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The Xavante Longitudinal Health Study in Brazil: Objectives, design, and key results

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Abstract

Objective: The Xavante Longitudinal Health Study was developed to permit granular tracking of contemporary health challenges faced by indigenous communities in Brazil, taking into consideration ongoing historical processes that may be associated with increases in child undernutrition, adult obesity, and cardiovascular disease risks.

Methods: This was an open-cohort study with six semiannual data collection waves from 2009 to 2012. The study was undertaken in two Xavante villages, Pimentel Barbosa and Etênhiritipá, State of Mato Grosso, Central Brazil. No sampling technique was used. Data collection placed emphasis on growth and nutrition of children under five and nutrition status, blood pressure, and blood glucose levels of adolescents and adults.

Results: Baseline data collection began in July/August 2009 with a population census (656 individuals). Between the first and final waves, the study population increased by 17%. At baseline, stunting and wasting was elevated for most age groups <10 years. Overweight, obesity, and increased risk of metabolic complications were expressive among individuals >17 years, disproportionately affecting females. Anemia was elevated in most age groups, especially among females. Mean systolic and diastolic blood pressure was moderate. The overall prevalence of high blood pressure was relatively low.

Conclusions: Our findings reveal marked health disparities relative to the Brazilian national population and a complex dietary health epidemiology involving the double burden of malnutrition, rapidly changing nutritional indicators, and elevated metabolic disease risk. The topically broad multidisciplinary focus permitted construction of the richest longitudinal data set of socio-epidemiological information for an indigenous population in Brazil.

1 | INTRODUCTION

Longitudinal studies have high potential to inform about possible causes and determinants of health and disease over the life course. In Brazil, the overall quality of health data is good due to major national health surveys (Malta & Szwarcwald, 2015) accompanied by several sophisticated cohort studies (Aquino et al., 2012; Horta et al., 2015; Lima-Costa, Firmo, & Uchoa, 2011). However, indigenous peoples in Brazil are rarely contemplated by national survey sampling methodologies and have not yet been addressed by any major cohort study. The statistical invisibility of this population segment also involves a lack of disaggregated national health data collection for the country's diverse indigenous population, which includes over 300 ethnic groups and 200 distinct languages. This deficiency was to be addressed in 1999 to 2000 by the creation of a specific national health information system for the country's indigenous population, but data reliability and access remain limited due to operational and political difficulties (Santos, Cardoso, Garnelo, Coimbra Jr, & Chaves, 2008; Sousa, Scatena, & Santos, 2007). Consequently, the main sources of information about indigenous people's health in Brazil are cross-sectional studies conducted in a few communities and ethnic groups, which limits knowledge about their real health needs and social determinants of health and disease.

According to the 2010 Brazilian National Census, the indigenous population (896 917) represented just 0.4% of the national population, which is among the smallest by proportion in Latin America. This demographic group carries a disproportionately heavy burden of both infectious and noninfectious chronic diseases (Anderson et al., 2016) and has much higher mortality levels than nonindigenous people (Campos, Borges, Queiroz, & Santos, 2017). Underfunded health services lacking appropriate intercultural sensitivity aggravate this discouraging scenario. Recent data from the First National Survey of Indigenous Peoples' Health and Nutrition, the only study nationally representative of Brazil's Indigenous population (Coimbra Jr. et al., 2013), reveal an enormous gap relative to the nonindigenous population. This evidence suggests they have not benefited equally from the country's dramatic improvements in infrastructure (housing, sanitation, and access to safe drinking water), health services, food security, nutrition, and elementary schooling over the last three decades. Disparities are also evident in indigenous children's health, including disproportionate morbidity and mortality due to preventable infections (Caldas et al., 2017; Cardoso et al., 2015; Escobar et al., 2015) and higher prevalence of undernutrition and anemia (Horta et al., 2013; Leite et al., 2013). Additionally, obesity and cardiovascular disease prevalence among adult indigenous women is catching up with the country's nonindigenous population due to recent accentuated nutrition transition (IBGE, 2012).

At the center of indigenous politics and anthropological research in Brazil since the 1950s (Coimbra Jr, Flowers, Salzano, & Santos, 2002; Coimbra Jr. & Welch, 2014; Garfield, 2001), the Xavante are among the country's largest indigenous ethnic groups. The Xavante Longitudinal Health Study (henceforth, Xavante Study) was developed to permit granular tracking of contemporary health challenges faced by a local indigenous community in Brazil, taking into consideration ongoing historical processes that previous cross-sectional studies (Coimbra Jr et al., 2002; Dal Fabbro et al., 2014; Ferreira, Welch, Santos, Gugelmin, & Coimbra Jr., 2012; Soares et al., 2015; Welch et al., 2009) suggest may be associated with increases in prevalence of child undernutrition, adult obesity, and cardiovascular disease risks. The study is expected to make methodological contributions by drawing on decades of multidisciplinary research experience with the Xavante. We aim to inform indigenous leaders, health professionals, and policy makers about current health needs and priorities, thereby contributing to the formulation of evidence-based and culturally appropriate health policies and programs.

The Xavante Study was designed to assess multiple interlinked dimensions of social determinants of health and nutrition based on longitudinal data collection waves in a Central Brazilian indigenous group. Our data structure permits future cohort and case-control studies to detect factors associated with health status changes, especially the appearance of events detectable within the timeframe of the study. Examples of study outcomes include acceleration and deceleration of child growth, weight onset during adolescence and adulthood, and blood glucose, blood pressure, and hemoglobin status changes. Possible contributing or determinant factors include changes in socioeconomic household environments, food access, and socioeconomic status.

