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The impact of the Inca Empire in Northwest Argentina: Assessment of health status and food consumption at Esquina de Huajra (Quebrada de Humahuaca, Argentina)

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Abstract

The Inca Empire annexed the modern territory of Northwest Argentina ca. 1450 AD. Inca presence manifested regionally with different intensity, highlighting that the Empire carried out different strategies when interacting with conquered populations even within the same region. Regional fluctuations in power centralization may affect the quality of life of local groups, regarding access to food, labour, conflict, or inequality. In this paper, we analyse stable isotopes, dental, and osteological information to evaluate if the individuals that inhabited the archaeological site Esquina de Huajra (Quebrada de Humahuaca, Jujuy) experienced a deprived life quality under Inca administration. Isotopic results signal a balanced diet composed of both vegetal and animal resources, and skeletal indicators of health do not suggest a population undergoing stress.

KEYWORDS

bioarchaeology, empires, Inca, Northwest Argentina, stable isotopes

1 | INTRODUCTION

Empires are expansive states that assume control over entities of varying complexity and must adjust their strategies to the conquered areas (D'Altroy, 1992, p. 9; D'Altroy et al., 2000; Menzel, 1959). The Incas established different kinds of control over the populations that inhabited the Tawantinsuyu involving different responses from local groups such as resistance, cooperation, or alliance (Alconini, 2005; Covey, 2000; D'Altroy et al., 2000; Dillehay, 1977; Gifford, 2003; Malpass & Alconini, 2010; Meddens & Schreiber, 2000; Morris, 1998; Mulvany, 2003; Nielsen & Walker, 1999; Taylor & Pease, 1994; Williams & Cremonte, 2013; Williams & Villegas, 2017).

Northwest Argentina was part of the *Qollasuyu*, the southeastern corner of the Empire, and was annexed by Topa Inca according to Rowe (1945, p. 271). In Northwest Argentina, Inca presence is manifested by the building of new settlements, spatial reorganization of previous settlements or their abandonment, construction of roads, way stations and warehouses, high altitude shrines, and Inca style materiality as ceramics, metals, textiles, lapidary, and *mullu* (Williams, 2010).

In the Quebrada de Humahuaca, the exploitation of mineral and agricultural resources and the production of handcrafts to support the hospitality of the State and exchange appear to be the main objectives sought by the Empire (Otero, Cremonte, & Ochoa, 2017). Reinforcement of the eastern border of the territory was important too, as testified by the construction of several forts (Cremonte & Garay de Fumagalli, 2013; Oliveto & Ventura, 2009). However, the eastern lands were also important for obtaining raw material, as seen through the generation of new roads and exchange circuits, and it is in this context that Esquina de Huajra must be unsderstood (Cremonte, Peralta, & Scaro, 2006–2007; Cremonte & Williams, 2007).

Although in some places, Inca occupation was intensive, in others, it was short-lived or was mainly based on negotitiation with ethnic leaders, leading to a "selectively intensive domination" (Williams & D'Altroy, 1998). Numerous studies have addressed the topic of "bioarcheology of imperialism" (Tung, 2012) and, specifically for the Inca time, have shown that the empire has variously altered lifestyles of communities in the provinces (Andrushko, 2007; Costin & Earle, 1989; Dorsey Vinton, Perry, Reinhard, Santoro, & Teixeira-Santos, 2009; Falabella, Planella, Aspillaga, Sanhueza, & Tykot, 2007; Hastorf, 1990; Santoro, Dorsey Vinton, & Reinhard, 2003; Williams & Murphy, 2013).

Considering that bioarchaeological research in Quebrada de Humahuaca supports the occurrence of nutritional, functional, and general stress indicators among prehispanic populations (Arrieta, 2012; Gheggi & Seldes, 2014; Seldes, 2006), the aim of this study is to assess the health status and food consumption in a sample of human remains from Esquina de Huajra, established under the Inca administration in the Humahuaca Valley. If imperial policies had a negative impact, we would expect to find high prevalence of metabolic-nutritional, infectious diseases, and/or general stress, coupled with the use of a less diverse and adequate diet.

Esquina de Huajra (1,900 masl) is a settlement located in the south-central area of the Quebrada de Humahuaca in Jujuy (Figure 1). This sector encompasses the southeastern valleys and the yungas of the Tiraxi-Tesorero basin being a transition zone between the semideserts of the north and the southern humid subtropical zone that stretches down the valley of Jujuy (Reboratti, 2003).

Excavations in Esquina de Huajra focused on three artificially levels called Terrace I, II, and III (from bottom to top). In Terrace III, residential and burial areas were located. The application of Bayesian statistics by Greco (2017, p. 170) on radiocarbon datings posits that "[…] the events of burial and rituals in Terrace 3 began sometime between the ending of 14th and mid-15th centuries, with a mean probability in 1387 AD. Those events may have finished in the mid-16th and late 17th century, with a mean in 1680 AD."

