-up and monitoring of mothers and children through strong health information systems able to capture programmatic targets on time; and 4) accessible quality-assured diagnostic services for HIV and syphilis and, when appropriate, use of point-of-care (POC) techniques" [4].

However, screening for *T cruzi* has fallen short of targets. In Argentina, only 60.3% of pregnant women were screened for *T. cruzi*, while only 88% of hospitals in Paraguay routinely performed this screening in 2019 [8, 9]. For hepatitis B, childhood vaccination coverage for the third dose reached 86% in both Argentina and Paraguay, below the EMTCT Plus target of 95% [10, 11]. As an advantage of EMTCT Plus, which integrates these programs, we hypothesized that an integral approach for ChD and hepatitis B may be more effective because the follow-up procedures for mothers and infants are similar. The study aims to assess the implementation of EMTCT Plus's focus on ChD and HBV, identify bottlenecks, barriers, and facilitators, and provide recommendations to improve screening and treatment coverage in the region.

Methods

Study setting

The Gran Chaco region is a cross-border area spanning northern Argentina, eastern Bolivia, western Paraguay, and west Brazil [11]. The region is known to have a high burden of NTDs and other infectious diseases with varying conditions in each country [12]. In Argentina, two non-governmental organizations (NGOs), Fundación Mundo Sano (FMS) and Asociación para el Desarrollo Sanitario Regional (ADESAR), in collaboration with local, regional, and national health authorities, have implemented the EMTCT Plus framework in the region since 2018 [13, 14].

Program implementation occurs in health posts from seven localities from the municipality of Santa Victoria Este and the locality of Alto la Sierra, Rivadavia Department, Salta Province (Argentina) and two health posts from the localities of Pozo Hondo and San Agustín, Boquerón Department (Paraguay). Details on the study setting and population demographics have been published elsewhere [13]. The program consists of two main pillars based on EMTCT Plus recommendations: (1) implementing ANC for all pregnant women in the area every 60 days by a specialized mobile team, including clinical evaluation, ultrasound evaluation, biochemical tests with serology for all MTCT as per recommendations, and (2) performing continuous follow-up of pregnant women through local teams [13]. Rapid serological

tests were used to screen pregnant women and children on site for *T. cruzi* and Hepatitis B, including confirmatory serology and *T. cruzi* specific PCR for newborns which were transported and performed in the national reference laboratory of Argentina (Instituto Nacional de Parasitología).

Data collection

Quantitative strand

An explanatory sequential mixed-methods design assessed the intervention's effectiveness and identified bottlenecks [15]. To address the epidemiological information, the quantitative analysis focused on the prevalence of *T. cruzi* and HBV among pregnant women and the congenital transmission rate. Moreover, a care cascade was analyzed to identify intervention bottlenecks [16]. Mothers who met all the following inclusion criteria from June 2018 to December 2022 were recruited: (1) mothers who received ANC at least once from one of the nine health facilities or outreach medical services in the catchment area, and (2) mothers whose medical records were available in the ANC registry. The opt-out was posted on the bulletin board of the health centers. If the participants wanted to withdraw from the study, they could contact the Principal Investigator. Mothers who opted out of the study were excluded. Patient data was extracted from the relational database management system, which FMS and local collaborators collected using open-source software. The census method was used to reflect the diversity of the characteristics of the population [17].

Qualitative strand

The Consolidated Framework for Implementation Research (CFIR) was used to assess the facilitators of and barriers to implementing the EMTCT plus intervention in the post-intervention period, which guides five domains: (1) intervention characteristics, (2) outer setting, (3) inner setting, (4) individual characteristics, and (5) process [18]. The interview guide was prepared using the CFIR interview guide tool initially published in 2009 [19]. Then, to explore the community's needs, additional questions about health-seeking were added, especially focusing on antenatal care and childbirth, Chagas disease, and hepatitis B, to describe the underlying views of the patients, community leaders, and health workers. The participants were recruited at the recommendation of the local coordinators. Key informant interviews (KIIs) with implementors (project coordinators and health workers) and service recipients (community leaders and pregnant women) from July 2022 to November 2022 explored barriers to and facilitators for accessing screening and treatment. Regarding the qualitative strand, all eligible participants who provided written informed consent were enrolled in the study. All the participants were adequately informed of the study before participation. When they agreed to participate, the local coordinator requested all participants sign the informed consent form. They were notified that their participation in the study was voluntary. They were free to withdraw from the study at any time during interviews. After finishing the data collection, the native speakers prepared verbatim transcripts in Spanish and sent them to the KIIs team. Then, the two skilled researchers coded the transcript. The results were compared and discussed until they reached an agreement. Then, the codes were integrated into the CFIR category to guide facilitators of and barriers to the screening and treatment for *T. cruzi* and HBV. The data were analyzed using ATLAS. ti software (Version 23.2.1). Finally, quantitative and qualitative data were triangulated to identify the challenges for *T. cruzi* and HBV screening and treatment programs in the target area.