To our knowledge, this is one of the few cohort health studies to have been conducted in an indigenous population in South America. Others include a growth study of indigenous and nonindigenous girls in Chile's Araucanía Region (Amigo, Lara, Bustos, & Muñoz, 2015; Amigo, Vásquez, Bustos, Ortiz, & Lara, 2012) and a 9-year panel study carried out among the Tsimane' indigenous people in Bolivia to access the impact of modernization and market exposure on overall health, nutrition, and perception of wellbeing (Gurven et al., 2017; Leonard et al., 2015). In Brazil, an ongoing prospective birth cohort study addresses social determinants of child respiratory health among the Guarani Mbya (Cardoso et al., 2015). Most other longitudinal health studies of indigenous peoples have been carried out in North America, Australia, and New Zealand (Jolly et al., 2015;

Mitrou et al., 2014; Thurber, Banks, & Banwell, 2015; Wahi et al., 2013).

In this article, we present the cohort study design and baseline results, while discussing the relevance of these results and potential applications of future longitudinal analyses. Six data collection waves were carried out between 2009 and 2012 to track demographic, socioeconomic, health, and nutrition variables for all residents of two adjacent Xavante villages in Central Brazil. Derived from a single village which split in 2006, their residents retained strong genealogical and social ties and access to similar natural, economic, and healthcare resources. The study placed emphasis on growth and nutrition of children under five and nutrition status, blood pressure, and blood glucose levels of adolescents and adults. To examine possible statistical associations and develop explanatory models for major health outcomes, the Xavante Study also collected data for a wide range of demographic, socioeconomic, and food access variables.

2 | POPULATION AND METHODS

In 2010, the Xavante ethnic group was comprised of nearly 20 000 individuals (IBGE, 2010a) distributed among 10 federally recognized indigenous reserves and urban areas in Central Brazil. Our research was conducted in two villages, Pimentel Barbosa and Etênhiritipá, located in the Pimentel Barbosa Indigenous Reserve. The total population of these two villages was about 650, while the population of the Pimentel Barbosa Indigenous Reserve was over 1500. The local vegetation is a scrubby variety of tropical savanna known as *cerrado*. This ethnic group was historically highly mobile, subsisting primarily on a combination of gathering, hunting, and fishing, with limited horticulture of maize, beans, and squash (Maybury-Lewis, 1967; Santos, Coimbra Jr., & Welch, 2013).

Since the 1970s, they are sedentary and rely increasingly on a mixed economy of traditional food acquisition along with heavy emphasis on household production of rice and other introduced crops and, increasingly, purchased foods. The group first entered into permanent contact with the Brazilian government in 1946, after which their engagement with Brazilian society, market insertion, and reliance on governmental support and benefits became essential dimensions of their food economy (Coimbra Jr et al., 2002). Between the 1940s and 1970s, the Xavante also suffered from epidemic diseases that severely reduced their population. During the same period, government development projects emphasizing internal colonization of Central Brazil and promotion of mechanized agriculture and cattle-raising resulted in circumscription of Xavante territories by large ranches and emergence of regional urban centers. More recently, during the 2000s, the Xavante came to receive primary health services via the Indigenous Health Care Subsystem implemented in 1999 (Santos et al., 2008).

Presently, salaried public service work is a major source of income within the villages, alongside government retirement pensions, and other forms of social assistance. These are major sources of income used by Xavante families to buy commercially available foods, often at the expense of traditional food acquisition activities or household rice production. These economic changes directly affect the quality of foods, which now more closely approximate the rural Brazilian pattern of rice with beans accompanied by chicken or beef, as well as sugar, coffee, salt, pasta, soda drinks, crackers, and cooking oil (Coimbra Jr et al., 2002; Santos et al., 2013; Welch, Santos, et al., 2013). These dietary changes are closely associated with the ongoing health transition taking place among the Xavante.

The Xavante of Pimentel and Etênhiritipá villages are among the most studied indigenous communities in Brazil, having been the focus of diverse publications on topics such as ecology, health, demography, ethnohistory, and social organization (Coimbra Jr et al., 2002). These specific villages, among others, factored importantly in public discourse since the mid-20th century for, among other things, being pioneers in the field of Brazilian indigenous politics (Garfield, 2001) and being pivotal in the development of anthropological structuralism (Maybury-Lewis, 1979). This body of data provides a significant and rare contextual basis for interpreting new studies in the same population. These villages were chosen for this study for this reason and due to their status as the "mother" villages of all others in the reserve, which were also first group to establish contact with the Brazilian government in the 1940s.

The first visit to the Xavante by members of our research group (Coimbra and Santos) occurred at Pimentel Barbosa village in July 1990. As we recalled in a recent review paper, "…[that] first visit made such an impression on us that we have returned many times. Although at the time we may not have anticipated the trajectory of our relationship with the Xavante of Pimentel Barbosa, our mutual involvement has deepened and diversified profoundly over the years." (Santos et al., 2013, p. 1). Since that time, our engagement with the Xavante increased to include another seven villages that divided from Pimentel Barbosa since the 1980s. In collaboration with students and researchers from diverse Brazilian and international institutions, our health research program expanded over the years to engage a range of topics and activities of interest to Xavante communities, including land claims, community-based cultural documentation, threatened foodways documentation, and public outreach (Coimbra Jr et al., 2002; Welch, Brondízio, et al., 2013; Welch, Santos, et al., 2013).

