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Bioarchaeological analysis of the human skeletal remains from cliff tomb burial of the Wangyuancun site in Leshan, Chengdu Plain, Southwest China

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Though archaeological and historical-document evidences for the cliff necropolises in ancient China were reported in literature, the bioarchaeological analysis for them is still absent. It is therefore the aim of this paper presents the first bioarchaeological analysis for the skeletal samples of cliff necropolises from the Iron Age in China. In this work, skeletal remains of 16 individuals (two males, three females, seven unsexed adults, one subadult, and three indeterminate sex and age individuals) of Wangyuancun site (on the border of the Chengdu Plain, China) were examined for the stature, dental pathologies, linear enamel hypoplasia, cribra orbitalia, degenerative osteoarthritis of the vertebrae and major joints, periostitis, trauma and other evidence of disease. The demographic structure of Wangyuancun site is characterized by a younger mean age at death and a low mortality rate for infants and children. The stature estimates show that these Iron Age people were similar in size compared with the people live in contemporary southwestern region of China. Most of the samples lacked indications of stress, but a few had cribra orbitalia, osteoarthritis, osteophytosis and various dental pathologies. Periosteal reactions were common, but the lesions are generally moderate or mild. These bioarchaeological results broaden our understanding of the health and lifestyle of the cliff tomb population of Chengdu Plain in the Iron Age. Our bioarchaeological examination of the skeletal samples of Wangyuancun site provides a rare opportunity to address questions concerning ancient people's diet, health, disease and stress of population in the Iron Age of Chengdu Plain, Southwest China.

KEYWORDS

bioarchaeology, palaeopathology, dental pathology, health, lifestyle, cliff tomb burial, Chengdu plain

1 Introduction

Bioarchaeological investigations provide important means to inform on the life experiences of past people and understand past population demographics, health and certain aspects of culture. (Katzenberg, 2008; Larsen, 2015). Bioarchaeology is currently experiencing growth in many regions of China, but there is still a big gap in the south, especially the southwest of China, where human bones are poorly preserved due to hot and humid climate and acidic soil conditions.

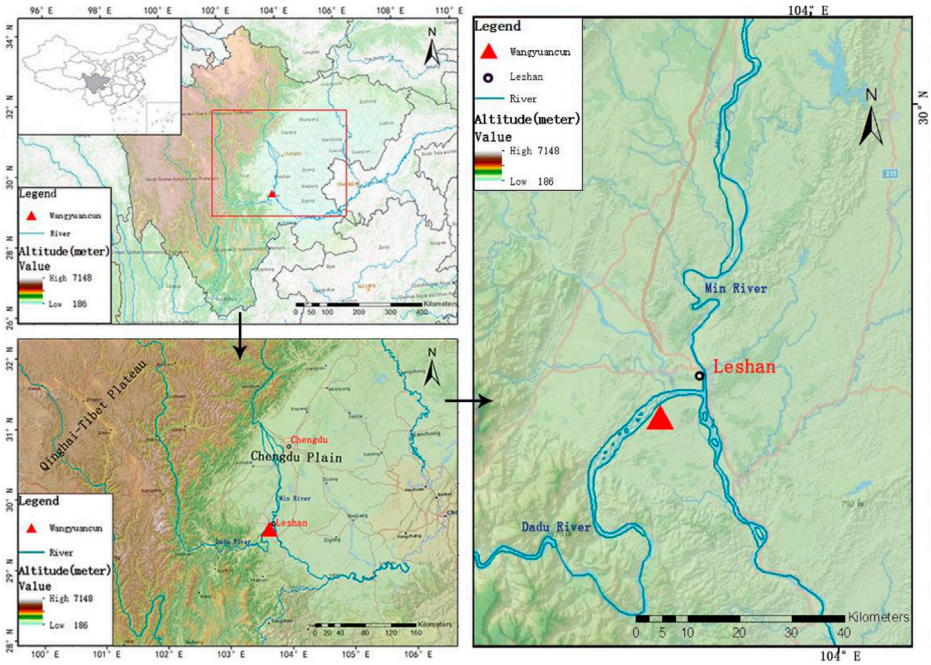

FIGURE 1
Map showing the location of Wangyuancun.

The Chengdu Plain is an alluvial plain located between the western Sichuan Basin and the southeastern edge of the Qinghai-Tibet Plateau, with an altitude of 400–750 m and an area of about 8,500 km^2 (Liang, et al., 2014), which is the largest plain in southwest China. This region has been the cultural and political center of the Sichuan Basin from prehistory to the present. In the pre-Qin period, Baodun culture in the late Neolithic age, Sanxingdui culture and Shierqiao culture in the Bronze age, etc. were born in this relatively independent geographical unit, which historians and archaeologists call ancient Shu civilization (Duan, 2011; Dianzeng, 2005; Xiang, 2018). In 316 B.C., Qin annexed Ba Shu (Qu et al., 1987), and since then the Chengdu Plain has been under the effective control of the central government. During the Han Dynasty, with the influx of immigrants, many cultural factors merged here and the burial system of the Chengdu Plain took on a complex and diverse appearance. It includes both traditional vertical shaft pits, which have been popular since the Warring States, and two new forms of burial, namely, brick chamber tombs distributed on flat dams and cliff tombs cut into the cliffs and slopes on both sides of rivers (Elias, 2019; Dehao, 2022). Thus far, only Zhang Jun, Yuan Haibing and other scholars have done research and reports related to physical anthropology on a few sites in this area (Zhang and Zhangyi, 2006; Yuan, 2016; Yuan et al., 2017). There have been few isotope studies that focus on archaeologically derived materials from the Chengdu Plain. Yi Bing and others (Yi, B., et al., 2018) conducted carbon and nitrogen isotopic analysis of human bone collagen (ribs and femora) as well as dentin serial sections from Gaoshan Ancient City site. Up to now, the general situation of the physical characteristics and health status of the ancient people in the Chengdu Plain is still unclear.