Results

Epidemiological situation of *T. cruzi* and HBV in the area

This study included 1,658 pregnant women, with 93.1% (n=1,543) residing in Argentina and 6.9% (n=115) in Paraguay. While no HBV infections were detected, 57 (3.4%; 95% CI 2.6–4.4%) women were identified as *T. cruzi*-positive, 54 from Argentina (3.4%; 95% CI 2.6–4.5), and three from Paraguay (2.6%; 95% CI 0.54–7.4). 54 of the 57 newborns (94.7%) met the inclusion criteria and were tested at least once via polymerase chain reaction (PCR) before 10 months of age. The congenital transmission rate of *T. cruzi* was 14.0% (95% CI 6.0–25.0), with all infants being from Argentina and completing treatment with benznidazole (Tables 1 and 2). Of the three

Table 1 Prevalence of *Trypanosoma cruzi* infection among pregnant women in the study area between Argentina and Paraguay from 2018 to 2022

Residence of pregnant women	Number of T. cruzi-positive pregnant women	Prevalence (%)	95% CI
Santa Victoria Este and Alto la Sierra, Rivadavia Department, Salta province, Argentina (n=1,543)	54*	3.4	2.6–4.5
Pozo Hondo and San Agustín, Boquerón Department, Paraguay (n=115)	3	2.6	0.54–7.4
Total (n=1,658)	57	3.4	2.6–4.4

*2 Seropositive mothers in Argentina had 2 pregnancies registered from 2018 to 2022

Table 2 Congenital transmission rate of *Trypanosoma cruzi* among seropositive pregnant women in the study between Argentina and Paraguay from 2018 to 2022

Residence of pregnant women	Number of T. cruzi-positive infants	Congenital transmission rate (%)**	95% CI
Santa Victoria este and Alto la Sierra, Rivadavia Department, Salta province, Argentina (*n* = 54)	8	14.8	5.3–24.3
Pozo Hondo and San Agustín, Boquerón Department Paraguay (*n* = 3)	0	0	0.0–70.8
Total (*n* = 57)	8	14.0	6.0–25.0

** The congenital transmission rate was calculated by newborns identified as seropositive / newborns born to seropositive mothers