Esquina de Huajra was embedded in extensive exchange networks Copper ores, turquoise beads, and metal objects of native copper, tin-bronze, or silver alloys were found (Angiorama, 2013; Cremonte, Botto, & Viña, 2009). Foreign pottery styles include Yavi/Chicha, Casabindo Pintado, or Inka Pacajes from southern Bolivian altiplano (Cremonte, 2014; Cremonte & Scaro, 2011). Huajra pottery also

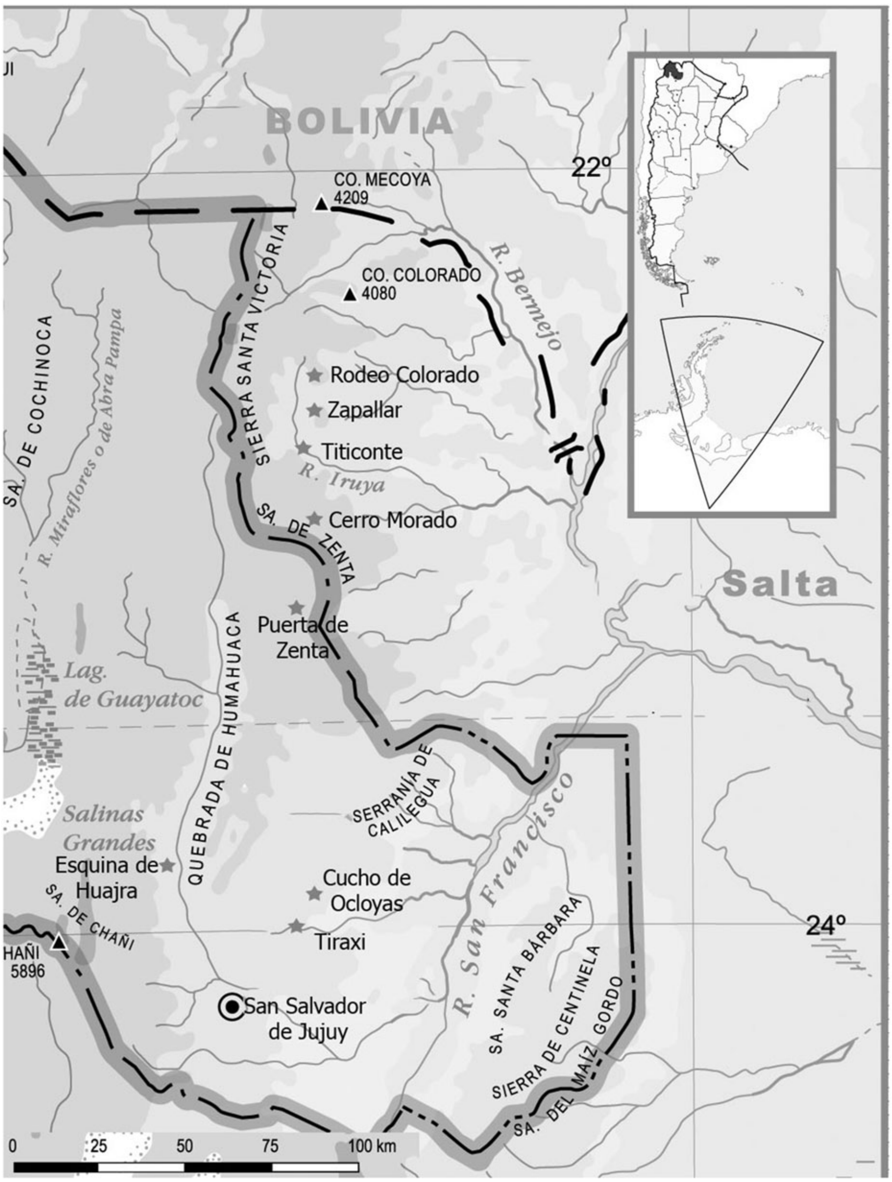

FIGURE 1 Map of the area showing sites mentioned in the text

reveals direct contacts with lower eastern valleys groups (Otero & Cremonte, 2014; Scaro, 2016), probably through contacts with productive and border enclaves located in the eastern Yungas where the Cucho de Ocloyas (small garrison dated to the mid-XVI century) and sites of Tiraxi system are located (Cremonte & Garay de Fumagalli, 2013). Cremonte, Garay de Fumagalli, and Sica (2003) suggested that in this southern area of the Quebrada de Humahuaca, indigenous people from eastern sectors and different ceramic traditions would have acted as a link with Humahuaca groups under Inca control. Human remains recovered in Esquina de Huajra consist of at least 18 individuals corresponding to the Inca period who were inhumed following different funerary practices (see Cremonte & Gheggi, 2012 for further description on the tombs characteristics).