A hallmark of our research among the Xavante is emphasis on fostering long lasting relationships and symmetrical forms of research engagement with local communities, which we strongly believe helps promote participation in health research through discussion and co-construction of research goals and approaches. Our research program strives to respond to Xavante concerns with the recent emergence of obesity and related chronic diseases. It also builds upon public health attention to global nutrition dynamics, including the health and nutrition transitions and double burden of malnutrition, characterized by the emergence of adult obesity in conjunction with the persistence of child undernutrition.

The study population included all Xavante residents of Pimentel Barbosa and Etênhiritipá, Pimentel Barbosa Indigenous Reserve, Mato Grosso state. Residence was defined as having lived in one of the villages for at least 3 months prior to each data collection wave. No sampling techniques were used. In 2009 (baseline), the two villages had total populations of 340 and 316, respectively, with 58.1% of individuals <15 years of age. Individuals of both sexes and all ages were invited to participate and were freely allowed to enter or exit the study at any time. Exclusion criteria were limited to physical capacity to be evaluated according to study protocols. Possible reasons for entrance after the first wave (baseline) or exit before the last were birth, death and relocation to or from the study villages. Consistent with open-cohort methods, the number of measurements varied through time (unbalanced data), as did the intervals between data points for some children (temporally unstructured data). Accordingly, different numbers of subjects were evaluated the maximum of six times (during all data collection waves) through the minimum of once (Figure 1).

3 | FIELDWORK

Baseline data collection in July to August 2009 began with a population census. Vital statistics of all eligible participants were collected from documents, local records, and self-reporting. Five subsequent data collection waves were done at 6-month intervals (July-August and January-February) to coincide with peak dry and rainy seasons, respectively. Scheduling of visits was negotiated through periodic communication with village leaders and key Xavante collaborators to avoid village-wide subsistence, economic, and ceremonial activities with the potential to reduce research participation. Demographic data were updated during each subsequent wave to enroll new participants (births and immigrants), record attrition (deaths and emigrants), and update household residency. All measurements and interviews were carried out during home visits.

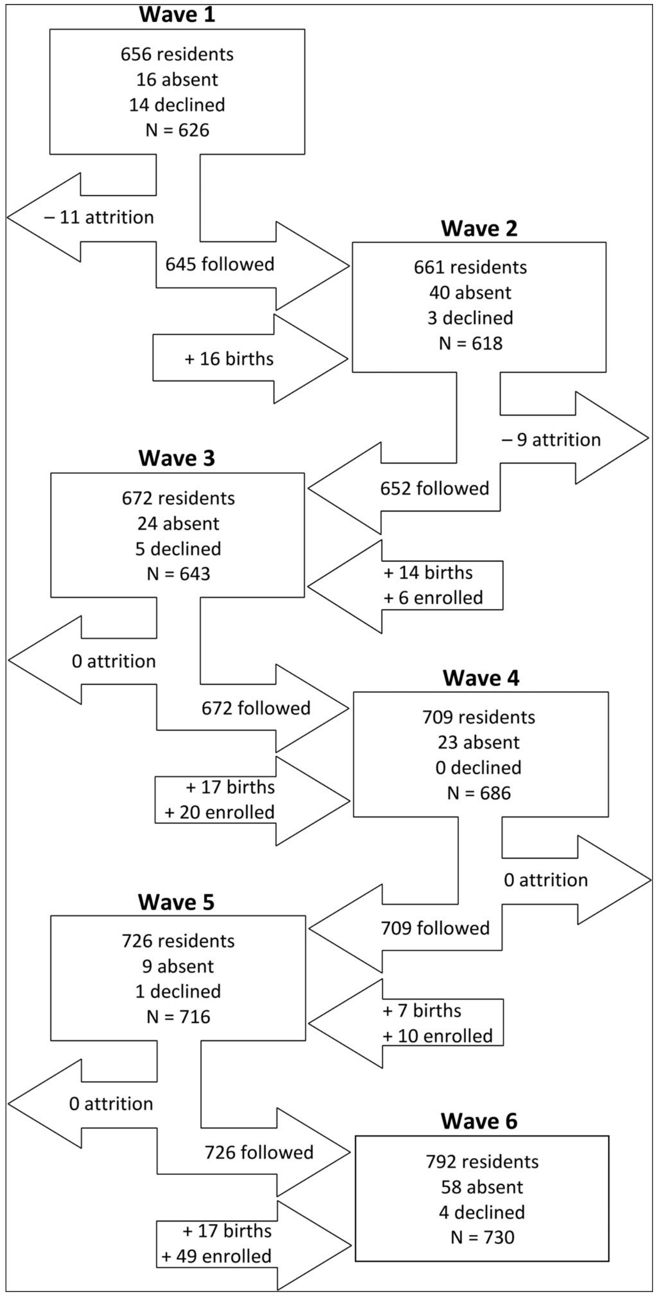

FIGURE 1 Participant flow during the Xavante Longitudinal Health Study, July to August 2009 to January to February 2012, Pimentel Barbosa e Etênhiritipá villages, Brazil

Interwave attrition ranged from 1.7% (11 individuals) following baseline enrollment to 0% following the third, fourth, and fifth waves. The baseline wave showed the largest rate of nonparticipation due to declination (2.1%), while the sixth wave showed the largest number due to absence (7.3%). Few deaths were observed during the study period (Figure 1). Given the prospective open-cohort methodology, with participation predominantly being determined by residence in the two study villages, challenges of attrition derived largely from culturally distinct demographic dynamics and social activities. Besides death, most attrition was due to prolonged visits or migration to nonstudy villages and regional cities. It is usual for Xavante individuals of all ages to visit relatives in other villages for months or years at a time. Some youth sought secondary and post-secondary education outside their villages. Several entire households relocated to or from the study villages between waves, which is a common practice in Xavante society. Attrition due to declination to participate was negligible, but elevated absences during the final wave caused some individuals to exit before the end of the study.