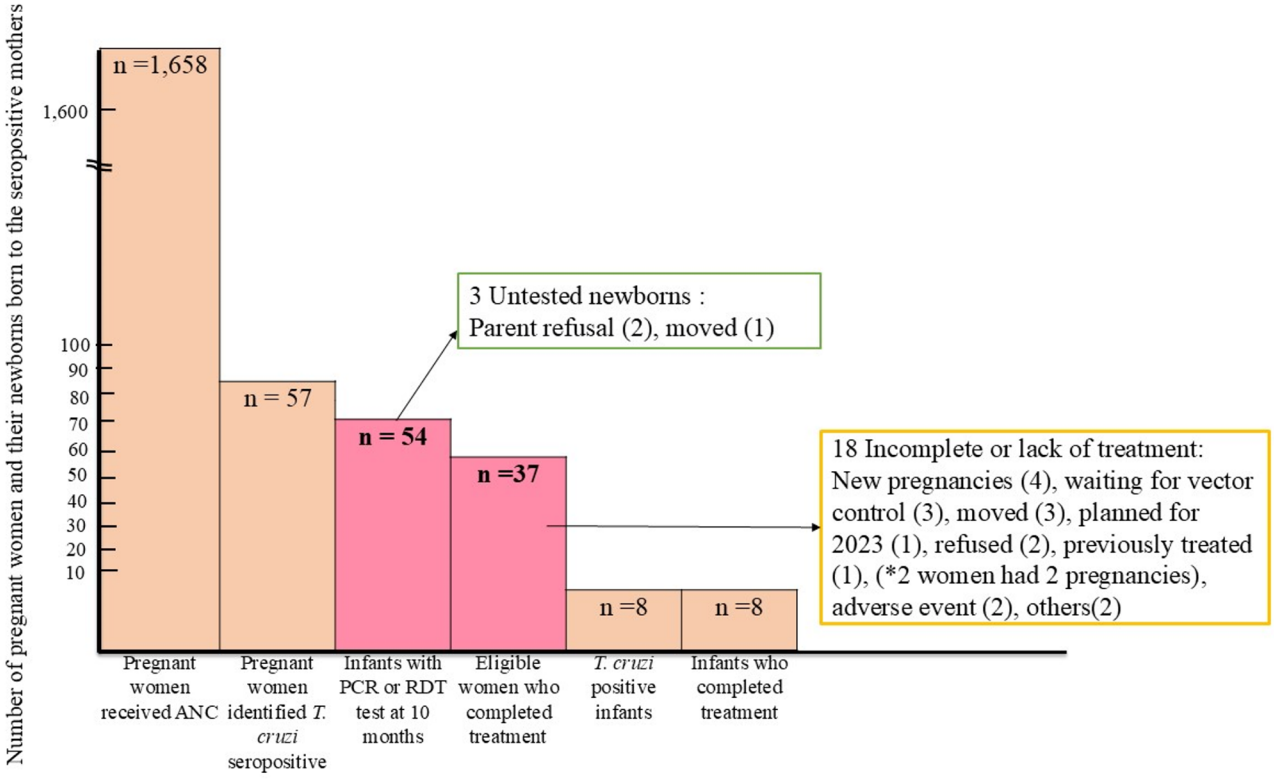

Fig. 1 The cascade of care for *Trypanosoma cruzi* screening and treatment from 2018 to 2022 in the study area between Argentina and Paraguay

lost-to-follow-ups, two newborns missed testing due to parental refusal, and one moved from the catchment area. While testing coverage for *T. cruzi* in pregnant women and treatment for positive newborns was 100%, challenges arose with maternal treatment, as only 64.9% (*n*=37) completed postpartum benznidazole therapy. Reasons for incomplete treatment included new pregnancies (*n*=4), awaiting vector control (*n*=3), treatment refusal (*n*=2), relocation (*n*=3), and adverse events (*n*=2) (Fig. 1).

In contrast, no HBV infections were detected among the 1,658 women.

The barriers to and facilitators for implementing an intervention program

KIIs were conducted with two project coordinators, six local health workers involved in the implementation, 16 mothers diagnosed with *T. cruzi* during ANC, and six community leaders (Table 3). According to the result of CFIR construct valence, participant engagement was the highest-rated facilitator for the implementation success, which helped achieve 100% ANC coverage and *T. cruzi* and HBV screening. However, barriers to the implementation included cultural challenges, the implementation climate, and self-efficacy issues. Facilitators and barriers were also identified in areas such as the strength and quality of evidence, as well as patient needs and resources (Table 4).

Table 3 Demographic characteristics of *Trypanosoma Cruzi*-positive mothers from the study area between Argentina and Paraguay who participated in the KIIs during 2022

Characteristics of the mothers (n = 16)*		N
Age (average)		32.3
Ethnicity		
	Wichí	13
	Chulupi	1
	Creole	2
Residential area		
	Santa Victoria Este	11
	Alto de la Sierra	3
	Paraguay (Pozo Hondo)	2
Education level		
	None	5
	Primary	10
	Tertiary	1
Marital status		
	Concubinage	12
	Single	3
	Married	1
	Divorced	1
Occupation		
	Housewife	6
	Teacher	1
	Don't know	9

*In total, 17 mothers were recruited. One mother was excluded because of withdrawal during the interview

Table 4 CFIR construct valence rating for implementation between 2018 and 2022 in Argentina and Paraguay

Domains	Rating	Domains	Rating
I. Intervention Characteristics		**III. Inner setting**	
A. Intervention Source	1	A. Structural Characteristics	0
B. Evidence Strength & Quality	X	B. Net working	1
C. Relative Strength & Quality	M	C. Culture	-2
D. Adapability	X	D. Implementation Climate	-2
E. Trialability	1	E. Readiness for Implementation	X
F. Complexity	-2		
G. Design Quality & Packaging	M	**IV. Characteristics of individual**	
H. Cost	X	A. Knowledge & Beliefs about the intervention	1
		B. Self Efficacy	-2
II. Outer setting		C. Individual Stage of Change	M
A. Patient's Needs & Resources	X	D. Individual Identification with Organization	1
B. Cosmopolitanism	0	E. Other Personal Attributes	X
C. Peer pressure	0		
D. External Policy & Incentives	-1	**V. Process**	
		A. Planning	M
		B. Engaging	2
		C. Executing	X
		D. Reflecting & Evaluation	1