2 | METHODOLOGY

2.1 | Bioarchaeological analysis

Bone and dental remains of 18 individuals from Esquina de Huajra were recorded for pathological conditions related to physiological and metabolic-nutritional stress: height, porotic hyperostosis and cribra orbitalia, periostic reactions, dental infections (caries and abscesses), antemortem tooth loss, and defects in tooth enamel deposition.

Adult sex was determined by recording morphological features of the pelvis and skull (Buikstra & Ubelaker, 1994). Adults' age was estimated from the characteristics of the pubic symphysis and the auricular surface of the ilium (Brooks & Suchey, 1990; Lovejoy, Meindl, Pryzbeck, & Mensforth, 1985; Todd, 1920, 1921). Subadult age was estimated by tooth eruption sequence (Ubelaker, 1989), the degree of development and fusion of secondary ossification centers and measures in long bones (Scheuer & Black, 2000). Seven age categories were defined: infant (0–3 years), child (4–14 years), juvenile (15–18), young adult (19–34 years), middle adult (35–49 years), older adult (+50 years), and indeterminate adult (+19 years) (Buikstra & Ubelaker, 1994; Scheuer & Black, 2000; Table 1).

In order to assess adult growth as a measure of sexual dimorfism and nutritional status (Huss-Ashmore, Goodman, & Armelagos, 1982; Larsen, 1987; Roberts & Manchester, 2003), the maximum lengths of all present and complete long bones were measured using an osteometric board and height was calculated (Genovés, 1967). A Students' *t* test was used for comparing mean height differences between males and females using SPSS v.22. Significance level used was $\alpha \leq 0.05$.

Cribra orbitalia and porotic hyperostosis were described and scored according to standard protocols that include state of healing, location, and severity (Buikstra & Ubelaker, 1994). Although both conditions have traditionally been associated with anemia, several other diseases can produce macrocospically similar lesions, so both conditions were taken as reflecting metabolic disease and not exclusively evidence for anemia (Ortner, 2003; Walker, Bathurst, Richman, Gjerdrum, & Andrushko, 2009).

Periostic reactions develop when the inner layer of the periostium is affected by trauma, infectious diseases, or any other inespecific disease (Ortner, 2003) and provide a general indicator of the health status of a population, especially if the stress was so severe or prolonged as to have exhausted the potential response of an organism's other systems (Huss-Ashmore et al., 1982).

Caries are multifactorial and multibacterial infections affecting calcified tissues of the teeth through the demineralization of the inorganic portion and destruction of the organic component (Langsjoen, 1998). Number and location (occlusal, interproximal, neck, or root caries) were recorded. Abscesses are the result of a localized infection produced by exposure, bacterial contamination of the endodontic cavity, and death of the pulp tissue and are strongly associated with caries (Hillson, 1996). Presence and location of the canal were recorded when a dental abscess was identified.

TABLE 1 Sex and age structure of the sample

		Tomb 1	Tomb 2	Tomb 3	Tomb 4	Tomb 6	
Age	Sex	N	N	N	N	N	Total
Infant	Indeterminate	1			1	1	3
Child	Indeterminate		4		1		5
Juvenile	Female					1	1
	Male						
	Indeterminate						
Young adult	Female						
	Male					1	1
	Indeterminate						
Middle adult	Female			1			1
	Male						
	Indeterminate						
Older adult	Female						
	Male	1					1
	Indeterminate						
Indeterminate	Female	2	2				4
	Male	1	1				2
	Indeterminate						
Total		5	7	1	2	3	18

Antemortem tooth loss produces progressive reabsorption of alveolar bone and is closely related to cariogenic activity. Thus, it positively covariate with carbohydrates rich diet and negatively with a high degree enamel tooth wear (Hillson, 1996; Powell, 1985). Antemortem tooth loss was recorded by macroscopic examination of maxillar and mandibular alveolus following Buikstra and Ubelaker (1994).

Enamel hypoplasias are defects occurring during the first phase of enamel deposition, resulting from an important metabolic stress so as to interrupt ameloblastic activity. As markers of unspecific stress, they are useful in estimating the overall health of past populations (Langsjoen, 1998). Hypocalcifications reflect imperfect enamel mineralization and are thought to represent systemic stress, and they normally appear as bands or oval areas on the labial or buccal surface of teeth (Buikstra & Ubelaker, 1994). Presence of macroscopic enamel defects was recorded following Buikstra and Ubelaker (1994).

Prevalence for caries and defects in tooth enamel deposition was calculated by dividing the number of lesions/number of teeth observed for each category (i.e., sex, age, and full sample). Dental abscesses and premortem tooth loss prevalence was calculated by dividing the number of affected teeth/number of observed alveolus for each category. For pathological conditions, prevalence was calculated for each bone element according to which they were compared (N affected/N observed) in each category.