The cliff tomb is a kind of tomb with local characteristics that was widely popular in southwest China from the Han Dynasty to the Sixth Dynasty in about five hundred years, featuring multiple chambers buried deeply into the cliffs, along the Yangtze River and its larger tributaries, such as the Fu, Tuo and Min Rivers (Erhu, 1988). This type of tombs is distributed in a large number in Sichuan Province, especially in the Chengdu Plain. Only some sporadic historical documents have records about the cliff tomb, it is generally believed that this is the so-called “immortal cave” where ancient immortals practiced alchemy (Liu, 815 AD; Du, 933 AD). Ming et al., local chronicles believe that the caves were the residence of local barbarians, and it is called the Barbarian Cave (Cao, 1614 AD; Chang and Yang, 1816 AD; Gong).

The first Western explorer to draw attention to the caves was Alexander Wylie. He traveled through Sichuan in 1868, and subsequently reported on the caves to the Royal Geographical Society in London (Alexander, 1869). Subsequent Western explorers followed Wylie. Thus it was that by the turn of the 20th century, the cliff-side caves in Sichuan were almost unanimously understood to have been the residences of barbarians. Japanese anthropologist Torii Ryuzō was the first professional archaeologist who visit Sichuan in 1902. After investigation, Torii believed that these caves were not the residences of barbarians, but ancient Han tombs (Ryuzo, 1926), which aroused the attention of academic circles. Subsequently, many Chinese and foreign scholars conducted investigations and researches on the caves one after another. It is well-known since they were reported by many researchers in China and abroad in the first half of the early 20th century (Torrance, 1910; Ségalen, 1915; Bishop, 1916; Ségalen et al., 1923; Bedford, 1937; Shang, 1940; Moruo, 1941; Zhigao, 1942; Dekun, 1946).

FIGURE 2
(A), Site view; **(B)** Interior of the cliff tomb (M38); **(C)** Sarcophagi in the coffin chamber (M52).

The archaeological excavation of the cliff tombs can be traced back to 1941, when the Academia Sinica's Institute of History and Philology and the Construction Society excavated dozens of cliff tombs in Pengshan (Nanjing Museum, 1991). After the founding of New China, as a large number of cliff tombs were investigated and excavated, the scholars' understanding of cliff tombs gradually became clear. Researchers generally agreed that cliff tomb is distinct to the southwestern region of China, and that this type of burial practice became a custom form of burial in the region by the period of Eastern Han dynasty (Liu, et al., 2014; Cheng, 1957; Liu, 1958; Kyong-McClain, J. 2010). Each tomb is usually used as a whole functioned as a shared burial space for the family or lineage and may have been employed over several generations, and some of which were reused during Tang-Song Period and even later (Xiaoliang Ma, 2012; Fei et al., 2016; Jiang, et al., 2022). These cliff tombs provided invaluable materials for the reconstruction of the tomb system, ideology, social economy, art, architecture and history in the region during this period (Erhu, 1988).

Numerous tombs of this type across the Leshan area on the southwestern edge of the Chengdu Plain (in the lower valley of the Min River), which is the most densely distributed, largest and most representative area in Sichuan have been published in architectural and archaeological surveys (Fuhua and Dan, 1956; Xiang, 2003; National Cultural Heritage Administration, 2009; Sichuan Province Institute of Cultural Relics and Archaeology, Sichuan Grotto Temple Conservation Research Institute, and Leshan Giant Buddha Grottoes Research Institute, 2022). However, there have been no study of bioarchaeology based on skeletal analysis, and we even know nothing about the people buried here themselves. Because graves were often (re-)used over long periods, coupled with the hot and humid climate and acidic soil in the Sichuan Basin, most of the human bones in the cliff tombs are difficult to preserve completely. The skeletal samples were very scarce, there was little opportunity to directly investigate the physical characteristics, health, and lifestyle of the people in cliff tombs. In order to get a clear picture of life quality and amount of physical stress of people in cliff tombs, in this work a comprehensive bioarchaeological study was conducted on the skeletal remains that were excavated from the Wangyuancun site near Leshan in the confluence of the Minjiang River and the Dadu River (Figure 1).

In the rest of this article, Section 2 will describe materials and methods used in this study. In Section 3, bioarchaeological results for Wangyuancun site will be shown in detail. And based on these results, a comparative study of demography, stature, oral health and dietary patterns, as well as physiological stress and health of ancient population in Wangyuancun site will be discussed in Section 4. Finally, concluding remarks will be made in Section 5.

2 Materials and methods

2.1 The site and skeletal samples

The cliff tomb group of Wangyuancun site (abbreviation as WYC) is located in the north of a village with the same name, Angu

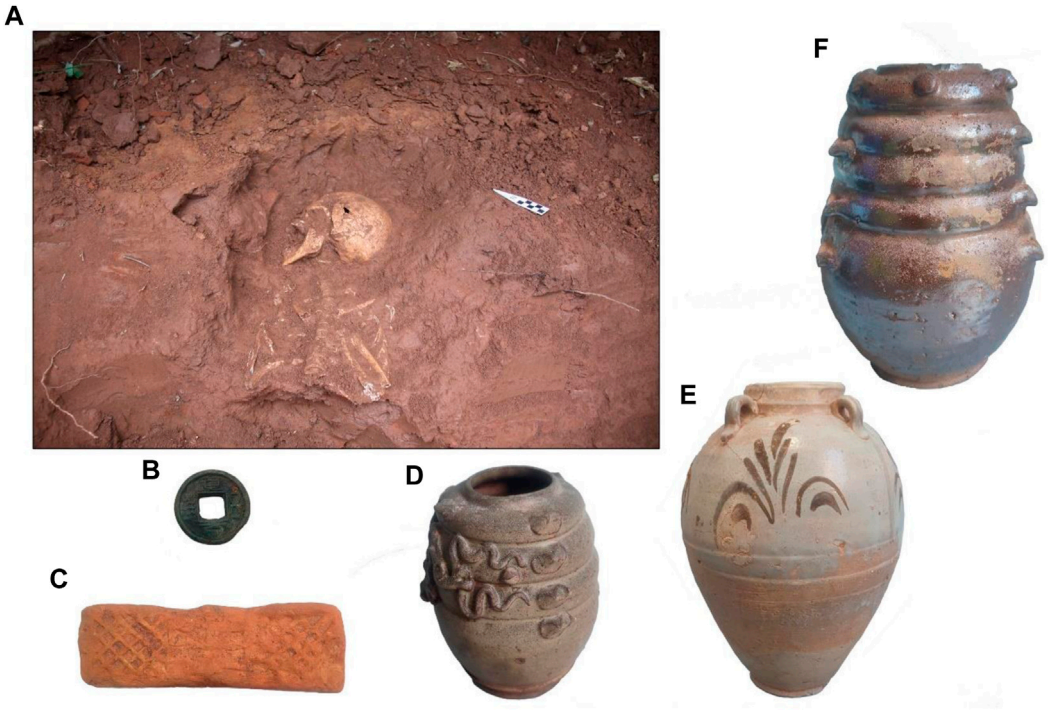

FIGURE 3
(A) Burial of 47 showing the human bone preservation; **(B)**–**(F)** Some artifacts from Cliff Tombs.