[Rating scale]

M: Lack of information

-2~-1: Negative

0: Neutral

1 ~ 2: Positive

X: Positive and negative opinion

Intervention characteristics

Evidence strength & quality

The program's strength lies in providing comprehensive ANC through collaboration between NGOs and local health authorities. Since 2018, the Ministry of Health of Argentina has offered periodic training on ChD, fostering strong relationships with health workers, hospitals, and laboratories. This public-private partnership ensured the continuity of ANC services. However, concerns about sustainability post-intervention still need to be addressed, particularly in Paraguay, where past NGO exits left gaps in care. Direct quotes highlighted the positive impact of ongoing support and the apprehension over potential service withdrawal.

> *"What we noticed throughout the five years of project implementation in the area deepened after the pandemic. The local team shows appreciation and respect for our work. Everyone already knows that we provide ANC and ChD control every 2 months. This has been implemented since July 2021, in collaboration with the local workers to provide immunizations, a nutritionist, dentistry, and general consultation, to carry out comprehensive monitoring of pregnant women, which is regulated by provincial policy." (Project Coordinator 2, female).*

> *"We did not know what an ultrasound was, a hemoglobin test, nor a glucose level in a pregnant woman. Now, the presence of ADESAR helps us a lot. They are the only ones that give us support. If not, we have nothing…they are the only ones." (Health Worker 3, female).*

Complexity

The intervention faced several complexities, including the lengthy ChD treatment protocol involving a 60-day regimen with weekly follow-ups to monitor adverse events [20]. This adds difficulty, particularly in areas with limited transportation and accessibility, heavily influenced

by climatic conditions. Additionally, the nomadic lifestyle of some indigenous populations, who frequently cross borders, complicates continuous healthcare provision. Similar challenges are encountered with other diseases requiring extended treatment and follow-up, such as tuberculosis.

> *"We perform tuberculosis treatment, which is very long and complex. Chagas disease treatment is required for two months, and tuberculosis is for six months. …the patient abandons the treatment because of a lack of explanation or because she is not willing to finish the treatment. So, good communication and better dialogue are required to reach him. They [the patients] need to understand the reason for the treatments, the time it takes, and the need to follow the indications. It would be good if we could do this with all the community health workers, but with some of them, it is not easy." (Health worker 1, female).*

Outer setting

Patient's needs and resources

Despite the success of ANC implementation for pregnant women, some informants mentioned that ChD was not considered a "problem" in the community. Additionally, some mothers refused newborn screening, which requires drawing blood from the newborn, as they did not want to see their children suffer.

> *"When I told my family that I had Chagas disease, they did not take it as something serious… they say, "Oh well," they see it as something normal. No one was surprised." (Mother 5).*

In contrast, HBV vaccine coverage is excellent in both operational areas, so this infection is not of concern. None of the mothers interviewed expressed worries about HBV infection. Even though they were unaware of HBV infection, they perceived and accepted vaccination as beneficial and necessary to protect their children from infections.

> *"As soon as the baby is born, we notify the health workers so that they can come to vaccinate them. There are no children who do not have vaccines. Everyone had it." (Health Worker 6, male).*

External policy and incentives

A major challenge in patient follow-up is the shortage of local health workers and the lack of incentives. In 2019, the Chaco region had 2.17 physicians and 5.54 nurses per 1,000 inhabitants, compared to 16.63 physicians and 6.64 nurses per 1,000 inhabitants in urban Buenos Aires [21]. In Chaco, most nurses are community health workers, while Buenos Aires employs licensed professionals. Furthermore, transportation issues, such as inadequate roads and public transport, and climatic challenges like summer flooding and porous borders, exacerbate the difficulties in monitoring and following up on ChD treatment.

> *"…Though community health workers have their motorcycle, which requires gasoline. We have no money. That is the first thing they mention. Then, they do not want to take blood [from the patients] again." (Health Worker 2, male).*

Most healthcare providers working in the study site are young professionals who have just finished their training and are from outside the area. Thus, they need to familiarize themselves with the local population's culture. Not being able to communicate with the indigenous population in Spanish poses additional challenges to service provision and delivery, as highlighted by a community leader below.