2.2 | Stable isotopes

Isotopic analysis of bone carbon and nitrogen provides information regarding macronutrient composition of diet during the last 10 to 25 years of an organisms' life, which is the turnover rate (Tykot, 2006). Bone carbon collagen follows a "routing" model because it mainly derives from the proteic portion of diet. However, apatite carbon isotopic composition accurately reflects the contribution of lipids, carbohydrates, and proteins, allowing for a complete examination of diet when used in tandem with collagen results (Ambrose, Butler, Hanson, Hunter-Anderson, & Krueger, 1997; Ambrose & Norr, 1993). Recent models using multivariate statistics have contributed to recognizing mixed diets in which the contributions of macronutrients come from different sources (C_3, C_4, or crassulacean acid metabolism; Froehle, Kellner, & Schoeninger, 2012; Kellner & Schoeninger, 2007).

The $\delta^{15}N$ value in human bone collagen provides information on throphic position, on the consumption of marine resources and weaning. Unlike carbon, all nitrogen present in bone collagen derives from dietary proteins and increases 4–5‰ along the food chain (Ambrose & Norr, 1993; Schoeninger, 1995). When nitrogen isotopic values of local ecology are known, this allows positing an organism in a trophic level according to its $\delta^{15}N$.

So far, 14 individuals from Esquina de Huajra were isotopically characterized (Table 4). Due to financial limitations, analyses were conducted in three different laboratories and, although results were reported according to the same standard (Vienna Pee Dee Belemnite for $\delta^{13}C$ and Air for $\delta\ ^{15}N$), caution should be exercised when combining and comparing data. A first set of five samples was sent to the Center for Applied Isotope Studies (University of Georgia) and a second set to Geochron. The methods and results of those analyses were reported in Gheggi and Williams (2013).

Seven samples were sent to the National Institute of Isotope Geology (INGEIS). An elemental analyser Carlo Erba EA1108 coupled to a Thermo Scientific Delta V Advantage mass spectrometer using a Conflo IV interface was used for the determination of isotopic ratios. Analytical error is 0.2‰ for $\delta\ ^{13}C$ and $\delta\ ^{15}N$. For carbon, conversion of the carbonate into CO_2 gas by reaction with phosphoric acid was conducted for 2 hr at constant temperature in a bath at 60 °C. CO_2 gas was purified in a vacuum line by cryogenic traps, and CO_2 gas finally was analysed at Finnigan Mat Delta S triple collector mass spectrometer. Analytical error is 0.1‰ (±2σ), and $\delta\ ^{13}C$ values are reported relative to V-PDB pattern and Air for δ 15N. Samples with an atomic C:N ratio between 2.9 and 3.6 were accepted for interpretation (Ambrose, 1992). All statistical comparisons were performed using SPSS v.22. The significance level to reject the nule hypoyhesis was $\alpha \leq 0.005$.

3 | RESULTS

3.1 | Dental and osteological analysis

In the total sample, 81 teeth and 134 sockets were analysed (Table 2). Twelve cases of dental infections, 20 antemortem missing pieces, and 10 cases of enamel deposition defects were found. No statistically significant differences were observed in the variation of the frequencies according to sex.

A prevalence of 15% of tooth loss was recorded in the complete sample and only in male individuals. Because tooth loss increases with age, it would be expected to find more incidence of this condition in the older age groups, as observed in this work. Regarding caries, 11 lesions were found both in adults and subadults (14.5%) and only one abscess was found in an older adult, as is expected for a condition related to increasing age. Moreover, antemortem tooth loss may also be related to the low prevalence of abscesses as they are related conditions. Hypocalcification was recorded in a subadult from Tomb 4, and hypoplastic lesions were recorded both in adults and subadults at a 14.15% prevalence.

Only one case of porotic hyperostosis was recorded in an adult, indicating a prevalence of 10% of total observed cases (Table 3). When comparing adult height between the sexes, a statistically significant result was obtained (p = .009, df 4, T Student = 4.134) indicating the existence of sexual dimorphism in the sample.

3.2 | Stable isotopes

Isotopic results for the entire sample (N = 13) are presented in Table 4. Comparing human data with carbon and nitrogen values from modern vegetables and archaeological fauna from the area (Killian Galván, Sanmartino, Castellano, Seldes, & Marbán, 2015; Killian Galván, Seldes, & Nielsen, 2016; Mengoni Goñalons, 2007) indicates an important contribution of a C_4 source to the proteic portion of diet (Figure 2).