Town, Leshan City, Sichuan province (Figure 1). It is situated in a typical hilly terrain, at an average altitude of 351 m. Since the 1950s, multiple institutions carried out a number of fieldworks on it. This cemetery contains 136 independent tombs carved into the side of a hill covering a range of approximately 580 m (National Cultural Heritage Administration, 2009). As at other sites in Sichuan province, these tombs are organized as groups laid out in horizontal layers along the upper reaches of the hills. The first excavation of this site was undertaken under the direction of one of the authors (Guolin JIN) in 2021, to cooperate with the construction of the Leshan-Xichang Expressway project. A total of 29 cliff tombs were cleared in this excavation, most of which were multi-chamber tombs of medium scale. The structure of the tomb is generally composed of tomb passages, tomb doors, corridors, front halls, main chamber or sacrificial chamber, coffin chambers, niches, etc. Three types of coffins, including stone sarcophagus, clay coffin, and wooden coffin, were found in different combinations in different tombs. Because most of the tombs were disturbed, the clay and wooden coffins were incomplete and human bones were scattered throughout the chambers (Figures 2, 3).

No radiocarbon dates have been carried out at this site, however, the burial objects showed that the tombs were erected around the East Han dynasty and then used for burial roughly more than one thousand years. Artifacts found with the WYC burials included coins from the Han Dynasty and Shu-Han Dynasty, potteries from the Han Dynasty, and porcelains from the Tang and Song Dynasties. Most tombs were empty, with no traces of skeletal materials, four graves (M54, M68, M71, and M73) contained at least one skeleton, and three graves (M38, M47, and M52) contained remains of more than three individuals. The skeletons were studied in the bioarchaeological laboratory at the Sichuan Province Institute of Cultural Relics and Archaeology in 2022.

The samples used consisted of at least 16 individuals (Table 1). During the excavation and retrieval of the commingled remains, we created secondary context by labeling skeletal elements according to the position in which they were discovered, thus allows as many skeletal elements as possible to be assigned to possible individuals. The skeletons in the burial were mostly disturbed, most of the human bones in the cliff tombs are difficult to preserve completely. Overall, the preservation condition of skeletons was not very good, some of them were fragmentary or incomplete. All human remains were cleaned with soft brushes and in some cases also with wooden or metal sticks to minimize post-excavation damages. Preservation and reconstruction were performed whenever necessary.

2.2 Methods

To gain an understanding of the health and living conditions of the WYC population, data on age, sex, osteometrics, and pathological conditions were collected on each burial. (Buikstra and Ubelaker, 1994).

Because the skeletons in the burial were mostly disturbed, the techniques used to sort the commingled remains were also used to assign these remains to the primary context skeletons. These techniques included a combination of the physical anthropological analysis and visual pair matching on the basis of bone morphology and taphonomy. The analysis of the remains

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TABLE 1 Skeletal samples used in this study.

Grave	MNI	MNI based on	Specimen no	Description	Sex	Age	Stature	Pathological condition
M38	4	femur	M38:R1	relatively complete skull; few broken vertebrae and ribs; incomplete limb bones	M	30–35	Yes	carious lesion, periodontal disease, calculus, periapical abscesses, AMTL, cribra orbitalia, maxillary sinusitis
			M38:R2	Clavicles, scapulas; incomplete limb bones; bilateral -calcaneus; bilateral -talus	Ind	Adult	—	PR (bilateral-tibiae)
			M38:R3	a few fragments of limb bones	Ind	Adult	—	—
			M38:R4	Only one teeth and a few tiny bone fragments	Ind	Adult	—	—
M47	5	femur	M47:R1	relatively complete skull; incomplete postcranial bones	F	30±	Yes	calculus, periodontal disease, mild OA (R scapulae, bilateral-auricular surface)
			M47:R2	Incomplete skull and postcranial bones	M?	30–40	—	calculus, periodontal disease, AMTL, PR (bilateral-femur, L ulna), OA (R mandibular condyle)、fracture (R radius)
			M47:R3	Incomplete bilateral hip bones and bilateral femurs	F?	Adult	—	PR (bilateral-femur), OA (bilateral hips, R knee)
			M47:R4	A few tiny bone fragments	Ind	Ind	—	—
			M47:R5	A few tiny bone fragments	Ind	Ind	—	—
M52	3	Teeth and wear	M52:R1	13 teeth only	Ind	20–25	—	—
			M52:R2	4 teeth only	-	7–10	—	—
			M52:R3	Only one tooth	Ind	25–30	—	—
M54	1		M54	Right tibial stump and few fragments	Ind	Ind	—	—
M68	1		M68	Incomplete skull; pelvis and clavicle; fragment of limb bones	F?	28–36	—	carious lesion, calculus, periodontal disease, AMTL, PR (bilateral-femur, bilateral-tibia)
M71	1		M71	Fragment of hips and limb bones	Ind	Adult	—	PR (bilateral-tibia, L fibula), OA (L hip)
M73	1		M73	Small fragment of femur	Ind	Adult	—	—

F, female; M, male; Ind, indeterminate sex or age; PR, periosteal reaction; OA, osteoarthritis; AMTL, antemortem tooth loss.

TABLE 2 Stature estimation for adults from WYC.

Individual (sex)	Side/bone	Measurement (mm)	Formula	Stature (cm)	Stature method
M38:R1(M)	Right humerus	309	751.77 + 2.88 (309) ± 44.24	164.2	Xiangqing (1984)
M47:R1(F)	Left radius	196	65.720+4.721 (196)	149.1	Zhang, (2001)

entailed a full standard physical anthropological analysis, and the "*Standards for Data Collection from Human Skeletal Remains*" by Buikstra and Ubelaker (1994) was used as a basis to document this information.