> *"Another issue is that new doctors and nurses often do not know how to treat pregnant women. The doctors do not know about the population's culture, why they go to see the health worker, why they did not get vaccinated, or why the newborn did not get vaccinated. There is still a lot to do. We must work with the local communities." (Community leader 3, female).*

In contrast, people moved from another area to seek better health. In fact, residents of Bolivia and Paraguay also come to Argentina to seek better healthcare services in the cross-border area. This was expressed in the community leader's quotation. This situation implies the presence of complex barriers at the health system, community, and individual levels that affect service provision and service uptake in this cross-border area.

> *"People came from the mountains, from Formosa, from Bolivia, and from Puntanas (to seek better healthcare). Everything was gathered here (Alto La Sierra) because this hospital can hospitalize. Also, more movements were coming and going because we had airplanes (to transfer patients to higher-level hospitals) (Community leader 4, male).*

Inner setting

In remote areas with significant socioeconomic challenges, non-urgent issues like ChD are often deprioritized in favor of more immediate concerns. As a result, ChD treatment requires enhanced community cooperation and a strong commitment to managing long-term

treatment, including periodic monitoring and multiple biochemical tests.

> *"…The patient abandoned treatment because the process was not explained well, or the patient was not motivated to complete it. Better dialogue and communication are required to reach the community. Then, they can understand the reason for treatment, the timing to take medicine, and the need to follow up. Working with all the health workers would be good but difficult."(Health Worker 1, female).*

This quotation illustrates the necessity of personalized follow-up of infected individuals. Due to the limited local workforce capacity, the NGO's involvement provided complement support, achieving 100% coverage of infant congenital ChD treatment. However, enhancing the local health system capacity is essential to maintain this progress effort and ensure treatment completion for women. Additionally, the low alarms of ChD due to the asymptomatic nature of most infected individuals illustrate the situation in the study area.

> *"If kissing bugs (vinchucas) bite today, nothing happens tomorrow. That is why people do not understand the consequences. Many doctors say to be careful with the vinchuca. But you live with it, and then it itches somewhere. But the next day, the person realizes that his tummy is full of blood, but then nothing happens, and the person doesn't die. They don't know they have symptoms, and they realize it when they go to the doctor and have tests done. (Community leader 3, female)*

Individual's characteristics

Knowledge and beliefs about the intervention, self-efficacy

The KIIs, revealed three key characteristics of *T. cruzi* seropositive mothers in the study area.

1) Low educational level, low literacy rate, and language barrier.

Most women had limited health-related knowledge, low literacy, and spoke primarily in the local language. They were often passive and appeared to have minimal control over decisions regarding their health. Many did not use birth control or engage in family planning. Health system interactions were typically only sought for severe issues requiring advanced care, affecting follow-up testing and treatment adherence for *T. cruzi*-positive women.

> *"They do not come back. They believe deeply in God and say, "No, I am fine," which is why you need to go look for them in a vehicle; otherwise, they will not return by their means…" (Health Worker 3, female).*

2) Social trauma and cultural beliefs affect health-seeking behaviors.

For communities, health is a right that health providers must fulfill without requiring duties from the recipient. This belief is particularly evident among community "leaders" who have authority and with "outsiders." They are the community's gatekeepers and view services provided by outsiders as a benefit to the provider, not the community.

> *"The manager asked me to open the door of the community. Then, they could come and pay attention to the community. Well, I told the manager I would discuss it with the people. Then, people asked me the reasons for this health service, and they accepted it. Because the door must be open when they want to come and serve the community." (Community leader 2, male).*

3) Perception of illness is tied to pain and suffering.

The community´s perception of illness is closely tied to pain and suffering, affecting their risk perception and indifference toward specific health problems. They seek medical help only in extreme situations, leading to more significant complications and potential transfers to a more complex hospital. Therefore, it's important to provide the correct information and continuous monitoring for the community to avoid loss of follow-up.

> *"People go to the health center when they already feel very sick, not only in this community but also in other communities. It is not like when you feel a little bit of a headache, you see a doctor. Thus, women only go to the health center when they are very sick" (Community leader 4, male).*

Considering the communities' characteristics, an intercultural approach is vital to improving treatment coverage of women and reducing refusal of infant screening in collaboration with local key personnel. Also, increasing women's empowerment to make decisions for their health and their children's health is essential.