The Xavante Study followed research standards stipulated by the Declaration of Helsinki and CIOMS International Ethical Guidelines. The study protocol was approved by the research ethics committee of the Escola Nacional de Saúde Pública and the Brazilian National Commission on Research Ethics (protocol # 2500.202987/2010-14). The Fundação Nacional do Índio (FUNAI) issued permission for conducting field work within federal indigenous land. All individuals or their adult guardians could allow or withdraw participation at any time.

4 | DATA

Biometric data collection was performed during each wave by previously standardized researchers with the assistance of Xavante community health agents. Weight and height were sought for all participants that were physically able. Waist circumference, mid-upper arm circumference, subscapular, and triceps skinfold measurements were sought once each year (July-August collection waves) for individuals ≥10 years. Two drops of capillary blood were obtained with one-way lancets to measure hemoglobin levels in all participants ≥6 months of age and random blood glucose levels in adults ≥18 years. All measurements and dosages strictly followed procedures adopted by the First National Survey of Indigenous Health and Nutrition in Brazil (Coimbra Jr. et al., 2013). Household socioeconomic data were collected annually (July-August). Variables included per capita income, durable household goods, and three indicators of food diversity/frequency. Baseline individual and household socioeconomic variables that were not repeated in all years included years of schooling, bilingualism, and having planted a food garden in the previous year. Table 1 summarizes variables collected at baseline and repeated annually or semiannually.

TABLE 1 Baseline demographic characteristics, July to August 2009, Pimentel Barbosa and Etênhiritipá villages, Brazil

Characteristic	Male % (n)	Female % (n)	Total % (N)
Sex	48.6 (319)	51.4 (337)	100.0 (656)
Village			
Pimentel Barbosa	53.0 (169)	50.7 (171)	51.8 (340)
Etênhiritipá	47.0 (150)	49.3 (166)	48.2 (316)
Age (y)			
<2	11.3 (36)	11.9 (40)	11.6 (76)
2 to 4	13.2 (42)	14.2 (48)	13.7 (90)
5 to 9	18.8 (60)	17.2 (58)	18.0 (118)
10 to 17	21.6 (69)	21.4 (72)	21.5 (141)
18 to 59	33.2 (106)	31.5 (106)	32.3 (212)
≥60	1.9 (6)	3.9 (13)	2.9 (19)
Spoken language proficiency			
Xavante only (monolingual)	59.9 (100)	98.9 (175)	79.9 (275)
Xavante and Portuguese (bilingual)	40.1 (67)	1.1 (2)	20.1 (69)

The anthropometric indicators used to evaluate nutritional status, as well as the criteria employed to identify anemia, risk of metabolic complications, arterial hypertension, and diabetes mellitus followed the World Health Organization (WHO, 2001, 2006, 2011), The Seventh Report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (Chobanian et al., 2003), and The Expert Committee on the Diagnosis and Classification of Diabetes Mellitus (American Diabetes Association, 2003), respectively.

5 | RESULTS

At baseline (July-August 2009), the total population of Pimentel Barbosa and Etênhiritipá villages was 656, of which 626 (95.4%) participated in the Xavante Study, 16 (2.4%) were absent, and 14 (2.1%) declined to participate (Figure 1). The baseline population was 51.4% female, 51.8% resident of Pimentel Barbosa village, and 32.3% in the age group 18 to 59 years (Table 1). Children <2 years comprised 11.6% of the baseline population, while those ≥60 represented 2.9%. In 2009, 20.1% of adult respondents reported speaking some Portuguese in addition to the Xavante language.

Between the first and final waves, the study population increased by over 20% to 792 residents, while the number of participants increased by 17% to 730. During this period, 71 births were recorded. Enrollments in subsequent waves for reasons other than birth ranged from 49 during the sixth wave to 0 during the second (Figure 1).

In the first published results of the Xavante Study, children were shown to be born with adequate weight and

TABLE 2 Baseline biometric variables by age group, July to August 2009, Pimentel Barbosa and Etênhiritipá villages, Brazil