The age-at-death of adults was estimated using the symphysis pubis, auricular surface of the ilium, sternal end of the rib, cranial suture closure, and (when necessary) tooth wear (Brothwell, 1981; Buikstra and Ubelaker, 1994). For immature individuals, approximate age was estimated based on dental decelopment and epiphyseal closure (Scheuer and Black, 2004). The sex estimation of the individuals was carried out by macroscopic assessments of the pelvis and skull (Buikstra and Ubelaker, 1994; Ubelaker, 1999). As the estimation of sex is known to be somewhat unreliable in the immature skeleton, no attempt was made to estimate sex for the subadult individuals.

Preservation of the long bones dictated which bone was used to estimate stature. Measurement maximum length of complete long bones after Martin (1914) was taken, and the stature was calculated following the formulas proposed for "Chinese" by Shao Xiangqing and Zhang jizong (xiangqing SHAO, 1984; ZHANG, 2001).

Each bone or tooth from the WYC sample was examined for the presence of pathological conditions, using macroscopic and non-destructive techniques. Special attention was paid to the identification of dental diseases, periostitis, degenerative joint

TABLE 3 Demography and dental sample summary for the WYC skeletal assemblage.

	Females	Males	Indeterminate sex	Total
N	2	2	0	4
Alveoli	46	42	0	88
Alveoli/N	23	21	—	22
N	2	2	4	8
Teeth	31	28	15	74
Teeth/N	15.5	14	3.75	9.125
Teeth/Alveoli	0.652	0.333	—	0.830

N, total number of individuals assessed.

diseases, cribra orbitalia, porotic hyperostosis, and traumatic injuries. Diagnoses were made according to the criteria outlined by Ortner (2003), Mann and Hunt (2013).

For the assessments of the oral conditions, the teeth were observed macroscopically with both fluorescent and incandescent lighting and a magnifying light when necessary. All pathologies were analyzed and presented by teeth and alveoli. The following variables were focused on: caries, calculus, antemortem tooth loss (AMTL), periodontal disease, abscesses and Dental enamel hypoplasia (DEH).

Periostitis, a non-specific indicator of infectious diseases, though it becomes increasingly rare in the present day, is one of the most commonly encountered abnormalities in archaeological samples, prior to the discovery of antibiotics and their use as a medical treatment modality (Ortner, 2003). The presence of periostitis has been reported worldwide as an important health marker of archaeological skeletons. Periostitis typically manifests as "fine pitting, longitudinal striations, and eventual formation of plaque-like new bone" (Roberts and Manchester, 2007; Larsen, 2015). We report frequencies of infection for the following postcranial bones: humerus, ulna, radius, femur, tibia, and fibula.

Degenerative joint disease (DJD), or osteoarthritis, is characterized by the progressive formation of bone spurs or lipping of the articular joint surfaces (Buikstra and Ubelaker, 1994; Ortner, 2003). These changes are associated with the normal aging process. Identified osteoarthritis through the presence of exophytic growth on the joint margins and erosion on joint surfaces (Larsen, 2015; Waldron 2009). A positive diagnosis of osteoarthritis was given based on the presence of porosities, lipping, and eburnation. Analysis of degenerative joint disease within the WYC population focused on the six major appendicular joints (shoulder, elbow, hip, knee, wrist and ankle) implementing recommendations from the "*Standards for Data Collection from Human Skeletal Remains*" (Buikstra and Ubelaker, 1994) for arthritis pathology. DJD of the temporomandibular articular surface (TMAS) and sacroiliac joint was also recorded in this study.

Because sample sizes were generally small, Fisher's Exact Test (FET) was used to test for statistical significance of categorical (discontinuous) data (Thomas 1986). All FET statistics were calculated with a significance level of $\delta = 0.05$ (two-tailed).

3 Results

3.1 Demography

The minimum number of individuals was determined by the visual pair matching of skeletal elements on the basis of similarities observed in bone morphology, age and sex, trauma and pathology and taphonomic alterations. Based on counts of skeletal elements, there is a minimum of 16 individuals. The age and sex distributions of the WYC burials are provided in Table 1. Three individuals are too fragmentary for precise age and sex estimation. Of the individuals over 18 years of age for whom sex could be determined, two are males or probable males, three are females or probable female, and seven lacked skeletal markers useful for sex estimation.

3.2 Estimated stature

Due to poor preservation of the skeleton, only two adult individuals of definable sex have well-preserved limb bones. The

TABLE 4 Dental pathology in the WYC collection.

	Tooth count					Individual count			
	A/O (%)					A/O (%)			
	Male	Female	Sex diff. *p*-value	Indeterminate Sex	Total	Male	Female	Indeterminate Sex	Total
Dental caries	2/28 (7.14)	2/31 (6.45)	1.000	0/15 (0.00)	4/74 (5.41)	1/2 (50.00)	1/2 (50.00)	0/4	2/8 (25.00)
Periodontal disease	3/28 (10.71)	7/31 (22.58)	0.306	0/0 (-)	10/59 (16.95)	2/2 (100.00)	2/2 (100.00)	0/0	4/4 (100.00)
Calculus	27/28 (96.43)	31/31 (100)	0.475	0/15 (0.00)	58/74 (78.38)	2/2 (100.00)	2/2 (100.00)	0/4	4/8 (50.00)
AMTL	5/42 (11.91)	2/46 (4.35)	0.251	0/0 (-)	7/88 (7.95)	2/2 (100.00)	1/2 (100.00)	0/0	3/4 (75.00)
Alveolar abscess	1/42 (2.38)	0/46 (0.00)	0.477	0/0 (-)	1/88 (1.14)	1/2 (50.00)	0/2 (0.00)	0/0	1/4 (25.00)
DEH	0/28 (0.00)	0/31 (0.00)		0/15 (0.00)	0/74 (0.00)	0/2 (0.00)	0/2 (0.00)	0/4	0/8 (0.00)

A/O, affected/observed; AMTL, antemortem tooth loss; DEH, dental enamel hypoplasia.
p is the probability of Fisher's exact test difference from sex.

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TABLE 5 Counts and prevalence rates by element of periosteal reaction in the WYC collection.