TABLE 2 Presence of diseases and conditions of dentition in the full sample

Caries	Affected	Observed	Prevalence	Enamel Deffects	Affected	Observed	Prevalence
Sex				Sex			
Females	4	32	12,5	Females	3	32	9,37
Males	3	15	20	Males	3	15	20
Indeterminate	4	29	3,8	Indeterminate	4	29	13,8
Age				Age			
Infant	0	0	0	Infant	0	0	0
Child	1	19	5,3	Child	4	19	21
Juvenile	0	10	0	Juvenile	0	10	0
Young adult	1	16	6,25	Young adult	3	16	18,75
Middle adult	3	11	27,3	Middle adult	0	11	0
Older adult	0	0	0	Older adult	0	0	0
Indeterminate adult	6	20	30	Indeterminate adult	3	20	15
Total	11	76	14,5	Total	10	76	13,15
Antemortem tooth loss	**Affected**	**Observed**	**Prevalence**	**Abscesses**	**Affected**	**Observed**	**Prevalence**
Sex				Sex			
Females	0	64	0	Females	0	64	0
Males	20	32	62,5	Males	1	32	3,125
Indeterminate	0	38	0	Indeterminate	0	38	0
Age				Age			
Infant	0	0	0	Infant	0	0	0
Child	0	19	0	Child	0	19	0
Juvenile	0	16	0	Juvenile	0	16	0
Young adult	0	32	0	Young adult	0	32	0
Middle adult	0	32	0	Middle adult	0	32	0
Older adult	7	3	77,77	Older adult	1	3	33,33
Indeterminate adult	13	32	68,42	Indeterminate adult	0	32	0
Total	20	134	15	Total	1	134	0,74

TABLE 3 Presence of pathological conditions in the skeleton

Porotic hyperostosis/cribra orbitalia	Affected	Observed	Prevalence	Periostic reactions	Affected	Observed	Prevalence
Sex				Sex			
Females	0	3	0	Females	0	6	0
Males	1	1	100	Males	0	4	0
Indeterminate	0	6	0	Indeterminate	0	8	0
Age				Age			
Infant	0	3	0	Infant	0	3	0
Child	0	3	0	Child	0	5	0
Juvenile	0	1	0	Juvenile	0	1	0
Young adult	0	1	0	Young adult	0	1	0
Middle adult	1	2	50	Middle adult	0	1	0
Older adult	0	0	0	Older adult	0	1	0
Indeterminate adult	0	0	0	Indeterminate adult	0	6	0
Total	1	10	10	Total	0	18	0

Moreover, carbon values of the inorganic and organic portion of bone present a linear correlation (R^2 = 0.79), signaling a similar main photosynthetic pathway for both components of bone. When plotted against regression lines proposed by Kellner and Schoeninger (2007), individuals cluster into three groups (Figure 3).[1]

TABLE 4 Isotopic results for the sample from Esquina de Huajra

Laboratory number	Provenience	Sample	Sex[a]	Age	δ ^{13}C col ‰ vs. VPDB	δ ^{13}Cap ‰ vs. VPDB	δ ^{15}N ‰ vs. AIR	Δ C^{13} ap-col	C/N[c]
UGA 2087[b]	T1 G1 MS	Left humerus	M	Adult	−11	−6.2	12.6	4.8	3.15
UGA 16200[b]	T1 G2 MS	Left humerus	M	Adult	−9.63	−4.8	6.7	4.83	3.10
INGEIS 33284/33476	T1 G3 MS	Left humerus	F	Adult	−11.7	−6.2	9.3	5.5	3.2
UGA 2088[b]	T2 I1	Right femur	Indet	6 ± 2 years	−11.3	−5.2	11.7	6.1	3.13
INGEIS 33286/33472	T2 I2	Right femur	Indet	5 years ± 6 months	−14	−7.7	9.2	6.3	3.2
INGEIS 33285/33473	T2 I3	Left femur	Indet	3 years ± 6 months	−12.2	−5.6	9.4	6.6	3.2
Geochron 32577[b]	T2 I4	Left tibia	Indet.	8 ± 2 months	−11.1	−6.5	9.7	4.6	ND
INGEIS 33287/33474	T2 I5	Right clavicle	F	Adult	−10	−4.4	10.7	5.6	3.1
INGEIS 33288/33475	T2 I6	Right clavicle	F	Adult	−10.1	−4.8	10.5	5.3	3.1
INGEIS 33289/33477	T2 I7	Right clavicle	M	Adult	−13.7	−8.4	9.7	5.3	3.1
Geochron 32576[b]	T3 I1	Left femur	F	40 ± 5 years	−11.3	−6	12.2	5.3	ND
UGA 2089[b]	T4 I1	Right femur	Indet.	7 ± 2 years	−12	−6.6	11.3	5.4	3.17
UGA 2090[b]	*T6 I1*	*Right tibia*	*F*	*17–21 years*	*−11.5*	*−6.7*	*12.1*	*4.8*	***9.27***
INGEIS 33290/33471	T6 I2	Right femur	M?	25 ± 5 years	−10.4	−4.3	8.5	6.1	3.2
Mean					−11.42	−5.95	10.25	5.46	
SD					1.23	1.16	1.58	0.59	
Max					−9.63	−4.3	12.6	6.6	
Min					−14	−8.4	6.7	4.6	

[a]M = male; F = female; Indet. = indeterminate.

[b]References: Gheggi and Williams (2013).

[c]Atomic C/N ratio. Italics indicate discarded data due to possible post-mortem alteration. Values in bold are outside accepted range for samples unaffected by post-mortem alteration.