Process

Engagement

The primary facilitators for successful ANC coverage were the project team's consistent engagement and collaboration with health workers over the last five years. The program, valued by the community, garnered support from local leaders and was seen as beneficial by pregnant women, who appreciated the opportunity to view their baby's face and sex via ultrasound.

> *"The ultrasounds and the explanation provided by the professionals who participate in the campaigns have made it possible for the mothers to visualize the baby in the womb, learn the sex, and verify the health status, which has also encouraged attachment from the mother to the baby (essential in these communities), a situation that was previously unthinkable and not even conceived by these women" (Project Coordinator 1, female).*

The key to this success was establishing a robust communication system by identifying key community personnel, such as local coordinators, community leaders, and health workers. This integral approach and continuous activities facilitated achieving high ANC coverage in collaboration with local health personnel as a public-private collaboration.

Discussion

These results show that the engaging domain was the most influential factor in the intervention's success, while culture, implementation climate, and self-efficacy emerged as barriers. This tailormade EMTCT plus intervention's strengths included the effective integration of periodic ANC services and collaboration between NGOs and local health systems, leading to a high *T. cruzi* screening coverage compared to national averages for each country (60.3% in Argentina and 88% in Paraguay) [8, 9]. Notably, 100% of *T. cruzi*-positive infants received treatment facilitated by the project's supplemental capacity support. However, challenges included the complex postpartum treatment for *T. cruzi*-positive mothers (67.3%), attributed to both local health system constraints (intervention characteristics) and low community prioritization of ChD (characteristics of individual). Also, limited knowledge of ChD among mothers and difficulties in accessing general healthcare is consistent with the findings of previous studies in Argentina, Bolivia, and other endemic countries [22–27]. To empower women to make health decisions, a bottom-up approach may increase women's participation at the community level. The implementation climate (inner setting), such as long-term follow-up procedures and management of adverse events, may also lead to a loss of follow-up [28]. To reduce the loss of follow-up, research into shorter-term regimens with fewer side effects might help overcome these barriers [29]. Besides, the implementation's sustainability is still unstable due to the vulnerability of the local health system because the intervention relies on NGOs to support the implementation of constant monitoring and treatment of *T. cruzi*. To overcome these difficulties, multisectoral approaches are essential to strengthening the capacity of the local healthcare system for sustainable improvement.

This study also provided valuable epidemiological data, showing a lower prevalence of *T. cruzi* infection among pregnant women (3.3%) in the study compared to the global estimated prevalence in the endemic LAC region (9%; 95% CI: 8–10) [14]. However, global estimates used data from a larger region, not solely the Gran Chaco region, making direct comparisons difficult. Other studies have also noted reduced *T. cruzi* prevalence in Argentina, likely due to vector control activities and efforts in *T. cruzi* screening and treatment [8]. While the heterogenic vector distribution in Argentina, some provinces are already certified as free of vector transmission [30]. Then, comparison with national-level study areas is not appropriate. In addition, the PCR methods used in this study have greater sensitivity than the standard micromethod, further complicating comparisons.

Regarding HBV infection, all 1,658 pregnant women included in the study were HBV-negative. According to UNICEF statistics, the coverage estimates of the third dose of HBV vaccination were 86% in Argentina and Paraguay [10]. Although specific coverage estimates of the study areas were unavailable, the adherence to vaccination among mothers, as reported by local health workers, supports the notion of higher vaccine coverage than the estimates. This aligns with interview data indicating that mothers recognize the benefits of vaccinating their children from the mother's view. On the provider side, the Ministry of Health provides vaccination guidelines that allow community health workers to complete vaccinations for all children. This situation increased vaccination acceptance by service providers and recipients, reflecting a lack of HBV detection in this population. Both facilitators may contribute to achieving high HBV vaccination coverage in this region.