	Male		Female		Indeterminate sex		Total	
	A/O	Freq	A/O	Freq	A/O	Freq	A/O	Freq
Femur	2/4	50%	4/5	80%	0/7	0%	6/16	37.5%
Tibia	0/0	—	2/2	100%	4/8	50%	6/10	60%
Fibula	0/0	—	0/1	0	1/3	33.33%	1/4	25%
Humerus	0/4	0	0/4	0	0/2	0	0/10	0
Ulna	1/4	25%	0/4	0	0/0	0	1/8	12.5%
Radius	0/3	0	0/3	0	0/	0	0/6	0
Total	3/15	20%	6/19	31.58%	5/20	25%	14/54	25.93%

A, number of affected long bones; O, number of observed long bones; Freq, frequency (%).

stature of the WYC people was estimated from the maximum length of the long bones, as summarized in Table 2. Stature of male (M38: R1) is assessed as approximately 164.2 cm from the maximum length of the right humerus, using Shao Xiangqing's stature formulae (Xiangqing, 1984), and the stature of female (M47:R1) is 149.1 cm from the maximum length of the left radius, using Zhang Jizong's stature formulae (Zhang, 2001). Male stature was about 15 cm higher than female stature.

3.3 Paleopathology

3.3.1 Dental pathologies

Teeth generally survive well and provide an important source of information about dental diseases. A summary of the demographic information, the number of individuals, and the tooth/alveoli analysis, is presented for the samples in Table 3, and the frequencies of oral diseases are shown in Table 4. Some photos for examples of dental diseases are shown in Figure 4.

The prevalence of caries is based on both the *insitu* teeth in the four skulls and the loose teeth from four individuals without skulls. The prevalence rate of WYC is 25% (2/8), and the frequency of caries is present in 5.41% (4/74) of the analyzed teeth (Figure 2). Carious lesions are not present among subadults while the frequency is similar for both sexes (7.14% vs. 6.45%), the difference is not statistically significant (p = 1). All the 4 affected teeth were mandibular molars, including 2 first molars, 1 s M and 1 third molar. Molars have significantly more caries than non-molars. From the location of lesions, the diseased parts are all at the cemento-enamel junction (CEJ), and the degree is relatively mild (Grade 1–2).

AMTL is present in 3 individuals (M38:R1, M47:R2, M68) out of 4 observables, or 7 of 88 teeth (8%). Among the 7 lost teeth, 3 were the mandibular middle incisors, 2 were the first premolars, and one each was the second M and the third molar. AMTL is present in 11.91% of the male and 4.35% of the female - the difference is not statistically significant (p = 0.251). It is worth noting that one of the AMTL incisor teeth (M38:R1) that had no sign of lesions around it, which is speculated to be caused by intentional tooth extraction or long-term use of the tooth as a tool.

Of the 4 individuals available for observation, all had significant periodontal disease. Considering only the adults, 59 teeth were examined, and 16.95% (10/59) had periodontal disease. Periodontal disease is present in 10.71% of the male and 22.58% of the females, and the difference is not statistically significant (p = 0.306).

Calculus is relatively common and is present in four out of eight individuals, or 50%. Calculus is present in 96.43% of the male and 100% of the female–the difference is not statistically significant (p = 0.475). All cases are of the supragingival type.

Furthermore, the series exhibit a low prevalence of periapical abscesses. 88 teeth and alveoli were available for analyzing, only one maxillary premolar (from an adult male, M38:R1) exhibits periapical abscesses. And there is no enamel hypoplasia on the 72 examinable permanent teeth.

Overall, the oral health condition of WYC people is characterized by higher incidence of calculus (78.38%) and periodontitis (16.95%), lower incidence of dental caries (5.41%), AMTL (7.95%), alveolar abscess (1.14%), and absence of enamel hypoplasia.

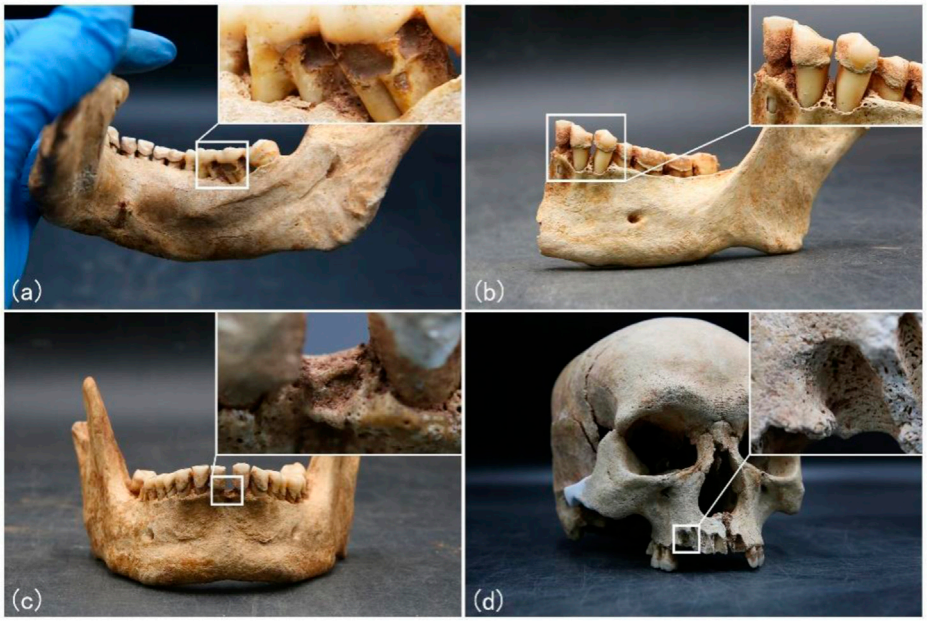

FIGURE 4
(A) Lingual views of mandible from M38:R1 showing carious lesions (arrow) at the cemento-enamel junction (CEJ) of RM_1 and RM_2; **(B)** left lateral views of the mandible of M47:R1, exhibiting periodontal disease. **(C)** Anterior view of mandible from M38:R1 showing dental calculus deposits affecting all teeth, AMTL (arrow) of LI_1; **(D)** Probable periodontitis and associated alveolar inflammation, M38:R1.