	Male				Female				Total			
Indicator	n	Mean (SD)	Min	Max	N	Mean (SD)	Min	Max	N	Mean (SD)	Min	Max
<5 years												
Weight (kg)	78	11.6 (4.3)	4.2	30.1	87	11.3 (4.1)	3.0	20.1	165	11.4 (4.2)	3.0	30.1
Stature (cm)	78	81.2 (14.2)	51.4	104.0	87	82.1 (15.8)	46.5	108.9	165	81.7 (15.1)	46.5	108.9
HAZ (z-score)	78	−1.4 (1.1)	−6.3	1.6	87	−1.5 (1.4)	−7.0	3.1	165	−1.4 (1.3)	−7.0	3.1
WAZ (z-score)	78	−0.4 (1.2)	−3.5	7.0	87	−0.7 (1.1)	−4.6	1.3	165	−0.6 (1.2)	−4.6	7.0
WHZ (z-score)	78	0.6 (1.8)	−3.7	13.2	87	0.3 (1.1)	−2.0	6.7	165	0.4 (1.5)	−3.7	13.2
BAZ (z-score)	78	0.7 (2.0)	−4.2	14.0	87	0.3 (1.1)	−2.3	6.4	165	0.5 (1.6)	−4.2	14.0
Hemoglobin (g/dL)	78	10.4 (1.4)	7.4	13.1	87	10.8 (1.4)	7.8	13.6	165	10.6 (1.4)	7.4	13.6
5 to 9 years												
Weight (kg)	59	23.4 (4.7)	16.5	33.3	57	23.1 (5.6)	16.1	38.1	116	23.3 (5.2)	16.1	38.1
Stature (cm)	59	119.0 (9.2)	99.9	136.6	56	118.5 (10.6)	98.8	142.9	115	118.7 (9.8)	98.8	142.9
HAZ (z-score)	59	−0.8 (0.7)	−2.6	1.1	56	−1.0 (0.9)	−3.5	1.2	115	−0.9 (0.8)	−3.5	1.2
WAZ (z-score)	59	−0.2 (0.7)	−2.0	1.3	57	−0.4 (0.9)	−2.9	1.3	116	−0.3 (0.8)	−2.9	1.3
BAZ (z-score)	59	0.4 (0.6)	−1.1	1.6	56	0.3 (0.6)	−0.9	1.4	115	0.4 (0.6)	−1.1	1.6
Hemoglobin (g/dL)	59	11.9 (1.2)	7.6	15.5	57	11.7 (1.1)	8.8	14.4	116	11.8 (1.2)	7.6	15.5
10 to 17 years												
Weight (kg)	62	48.3 (14.8)	25.0	83.6	62	51.5 (11.7)	29.5	85.5	124	49.9 (13.4)	25.0	85.5
Stature (cm)	62	151.7 (13.5)	126.9	173.2	67	150.3 (7.3)	131.4	164.7	129	150.9 (10.7)	126.9	173.2
HAZ (z-score)	62	−0.8 (0.8)	−2.5	0.7	67	−0.9 (0.8)	−2.4	0.9	129	−0.9 (0.8)	−2.5	0.9
BAZ (z-score)	62	0.6 (0.7)	−1.8	2.5	62	1.0 (0.8)	−1.2	2.5	124	0.8 (0.8)	−1.8	2.5
Waist circumference (cm)	58	73.8 (11.3)	28.9	109.0	62	80.8 (9.6)	59.7	102.4	120	77.2 (11.1)	28.9	109.0
Hip circumference (cm)	58	81.3 (9.8)	62.9	97.8	62	89.1 (9.4)	66.8	112.7	120	85.4 (10.3)	62.9	112.7
Mid-upper arm circumference (cm)	58	25.8 (10.4)	17.4	97.0	62	26.8 (3.7)	19.5	37.8	120	26.3 (7.7)	17.4	97.0
Subscapular skinfolds (mm)	58	10.3 (3.1)	5.7	20.0	62	15.3 (5.0)	7.7	28.3	120	12.9 (4.9)	5.7	28.3
Triceps skinfolds (mm)	58	10.5 (3.3)	5.0	20.7	62	18.8 (5.3)	8.3	34.7	120	14.8 (6.1)	5.0	34.7
Systolic blood pressure (mm Hg)	25	120.4 (9.1)	102.7	134.7	38	111.0 (8.3)	97.3	135.0	63	114.7 (9.7)	97.3	135.0
Diastolic blood pressure (mm Hg)	25	74.3 (8.6)	55.0	87.7	38	69.8 (6.7)	52.0	86.3	63	71.6 (7.8)	52.0	87.7
Random blood glucose (mg/dL)	26	110.0 (22.0)	72.0	164.0	44	110.0 (21.0)	78.0	168.0	70	110.0 (21.0)	72.0	168.0
Hemoglobin (g/dL)	62	12.9 (1.3)	10.4	15.9	67	11.9 (1.5)	7.1	14.7	129	12.4 (1.5)	7.1	15.9
≥18 years												
Weight (kg)	98	76.0 (8.7)	54.0	93.5	109	66.4 (10.5)	43.0	96.5	207	70.9 (10.8)	43.0	96.5
Stature (cm)	98	166.3 (6.9)	121.4	181.7	113	154.3 (4.7)	140.8	168.2	211	159.9 (8.3)	121.4	181.7
BMI (kg/m^2)	98	27.6 (3.6)	21.2	47.4	109	27.8 (3.9)	20.4	39.9	207	27.7 (3.7)	20.4	47.4
Waist circumference (cm)	98	93.9 (8.6)	76.0	112.8	106	96.2 (7.9)	77.6	121.1	204	95.1 (8.3)	76.0	121.1
Hip circumference (cm)	98	99.0 (7.2)	53.1	111.5	106	99.5 (7.5)	80.7	123.9	204	99.3 (7.4)	53.1	123.9
Mid-upper arm circumference (cm)	98	32.3 (2.6)	25.4	37.7	106	31.6 (3.2)	24.3	39.7	204	32.0 (2.9)	24.3	39.7
Subscapular skinfolds (mm)	98	17.4 (3.8)	9.3	29.3	105	20.7 (5.7)	7.7	38.3	203	19.1 (5.1)	7.7	38.3
Triceps skinfolds (mm)	98	15.2 (4.9)	5.7	25.3	105	24.3 (6.5)	9.0	40.3	204	19.9 (7.3)	5.7	40.3
Systolic blood pressure (mm Hg)	97	119.1 (10.9)	100.0	159.0	109	114.0 (14.2)	89.0	165.3	206	116.4 (12.9)	89.0	165.3
Diastolic blood pressure (mm Hg)	97	76.8 (8.2)	58.0	103.7	109	69.8 (8.8)	48.0	92.0	206	73.1 (9.2)	48.0	103.7
Random blood glucose (mg/dL)	99	121.0 (48.0)	75.0	478.0	113	121.0 (39.0)	77.0	407.0	212	121.0 (43.0)	75.0	478.0
Hemoglobin (g/dL)	99	13.8 (1.3)	8.8	16.9	114	11.7 (1.2)	6.9	14.4	213	12.6 (1.6)	6.9	16.9