Contrary to our hypothesis that combining these two diseases' implementation is effective, the factors that affected the ChD and HBV screening and treatment outcomes differed among this population. Specifically, loss of follow-up and refusal of screening and treatment of ChD occurred for complex reasons, as shown by the culture (inner setting) of the CFIR construct. Among the Indigenous population, mothers' risk perceptions were influenced by their cultural beliefs and social trauma, consistent with previous literature [31, 32]. Additionally, a common factor in most interviews was the fear of being transferred to distant institutions, which has implications for the entire family and raises other health problems and complications as well. However, if we can avoid producing severe health conditions through the early diagnosis and treatment of health problems, they may prevent transfer to a higher-level hospital. Thus, increasing women´s awareness of prevention may reduce loss of follow-up and refusal to screen their newborns. One recommendation for increasing coverage for ChD is integrating

it with the vaccination program at the community level. For example, testing children in conjunction with the national vaccination schedule may reduce the loss of follow-up for *T. cruzi* screening. Nevertheless, integrating health programs requires high-level discussions at the policy level. Thus, strengthening the capacity of the local health system with policymakers is necessary to ensure the intervention's sustainability and increase effectiveness with the EMTCT Plus framework.

Limitations

This study had several limitations that should be considered when interpreting the findings.

First, sampling bias might have occurred considering that the study was conducted in only two health centers on the Paraguayan side, which may only partially represent the diversity of the health situations across the entire study area. Geographical access issues may have biased the selection of participants and affected the generalizability of the results. Second, this study may have underestimated the prevalence and congenital transmission rate due to population mobility within the study area and between countries. Mothers who moved from the catchment areas had more difficulty following up, potentially skewing the data. Also, follow-up data of newborns after treatment could not be performed given the study period was defined up to December 2022. Finally, the COVID-19 pandemic may have affected health-seeking behavior and healthcare service availability from March 2020 to July 2021.

Conclusions

The implementation of the EMTCT Plus framework within the context of ANC has improved access to quality prenatal care and screening coverage of ChD and HBV for pregnant women in this Indigenous population. The key facilitators of this intervention's success were the community engagement and the project team's consistency. However, challenges persist in ensuring continuous follow-up for *T. cruzi* screening and treatment in the target area. To maintain activities in compliance with the ETMCT Plus strategy, efforts to strengthen the local health system's capacity by a multisectoral approach and adopt an intercultural approach to empower women are recommended for the sustainability of the implementation.

Abbreviations

ANC	Antenatal care
ADESAR	Asociación para el Desarrollo Sanitario Regional
ChD	Chagas disease
CFIR	The Consolidated Framework for Implementation Research
COVID-19	The coronavirus disease 2019
ELISA	Enzyme-linked immunosorbent assay
EMTCT	Elimination of mother-to-child transmission
HAI	Hemagglutination
HBV	Hepatitis B Virus
HIV	Human Immunodeficiency Virus
IIF	Indirect Immunofluorescence
KIIs	Key Informant Interviews
LAC	Latin America and the Caribbean
MCH	Maternal and Child Health
MTCT	Mother-to-child transmission
NTDs	Neglected Tropical Diseases
PAHO	Pan American Health Organization
PAHOERC	PAHO Ethics Review Committee
PCR	Polymerase chain reaction
RDTs	Rapid diagnosis tests
T. cruzi	*Trypanosoma cruzi*
WHO	World Health Organization

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Author contributions

YT, MF, FC, MVP, MS, HA, KH, and FP were involved in the conception and design of the study. SA, KC, MF, and FC were involved in the data collection. YT, KC, and SC analyzed the data. YT and MVP drafted the first version of the manuscript. MF, FC, MS, HA, KH, SC, and FP made critical revisions to the manuscript. All authors read and approved the final manuscript.

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Data availability

Due to ethical considerations, the de-identified datasets are not available. Also, the interview and survey files contain personally identifiable information that could be linked to specific roles with the Ministry of Health in Salta and Paraguay. Protecting participant confidentiality is essential, and data access is restricted accordingly.

Declarations

Ethical approval

This study was approved by the Pan American Health Organization Ethics Review Committee (PAHOERC) (Ref. No. 0430.01), the Research Ethics Committee of the Centro de Educación Médica e Investigaciones Clínicas "Norberto Quirno" (CEMIC), Buenos Aires (Argentina) (Ref. No.: 1232), the institutional review board of Nagasaki University, Nagasaki (Japan) (Ref. No. NU_TMGH_2022_219_1), and the Ethical Committee of the Ministerio de Salud Púbica y Bienestar Social of Paraguay (Ref. No. SIMESE N° 76.3521202). For quantitative strand, the opt-out was posted on the bulletin board of the health centers. Regarding the qualitative strand, all eligible participants who provided written informed consent were enrolled in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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