3.3.2 Periostitis

Periosteal reactions were common in WYC population. Of 10 individuals able to be scored, 5 showing signs of osteoperiostitis on one or more skeletal elements. 25.93% long bones (14/54) displayed periosteal lesions unrelated to traumatic events. All of the recorded cases of this pathology represent mild to moderate lesions. The lower limbs were the most commonly affected area, 60% (6/10) had tibial lesions and 37.5% (6/16) had tibial lesions. Periostitis is present in 31.58% of the female long bone and 20% of the male long bone. No statistically significant sex difference is present in the frequencies of these conditions (Table 5; Figure 5).

3.3.3 Degenerative joint disease (DJD)

DJD is present in four out of nine individuals, or 44.44% of the sample. The main infection joint involves the sacroiliac joint, hips, shoulders, knees, and temporomandibular joint. The individuals with osteoarthritis of major appendicular joints were a young female and two adults of indeterminate sex, M47:R1, M47:R3 and M71. M47:R1, a female of age 30, exhibits mild degeneration in the right glenoid fossa of scapula. But the corresponding humeral head does not exist. M47:R3, an adult of indeterminate sex, bilateral hips joint present with mild to moderate osteoarthritis. M71, an adult of indeterminate sex, shows more severe arthritis on the right hip. The vertebrae were generally poorly preserved, precluding many observations including identification to individual elements in many cases. Only one individual (M47:R1, a female of 30 age) had evidence of degeneration of the spine (cervical was affected). The right shoulder joint shows a slight inflammatory response. M47:R1 was the only one of the concerned individuals to exhibit some osteophytes and erosive lesion of the auricular surface of bilateral ilium, which suggests signs of sacroiliitis. In addition to the above pathological conditions, we also found evidence of temporomandibular arthritis in one individual (M47:R2, a male of age 30–40).

The total frequency of DJD in major joints in the analyzed sample is 20.51%, with a higher frequency in females (27.78%) compared to males (9.09%), but without statistical significance. (Table 6; Figure 6).

3.3.4 Traumatic injuries

Traumatic injury is not explicitly presented in this sample. There was only one individual, M47:R2, a middle-aged male, whose right distal radius with proliferative bone formation may exhibit evidence of suspected Corley's fracture.

3.3.5 Cribra orbitalia and porotic hyperostosis

A total of 4 individuals with complete or fragments of the cranium were assessed for porotic hyperostosis. Only one individual (M38:R1) had lesions, which was located on the frontal bone. The individual was a male of age 30–35, have both porotic hyperostosis and cribra orbitalia (Figure 7).

4 Discussion

4.1 Demography and burial practice

The WYC skeletal series are characterized by an evident under-representation of sub-adults, and lack of infants. There was only one

FIGURE 5
Non-specific periosteal reaction widespread periosteal reaction of the lower limbs (M68, left tibia).

TABLE 6 Counts and prevalence rates by surface of DJD in the WYC collection.

	Male		Female		Indeterminate sex		Total	
	A/O	Freq	A/O	Freq	A/O	Freq	A/O	Freq
DJD (TMAS)	1/3	33.33%	0/3	0.00%	0/0	0.00%	1/6	16.67%
Shoulder	0/2	0.00%	1/2	50.00%	0/0	0.00%	1/4	25.00%
Elbow	0/4	0.00%	0/3	0.00%	0/1	0.00%	0/8	0.00%
Wrist	0/3	0.00%	0/2	0.00%	0/0	—	0/5	0.00%
Sacroiliitis	0/2	0.00%	2/2	100.00%	0/0	—	2/4	50%
Hip	0/0	—	2/4	50%	1/1	100%	3/5	60%
Knee	0/0	—	1/2	0	0/2	0%	1/4	25.00%
ankle	0/0	—	0/0	—	0/3	0%	0/3	0.00%
Total	1/11	9.09%	5/18	27.78%	1/9	11.11%	8/39	20.51%

A, number of affected articular surface; O, number of observed articular surface; Freq, frequency (%); TMAS, temporomandibular articulating surface of temporal bone.

subadult identified, comprising 6.25% of the total analyzed samples. In most of populations from the prehistorical period of China these values are between 15% and 30% (XIN, 2004; Wang, 2012), while in some exceptional cases these values can rise to as high as 61% (Xi'an Banpo Museum. 1988). However, in samples of Iron Age, the percentage of sub-adult skeletons is reduced to 2%–6% (Liang, 2008; Sun and Zhu, 2014; Dongyue et al., 2022). A review of the available literature implies that this observation is a common phenomenon that under-representation of sub-adults exists in the youngest age group during the late Iron Age of China (Hou, 2013; ZHOU, 2014). The following conjectures may be for the lack of young children in WYC. Animal activity and flooding should be

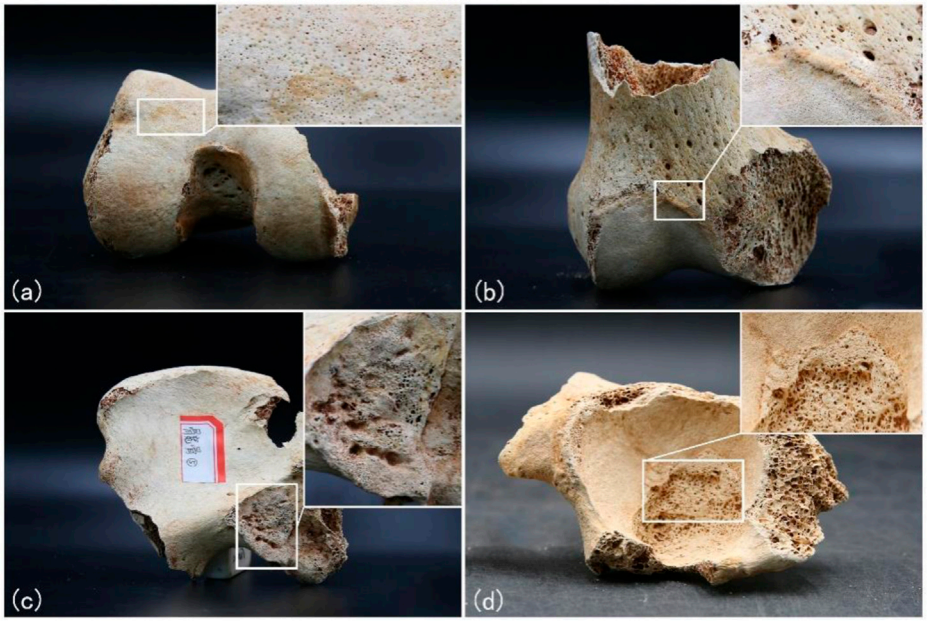

FIGURE 6
(A): Porosity on the Patellar Surface of Femur (M38:R1); **(B)**: Localized Osteophytes on patellar surface of femora; **(C)**: the auricular surface of ilium from M47:R1 showing some osteophytes and erosive lesion, which suggest signs of sacroiliitis. **(D)**: M47:R3.