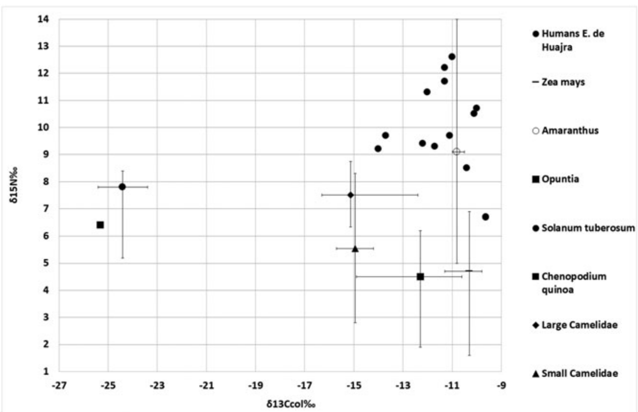

FIGURE 2 Estimation of human diet from Esquina de Huajra according to carbon and nitrogen values from modern and archaeological resources from the area. *Zea mays*, *Amaranthus c*., *Solanum tuberosum*, *Opuntia*, and *Chenopodium quinoa* modern samples were corrected for Suess effect (Killian et al. 2015). Camelidae values from Esquina de Huajra after Mengoni Goñalons (2007, 2009). Error bars represent maximum and minimun values of each species

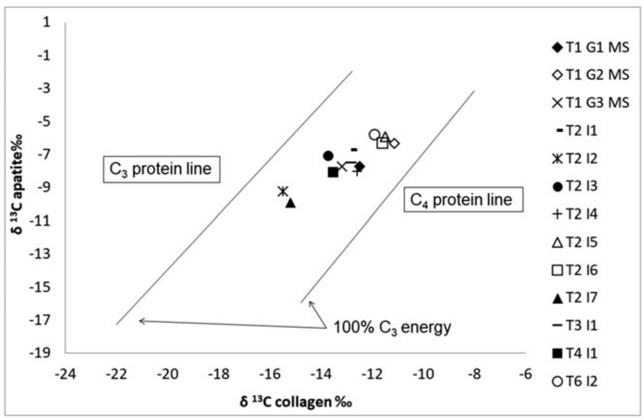

FIGURE 3 Complete data plotted against the model of Kellner and Schoeninger (2007)

When isotopic data were plotted against Froehle et al. (2012) dietary clusters most individuals fall within Cluster 2, composed of a mixed diet of both C_3 and C_4 resources, but with a higher consumption from C_4 proteins (+50%; Figure 4). Two individuals (T2I2 and T2I3) are partially located in Cluster 5, indicating a mixed diet also but possibly with higher protein intake from a C_3 source. Finally, an individual (T1G2) lies outside Cluster 2, possibly because its diet was made-up from a significant percentage of C_4 resources (δ value ^{13}Ccol −9.63‰, δ ^{13}Cap value −4.8‰) and also because its nitrogen value is the lowest in the sample (δ ^{15}N 6.7‰).

However, in spite of the possibly different diets that are represented in the clusters, no statistically significant differences existed when comparing the four isotopic measurements for sex (male vs. female) or age (adult vs. subadult). Another possible interpretation is that diet clusters are representative of individuals from different origins, but we have no elements to prove this hypothesys yet (i.e., oxygen or strontium isotopic values).

[1]Values were normalized to today's δ ^{13}C value of atmospheric CO_2 by subtracting 1.5‰ as recommended by Kellner and Schoeninger (2007).

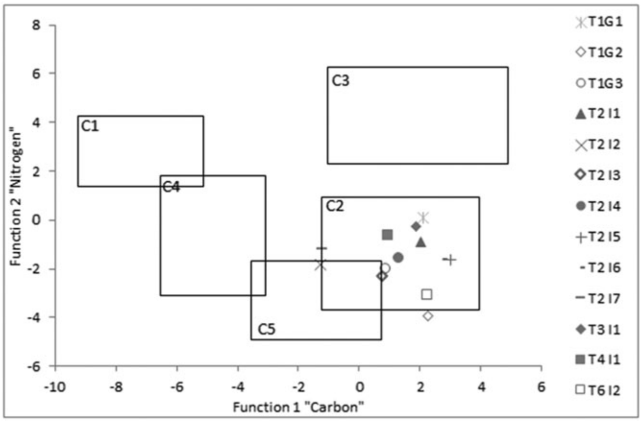

FIGURE 4 Discriminant analysis of isotopic data from Esquina de Huajra plotted against dietary clusters generated by Froehle et al. (2012)

4 | DISCUSSION

Considering previous research regarding how the Incas managed the lands they conquered, we expected that the biological impact of Inca imperialism would vary by region and by cultural group. For example, the Empire favoured the cultivation and consumption of maize by local populations in the Jauja Valley of Perú (Hastorf, 1990; Hastorf & Johanessen, 1993) but results reported by Falabella et al. (2007) in central Chile showed depleted carbon isotopic signatures when compared with previous periods, signaling the consumption of more C_3 resources. This may imply that although the Incas favoured the cultivation of maize, this resource may not have consumed by the populations that grew it.