Abbreviations: BAZ, body mass index (BMI)-for-age z-score; HAZ, height-for-age z-score; SD, standard deviation; WAZ, weight-for-age z-score; WHZ, weight-for-height z-score.

TABLE 3 Prevalence for baseline health indicators by age group, July to August 2009, Pimentel Barbosa and Etênhiritipá villages, Brazil

	<10 years			10 to 17 years			≥18 years		
Health indicator	**Male % (n)**	**Female % (n)**	**Total % (n)**	**Male % (n)**	**Female % (n)**	**Total % (n)**	**Male % (n)**	**Female % (n)**	**Total % (n)**
Stunting[a]	11.8 (16)	20.3 (29)	16.1 (45)	11.3 (7)	6.0 (4)	8.5 (11)	-	-	-
Wasting[b]	2.9 (4)	8.4 (12)	5.7 (16)	-	-	-	-	-	-
Underweight[c]	0.7 (1)	1.4 (2)	1.1 (3)	0.0 (0)	0.0 (0)	0.0 (0)	1.0 (1)	3.7 (4)	2.4 (5)
Overweight (BMI)[d]	8.9 (12)	8.5 (10)	7.9 (22)	17.7 (11)	46.8 (29)	32.3 (40)	45.9 (45)	53.2 (58)	49.8 (103)
Overweight (weight-for-stature)[e]	2.9 (4)	2.3(2)	2.2 (6)	-	-	-	-	-	-
Obesity (BMI)[f]	0.0 (0)	0.0 (0)	0.0 (0)	3.2 (2)	8.1 (5)	5.6 (7)	23.5 (23)	23.9 (26)	23.7 (49)
Obesity (weight-for-stature)[g]	0(0)	0.0 (0)	0 (0)	-	-	-	-	-	-
Increased risk of metabolic complications[h]	-	-	-	-	-	-	38.8 (38)	16.0 (17)	27.0 (55)
Substantially increased risk of metabolic complications[i]	-	-	-	-	-	-	15.3 (15)	82.1 (87)	50.0 (102)
Mild anemia[j]	24.8 (31)	22.4 (30)	23.6 (61)	19.4 (12)	26.9 (18)	23.3 (30)	23.2 (23)	33.3 (38)	28.6 (61)
Moderate anemia[k]	22.4 (28)	23.1 (31)	22.8 (59)	1.6 (1)	20.9 (14)	11.6 (15)	3.0 (3)	19.3 (22)	11.7 (25)
Severe anemia[l]	0.8 (1)	0.0 (0)	0.4 (1)	0.0 (0)	1.5 (1)	0.8 (1)	0.0 (0)	0.9 (1)	0.5 (1)
High blood pressure[m]	-	-	-	-	-	-	6.2 (6)	5.5 (6)	5.8 (12)
Elevated random blood glucose[n]	-	-	-	-	-	-	2.0 (2)	3.5 (4)	2.8 (6)

Abbreviations: BAZ, body mass index (BMI)-for-age z-score; HAZ, height-for-age z-score; WHZ, weight-for-height z-score.

[a]HAZ < −2.

[b]WHZ < −2.

[c]BAZ < −2 (<18 years), BMI < 18.5 (18-59 years), BMI ≤22.0 (≥60 years).

[d]2 < BAZ ≤ 3 (<5 years), 1 < BAZ ≤ 2 (5-17 years), 25.0 ≤ BMI < 30.0 (18-59 years), BMI > 27.0 (≥60 years).

[e]2 < WHZ ≤ 3 (<10 years).

[f]BAZ > 3 (<5 years), BAZ > 2 (5-17 years), BMI ≥ 30.0 (18-59 years).

[g]WHZ > 3 (<10 years).

[h]94 < WC ≤ 102 (males), 80 < WC ≤ 88 (females).

[i]WC > 102 (males), WC > 88 (females).

[j]10.0 to 10.9 g/dL (6-59 months), 11.0 to 11.4 g/dL (5-11 years), 11.0 to 11.9 g/dL (12-14 years), 11.0 to 11.9 g/dL (nonpregnant females ≥15 years), 11.0 to 12.9 g/dL (males ≥15 years).

[k]7.0 to 9.9 g/dL (6-59 months), 8.0 to 10.9 g/dL (≥5 years).

[l]<7 g/dL (6-59 months), <8 g/dL (≥ 5 years).