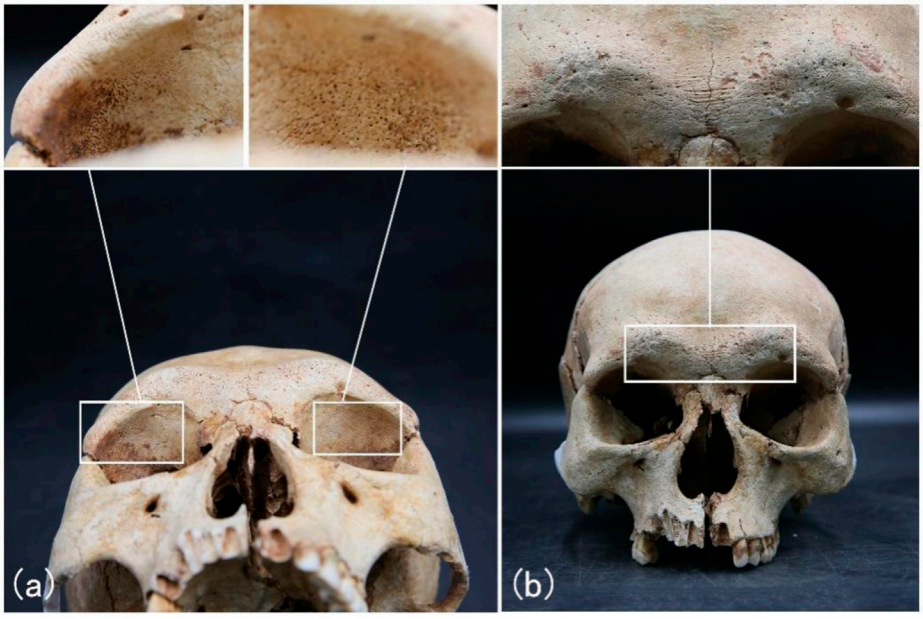

FIGURE 7
healed cribra orbitalia **(A)** and porotic hyperostosis **(B)** were found on the skull of M38:R1.

considered as potential causes of young children's bone loss in our case, as young children's bones are smaller and lighter and therefore probably more prone to those influences. Another probable reason may be that (very) young children received different burials, because cliff tomb is used as a family cemetery, and younger children may not be eligible to be buried in.

In tomb 47 (M47), at least one adult male and two adult females were identified. In tomb 52 (M52), at least two adults and a child aged 7–10 were identified. The demographic profile of the individuals in the cliff tomb with multiple burials therefore reveals that the choice of corporeal treatment was not determined solely by age or sex: males, females and children were both inhumed. In addition, except that

TABLE 7 Comparison of prevalence rates and dental caries between WYC and other ancient groups.

Population	Location	Period	Economy	Individual number/teeth number	Caries prevalence of individual (%)	Caries prevalence of tooth (%)	References
Qinglongquan	Yunxian, Hubei Province	Late Neolithic	Agriculture	87/1,075	55.2	11.9	ZHOU, et al., (2013)
Baojialiangzi	Chengdu, Sichuan Province	The Warring States—Han Dynasty	Agriculture	57/457	15.79	2.84	YUAN., et al., (2018)
Xitun	Beijing	Western Han Dynasty	Agriculture and Livestock	201/3,784	39.30	6.77	ZHOU, et al., (2017)
Wangyuancun	Leshan, Sichuan Province	Eastern Han—Song Dynasty	Agriculture	8/74	25	5.41	This study
Changan group	Changan county, Shaanxi Province	Tang Dynasty	Agriculture	62/632	62.90	14.58	Yong (2008)
Zhongnanshijicheng	Guangrao, Shandong Province	Ming Dynasty	Agriculture	17/248	82.35	15.73	Yuni et al. (2021)

M71 has only one main tomb, the internal structures of the other tombs include multiple coffin chambers in addition to the main tomb, implying that multiple individuals were buried in it. Multiple individuals buried in one tomb plausibly represents several generations of a lineage or household. The demographic profile supports the interpretation of multiple individuals in one tomb as parents/children or spouses.

4.2 Stature

Adult stature is influenced by genetics, environment, diet and other factors, it is considered a broad, non-specific indicator of the relationship between humans and their social, economic, and cultural contexts (Larsen, 2002). The stature of the male individual (M38:R1) is similar to that of modern Sichuan rural men (165.39 cm) (Xilin et al., 1994), but is shorter than the average stature of prehistoric Yingpanshan men (168.33 cm) (Yuan et al., 2018) who lived in the upper reaches of the Min River. However, the stature of the female individual (M47:R1) is significantly shorter than that of modern Sichuan rural women (154.65 cm) (Xilin et al., 1994) and also shorter than that of Tang Dynasty women in Chengdu Plain, of 156.01 cm (Yuan, 2016). Due to differences in genetics, environment, and dietary levels, populations in various parts of China have different physical characteristics. Previous studies showed that the height of population in southwest region, where WYC is located, is the shortest region in modern China (Zhang, 1988; Lei et al., 2004; Liguang Ma, et al., 2008), and the limited two stature data of WYC are consistent with this.

4.3 Oral health and dietary patterns

Dental caries is the most commonly reported oral paleopathological condition in the osteological literature. Its etiology is complex, but diet is an essential factor in the process (Hillson, 2008a). The carbohydrate content of the diet is generally considered to be the most important factor affecting the prevalence of dental caries in ancient humans, because the presence of carbohydrate-rich cereals in the oral cavity can easily lead to the growth of bacteria that cause dental caries (Arens, 1999; Hillson, 2008b; Larsen, 2015).