Diets may also have changed, as in the case of Yanamarca in Perú, where elite and nonelite diets became more similar (Costin & Earle, 1989). In Northern Chile, Santoro et al. (2003) found a high prevalence of parasitism in Lluta samples, associated with the consumption of larger quantities of fish and the habitation in denser settlements during the Inca occupation in the area. For this same valley, coprolites analysis conducted by Dorsey Vinton et al. (2009) indicate lower consumption of chicha and increased consumption of tubers. Results from the study of Williams and Murphy (2013) show that in the Puruchuco-Huaquerones area of Peru, although individuals showed osteological signals of stress, they were healthy enough to recover partly due to a sufficiently nutritious and varied diet as isotope data indicates.

In a comprehensive study of osteological samples from populations of Cusco and its periphery from pre-Inca and Inca times, Andrushko (2007) recorded important signals osteoperiostitis and articular disease over time. Gheggi and Seldes (2014) found that the increase in degenerative diseases in the joints over time, including samples of the Inca period, was the only condition that was statistically significant in a human bone sample in Quebrada de Humahuaca. This might suggest a heavier work load associated with Inca imperialism.

In order to frame our results into wider comparative data and to evaluate the potential impact of Inca imperialism in the Humahuaca region, we compared our results against published regional data both for osteological conditions (Table 5) and stable isotopes (Table 6). As there are no samples that could clearly be assigned to Inca times, our data were compared with samples from former periods (Formative and Regional Development) and a sample from a later period (Hispanic-Indigenous).

TABLE 5 Regional comparison for osteological conditions

Sample	Chronology	HP	CO	Periostic reactions	Caries	AMTL	Abscesses	Enamel deffects	References
Mulqui	F	4/10 40%	3/11 27.27%	1/11 9.09%	25/242 10.33%	15/261 5.74%	6/257 2.33%	8/13 61.53%	Arrieta (2012)
Flores 1	F	1/3 33.33%		0/5	0/4	1/71 1.40%	No data	0/3	Seldes (2006)
Barrio Corrales (Til 1)	RDP	1/18[a] 5.55%	1/18[a] 5.55%	1/11 9.09%	11/114 9.65%	10/167 6.36%	3/152 1.97%	10/12 83.33%	Arrieta (2012)
Yacoraite	RDP	6/22[a] 27.27%	5/21[a] 23.8%	3/48 6.25%	29/150 19.33%	94/438 21.46%	18/367 4.9%	6/7 85.7%	Arrieta (2012)
Muyuna	RDP	0/11		0/10	8/8[b] 100%	23/114 20.17%	No data	0/11	Seldes (2006)
Hornillos	RDP	2/4 50%		0/9	3/5[b] 60%	24/106 22.64%	No data	0/4	Seldes (2006)
Los Amarillos (complejo E)	RDP	1/10 10%		2/10 50%	5/13[b] 38.46%	48/218 22%	No data	3/12 25%	Seldes (2006)
Los Amarillos (400)	RDP	8/16 50%		6/10 60%	6/10[b] 60%	77/343 22.44%	No data	4/13 30.77%	Seldes (2006)
Esquina de Huajra	I	1/10[a] 10%	0/10[a]	0/18	11/76 14.5%	20/134 15%	1/134 0.74%	3/9 33.33%	This study
La Falda	HI	12/21 57.14%	11/19 57.89%	4/34 11.76%	63/411 15.32%	50/509 9.82%	18/487 3.69%	9/13 69.23%	Arrieta (2012)

Note. F = formative (ca. 500 BC–900 AD); RDP = Regional Development Period (ca. 900–1450 AD); I = Inca (ca. 1450–1532 AD); HI = Hispanic-Indigenous (ca. 1532–1600 AD).

[a]Affected and observed cases were added in order to be compared with other cases.

[b]They were not considered for statistical comparisons as prevalence was originally calculated by individuals and not by dental pieces as in the other studies reported.