[m]≥140 × 90 mm Hg.

height, but to fall behind in weight gain and linear growth before the end of the first year and to undergo inconsistent recovery before 10 years (Ferreira, Welch, Cunha, & Coimbra Jr., 2016). During the baseline data collection wave (July-August 2009), mean z-scores for children of both sexes <10 years were below 0 for weight-for-age and below −1 for height-for-age (Table 2). Mean height-for-age z-scores remained close to the reference population median from 10 to 17 years.

At baseline, prevalence of stunting was high for children <5 years (22.6%, data not shown) and <10 years (16.1%, Table 3). Stunting was elevated in the age group 10 to 17 years (males: 11.3%; females: 6.0%; Table 3). Among children <10 years, the frequency of wasting was elevated among males (2.9%) and high among females (8.4%). Cases of underweight in this age group were negligible (males: 0.7%; females: 1.4%). Cases of underweight were absent in the age group 10 to 17 years and isolated among those ≥18 years (2.4%).

Relatively few children <10 years were classified as overweight according to the indicators BMI-for-age z-score (7.9%) and weight-for-age z-score (2.2%; Table 3). Overweight prevalence was less expressive in the age group 10 to 17 years (males: 17.7%; females: 46.8%) than ≥18 years (males: 45.9%; females: 53.2%). No cases of obesity were documented among children <10 years according to the indicators BAZ and WHZ. Obesity was low in the age group 10 to 17 years (males: 3.2%; females: 8.1%) but very high in those ≥18 years (23.7%). No cases of severe obesity were observed in participants <18 years (data not shown). Among participants ≥18 years, mean BMI was 27.6 kg/m^2 among males and 27.8 kg/m^2 among females (Table 2). Increased risk of metabolic complications was more prevalent among males (38.8%) than females (16.0%), while substantially increased risk of metabolic complications disproportionately affected females (82.1%) as compared to males (15.3%; Table 3).

Mean hemoglobin levels were similar for males and females in the age groups <5 years (10.6 g/dL) and 5 to 9 years (11.8 g/dL). Women had lower mean hemoglobin levels than men in the age groups 10 to 17 years (females: 11.9 g/dL; males: 12.9 g/dL) and ≥18 years (females: 11.7 g/dL; males: 13.8 g/dL; Table 2). Mild anemia was elevated among males and females of all ages, ranging from 19.4% in males from 10 to 17 years to 33.3% in females ≥18 years (Table 3). Moderate anemia affected children <10 years of both sexes (males: 22.4%; females: 23.1%), females from 10 to 17 years (20.9%), and females ≥18 years (19.3%) more than males from 10-17 years (1.6%) and ≥18 years (3.0%). Cases of severe anemia were isolated for males and females of all ages.

Mean systolic and diastolic blood pressure was moderate for males and females in the age groups 10 to 17 years (males: 120.4/74.3 mm Hg; females: 111.0/69.8 mm Hg) and ≥18 years (males: 119.1/76.8 mm Hg; females: 114.0/69.8 mm Hg; Table 2). The overall prevalence of high blood pressure in the age group ≥18 years was relatively low for males (6.2%) and females (5.5%; Table 3).

Random blood glucose levels were the same for males and females in the age groups 10 to 17 (110.0 mg/dL) and ≥18 years (121.0 mg/dL; Table 2). The prevalence of elevated random blood glucose in the age group ≥18 years was 2.8% (Table 3).

6 | DISCUSSION

Our baseline findings from 2009 point to marked health disparities relative to the Brazilian national population and deterioration of some indicators when compared to earlier studies in the same Xavante study population. Stunting and wasting frequencies among Xavante children <10 years were higher than in nonindigenous children in Brazil (IBGE, 2010b). Although our results show a marked difference in stunting between males and females <10 years (11.8% and 20.3%, respectively), this difference disappeared in subsequent data collection waves and may be attributed to selection bias due to the small size of our study population. The overall trend during subsequent waves was stunting parity between males and females under 10 years. Our results also show stunting prevalence among Xavante children <5 years (22.6%) was higher than reported for nonindigenous children nationwide in 2006 (7.1%) and similar to indigenous children nationwide in 2008 to 2009 (25.7%; Horta et al., 2013; IBGE, 2010a). Whereas prevalence of child wasting and underweight in all age groups was very low, prevalence of overweight was more pronounced in all age groups and showed marked increases compared to findings from earlier studies in the same study population (Ferreira et al., 2012; Welch et al., 2009).

The overall frequencies of adolescent and adult overweight and obesity observed among the Xavante were substantially higher than in the overall and indigenous national populations in comparable years (Coimbra Jr. et al., 2013; Moura & Claro, 2012). The few local indigenous case studies in Brazil that address adolescent excess weight also show elevated frequencies (Castro et al., 2010; Sampei et al., 2007). Other indigenous case studies in the country show adult excess weight prevalence similar to our baseline findings for the Xavante (Fávaro, Santos, Cunha, Leite, & Coimbra Jr., 2015; Lourenço, Santos, Orellana, & Coimbra Jr., 2008; Oliveira et al., 2015). The differences in excess weight prevalence observed in the national indigenous population and local case studies, including the Xavante Study, suggest a need for additional community research with different ethnic groups throughout Brazil.

More favorable results were encountered for anemia and blood pressure prevalence. Anemia was similarly or less prevalent among Xavante children and women than in the overall and indigenous national populations (Leite et al., 2013; Ministério da Saúde [Brasil], 2009). Also, adult hypertension prevalence was lower among the Xavante than has been documented in these two national reference populations (Coimbra Jr. et al., 2013; Picon, Fuchs, Moreira, Riegel, & Fuchs, 2012). These baseline results reveal a complex dietary health epidemiology involving the double burden of malnutrition (elevated child stunting and adult excess weight) against a backdrop of rapidly changing nutritional health indicators and elevated risk of metabolic complications. Although prevalence of anemia, high blood pressure, and elevated random blood glucose were detected in most age and sex categories, they did not yet affect this indigenous population as markedly as other population segments in Brazil and elsewhere. Our longitudinal data set will be used to further ascertain how these health challenges evolved during the study period and which determinants contributed to favorable and unfavorable health events among participants.

For example, our first published results of the Xavante Study tracked children's growth through the six data collection waves in order to more accurately calculate actual linear and ponderal growth curves. Our future research based on this data set will allow us to study factors contributing to these patterns, such as risk factors for early childhood growth deceleration and protective factors for late childhood growth catchup. Similarly, participants presenting the appropriate characteristics for inclusion in cohort and case-control studies designed to explain health events related to double burden of nutrition, anemia, hypertension, and diabetes mellitus. Through its longitudinal design, the study has the potential to answer many hypotheses and potential explanations for these events proposed by previous cross-sectional studies. In this manner, the Xavante Study presents new opportunities to clarify urgent theoretical and methodological questions regarding health change among indigenous peoples in South America, a disadvantaged population in terms of health conditions and access to health services.

A recurrent challenge for longitudinal epidemiological studies is participant attrition due to withdrawal, relocation, and declination. The Xavante population presents unique challenges for longitudinal studies due to high levels of mobility due to subsistence activities and occasional relocation of individuals and households between villages. Despite these challenges, adhesion to the study was high and attrition levels were low. We believe this strength of the study derives in part from the longstanding relationships that exist between the study community and our research group. Also, our fieldwork teams included community representatives, including Xavante community health agents, who facilitated scheduling, communication, and methodological cross-cultural sensitivity. Furthermore, our experience with this Xavante community suggests a high level of interest in collaborating with scientific studies with the potential to elucidate contemporary challenges to their health and wellbeing.

Many Central Brazilian and Amazonian indigenous populations also present unique research challenges due to their remoteness relative to urban research centers and small community sizes, conditions favoring transversal studies with very small participant populations. By maintaining a regular schedule of data collection waves and adopting a prospective open-cohort methodology, the Xavante Study successfully overcame some of these issues. Community members anticipated our prescheduled semiannual visits and collaborated by making themselves available for interviews and examinations. Although the overall population of the two study villages is smaller than ideal for longitudinal research, the total number of participants was higher than has been reported for the great majority of community studies in Brazil and the greater Amazon region, with the exception of the First National Survey of Indigenous Peoples' Health and Nutrition based on a representative sample of indigenous villages in Brazil (Coimbra Jr. et al., 2013).

Despite the Xavante Study's innovative potential for cohort and case-control research into nutritional and cardiovascular health events in an Amazonian population, several fragilities must be considered in analyses and interpretation of results. Due to limitations of our research logistics and governmental primary care health records in the indigenous reserve, it was not possible to organize a local nursing team to systematically register common morbidities, such as diarrhea and respiratory infections. Also, intravenous blood samples were not collected considering local politics involving biological samples and challenging fieldwork conditions, which made it impossible to perform biochemical tests necessary for characterizing metabolic syndrome.

7 | CONCLUSION

The multidisciplinary focus and topical breadth of biological, demographic, and socioeconomic variables collected annually during the study permitted construction of the richest longitudinal data set of socio-epidemiological information for an indigenous population in Brazil. The Xavante Study research design will permit cohort and case-control studies to address research questions about the implications of population and socioeconomic dynamics for the determination of child and adult health and nutrition among the Xavante. Through this effort, we aim to produce previously elusive epidemiological insights into the causes of persistent inequalities between indigenous and nonindigenous peoples in Brazil. Our publication strategy seeks to reach an international community of scientists, policy makers, and indigenous leaders involved in finding solutions to bridge the growing health status divide between indigenous and nonindigenous populations, particularly in Latin American Countries.

Historically, epidemiological studies of indigenous peoples' health in Brazil and elsewhere in South America have focused on identifying and characterizing health disparities in order to increase awareness of previously unrecognized health inequities, reduce their social exclusion, promote their statistical visibility, and stimulate adequate public policy recognition and resource allocation. The Xavante Longitudinal Health Study marks a shift beyond the study of health inequities toward more sophisticated epidemiological understandings of health processes through time. This advance also has the potential to affect public policy by providing sorely needed information about health and disease processes among indigenous peoples that can be used to formulate innovative solutions and formulate new models for effective health services in Brazil and elsewhere.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

J.R.W., C.E.A.C., and R.V.S. designed the study, and directed implementation and data collection. J.R.W., C.E.A.C., A.A.F., M.V.G.O., and J.R.M.L. participated in field data collection. A.A.F., F.G.T., J.R.M.L., J.R.W., and C.E.A.C. analyzed the data. J.R.W. and C.E.A.C. wrote the manuscript. R.V.S., A.A.F., F.G.T., and J.R.M.L. provided critical comments on the manuscript. All authors participated in data interpretation and approved the final manuscript.

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