TABLE 6 Isotopic values from regional samples

Sample	Chronology	Stable isotopes (mean value)				References
		δ ^{13}C col ‰ vs. VPDB	δ ^{13}Cap ‰ vs. VPDB	δ ^{15}N ‰ vs. AIR	Δ C^{13} ap-col	
Til 20[a]	F	−9.2	−3.2	12.2	6.1	Lynch Ianniello, Mendonça, Arrieta, Bernardi, & Bordach, 2017
Los Amarillos (complejo E)	RDP	−10.4	−5.2	10.4	5.2	Killian Galvan et al. (2016)
Los Amarillos (400)	RDP	−10.0	−4.5	10.2	5.5	Killian Galvan et al. (2016)
Til 1[a]	RDP	−11.7	−5.4	10	6.7	Lynch Ianniello et al., 2017
Yacoraite[a]	RDP	−11.1	−5.8	11	5.3	Lynch Ianniello et al., 2017
Total RDP		−10.8	−5.22	10.4	5.67	
Esquina de Huajra	I	−11.42	−5.95	10.25	5.46	This study
Til 43[a]	HI	−10.3	−6.4	10.4	4.2	Lynch Ianniello et al., 2017

Note. F = formative (ca. 500 BC–900 AD); RDP = Regional Development Period (ca. 900–1450 AD); I = Inca (ca. 1450–1532 AD); HI = Hispanic-Indigenous (ca. 1532–1600 AD).

[a]Mean values include teeth and bone samples.

Our data showed statistically significant results when comparing CO and PH with the Formative period (p = .0075, Fisher's exact test) and the Hispanic-Indigenous Period (p = .011, Fisher's exact test), indicating that both conditions appeared less frequently during Inca times. Also, a significant result was obtained comparing antemortem tooth loss between Formative versus Inca period (p = .0004, Fisher's exact test) and dental abscesses for Inca versus Hispanic-Indigenous (p = <.0001, Fisher's exact test). It is interesting that no differences were found, at least for the health conditions compared here, between the RD and Inca periods suggesting that although profound changes were experienced regarding social, economic, and demographic aspects, they did not impact negatively in peoples health. However, there appears to be a significant difference between the Formative period and those after it, both in isotopic values and health conditions, probably indicating a major shift in Formtative communities' lifestyle that affected their health.

Regarding isotopic results, a Kruskal-Wallis H test showed that there was a statistically significant difference in the distribution of δ ^{13}C col, δ ^{13}Cap, and δ ^{15}N between time periods (X2 (3): 11.741, p = .008; X2 (3): 10.956, p = .012; X2 (3): 9.822, p = .020, respectively). Pairwise post hoc tests showed statistically significant differences in mean values for δ ^{13}Ccol (p = .005) and δ ^{13}Cap (p = .006) between Formative and Inca samples. Regarding δ ^{15}N results, there were significant differences between Inca and Formative (p = .018) and PRD and Formative (p = .024). Thus, the Formative sample is enriched in carbon and nitrogen in comparison to the Inca sample due to a larger consumption of food from a C_4 source that could come from lower altitude cereals as well as camelids feeding in lower altitudes (Killian Galván et al., 2014).

The isotope data from Esquina de Huajra presented here are consistent with a diet that incorporated a variety of both plant and animal food with mainly C_4 protein, which for the area could include maize and amaranth and possible meat from camelids feed on maize stubble (Mengoni Goñalons, 2007). However, C_3 resources were also comsumed that could include tubers and quinoa and contributed to a wider and nutritious diet. Apparently, this diet was sufficient to meet the nutritional demands of the body as low prevalence of nutritional and dental pathology was found in the Huajra sample when compared with other regional samples.

5 | CONCLUSIONS

The overall objective was to evaluate the quality and composition of the diet and health through the joint study of isotopic and osteological data of the population from Esquina de Huajra during the Inca occupation of the territory of Humahuaca. Stable isotopes data indicate a diet that incorporated a variety of foods, both C_3 and C_4 plant resources and meat proteins. This would increase the possibility of a nutritionally adequate diet (Foote, Murphy, Wilkens, Basiotis, & Carlson, 2004). No statistically significant difference was found when comparing frequencies according to sex or age, although three dietary clusters were recognized.

Osteological conditions that may be related to general health status, such as porotic defects of the skull and infectious diseases, were recorded in low prevalence in the whole sample, suggesting that the individuals analysed did not suffer significant events of nutritional and infectious stress or chronic diarrhea that may have damaged their health. Although dental hypoplasia lines found in adults refer to the presence of episodes of inespecific stress, the fact that they survived indicates that they were healthy enough to overcome it. Sexual dimorphism, as reflected in adult stature, was present in this population, and its difference between the sexes was statistically significant. This evidence together supports the interpretation that the inhabitants of Esquina de Huajra were not a heavily stressed population, which had no major nutritional pressures and whose health was not compromised under imperial control.

Despite some individuals (older subadults, adolescents, and adults) survived systemic episodes of stress, demonstrating its presence in bones and teeth, a more vulnerable group existed, the nonsurvivors, who died during the first years of life and integrated the high proportion of subadult skeletons found. This is supported by the presence in the mortality profile of a group of subadults under 5 years of age without bone sequelae but showing dental hypoplasia and hypocalcification lines indicating recurrent stressful events that surely affected their survival. This information suggests that to further understand the relationship between health, diet, and survivorship, we should consider the palaeodemographic processes that could account for the formation of the bioarchaeological record of populations who lived under imperial administration while considering the presence of a paradoxical interpretation of health indicators.

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