The WYC sample has a lower caries frequency (25% of individuals; 5.41% of teeth) than most other historic populations in China, but slightly higher than that of the Bronze-Early Iron Age Baojialiangzi site (15.79% of individuals; 2.84% of teeth) in the Chengdu Plain (Table 7). This result may be related to rice farming in the Chengdu Plain. Previous stable isotopic and phytoarchaeological studies suggest that the Chengdu Plain began to plant rice in the late Neolithic Age, and a large number of rice was planted in the Sanxingdui culture (d'Alpoim Guedes, 2011; Guedes et al., 2013; Yu and Jiao, 2015; Yi, B. et al., 2018; Ying et al., 2021). Rice became the main source of ancient food for people, and this situation continued until the Ming Dynasty (Sun, 2009). Although there is currently no data on dental caries in the rice farming population in China, however, based on evidence from prehistoric bone samples from a series of prehistoric sites in Southeast Asia suggest that there is a limited relationship between rice agriculture and caries (Tayles et al., 2000; Willis, A., & Oxenham, M. F., 2013).

Dental calculus is another oral paleopathological condition that is highly related to diet. Although oral hygiene, salivary flow and other non-dietary factors can influence calculus rates (Lieverse, 1999), diet is the main factor affecting frequencies on a population level (Novak, 2015). The relationship between diet and the formation of dental calculus is not straightforward (Hillson, 2001), and high calculus rates have been associated with both high protein and high carbohydrate diets (Meiklejohn and Zvelebil, 1991; Lieverse, 1999). The presence of large amounts of calculus on ancient teeth is by itself not necessarily an indicator of specific dietary components but does supply evidence that assist in determining dietary patterns.

Few studies of skeletal remains in this region reported the prevalence of dental calculus. Compared with a small number of sites reported in other parts of China, the high rate and severity of dental calculus in WYC sample is similar to Xiaohe Cemetery which is a Bronze Age site

located in the Lop Nur area of Xinjiang. The Xiaohe people ate beef, mutton, milk and other carnivorous foods, as well as plant foods with relatively high carbohydrate content such as wheat and millet.

Analysis of oral diseases, especially dental caries and calculus, suggests a high-carbohydrate and high-protein dietary pattern among WYC population. Cliff tomb burials developed during a period in the southwest's history when it experienced relative social and political stability and great economic prosperity. Since the Qin and Han Dynasties, the level of agricultural production in the Chengdu Plain has developed rapidly and it has become a well-known grain-producing area in the country (Gu, 111 AD). People eat rice and other grains as their staple food, and pigs, cattle, sheep, chickens, dogs, and aquatic fish are their main sources of meat, forming a stable and rich food structure, and points to a reliance on a high carbohydrate and high protein diet.

4.4 Physiological stress and health

Generic measures of health are usually drawn from evidence of metabolic diseases like anaemia, in which frequencies of porotic hyperostosis, and childhood stress is recoverable through evidence of dental enamel hypoplasias. The sample used represents a population with relatively low levels of stress and disease. The frequencies of the non-specific markers of stress in the WYC series are slightly low. There is only one individual cribra orbitalia and no enamel hypoplasia. Previous studies suggest that the low frequency of cribra orbitalia may be a result of sufficient levels of vitamins B12 and C in food (Walker et al., 2009). Studies of living children have documented association between higher frequencies of hypoplastic defects and poor nutrition and low socioeconomic status (Goodman et al., 1991; Goodman et al., 1992). In addition, periosteal reactions were common in WYC population, but the lesions are generally moderate or mild. No signs of violence-related trauma were found in any of the bone samples (only one suspected Kresh fracture was found), suggesting that WYC residents lived in a relatively peaceful society. All the evidences indicate a relatively good quality of life for the majority of WYC population and can therefore be argued that environmental hardships were not excessive in the area.

Results of disease and health analyzes are consistent with the documented. According to ancient documents, during the Warring States Period, the economic production of the Chengdu Plain, including agriculture, had reached a relatively high level (Qian, 91 BC; Qu, 1984, Jin dynasty). After the Han Dynasty, with the influx of immigrants from the north, the productivity level of Chengdu Plain increased significantly, and agriculture developed rapidly, gradually becoming a "Land of Abundance".

5 Conclusion

In this work, a comprehensive bioarchaeological study of iron age skeletal samples from the cliff tomb group of Wangyuancun (WYC) site was carried out. The minimum number of individuals was determined by the visual pair matching of skeletal elements based on similarities observed in bone morphology, age and sex, trauma and pathology and taphonomic alterations. Bioarchaeological techniques were used, and the following results were obtained.

Of the 16 individuals, two individuals were identified to be males, three possibly female and one juvenile. Death age of 7 individuals was determined, mostly in youth-middle age, and no infant individuals identified. The state of preservation of the bones is not very good. Non-etheless, the remains furnish considerable information about the mortuary practices of residents buried in the cliff tombs of Southwest China during the Iron Age. The identification of males, females and subadults among the bones and teeth in the same tomb suggests that spouses, parents and children probably from several generations of the same lineage or household were buried there. Reconstruction of the height of an adult male and an adult female, respectively, reveals that WYC was shorter in stature compared with other ancient Chinese populations. Each bone or tooth was examined for the presence of pathological conditions, and special attention was paid to dental diseases, periostitis, degenerative joint diseases, cribra orbitalia, porotic hyperostosis, and traumatic injuries. 5.41% of teeth have at least one carious lesion, and the presence of calculus was recorded in 78.38% of teeth within the sample. This sample showed a lower level of carious lesions and a higher frequency of calculus, suggests a high-carbohydrate and high-protein dietary pattern among WYC population. Most of the samples lacked indications of stress, but a few had cribra orbitalia, osteoarthritis, osteophytosis and various dental pathologies. Periosteal reactions were common, but the lesions are generally moderate or mild. The analyzed pathological changes indicate a relatively good quality of life for the majority of the population and can therefore be argued that environmental hardships were not excessive in the area.

These bioarchaeological results broaden our understanding of the health and lifestyle of the cliff tomb population of Chengdu Plain in the Iron Age. Our bioarchaeological examination of the skeletal samples of WYC site provides a rare opportunity to address questions concerning ancient people's diet, health, disease and stress of population in the Iron Age of Chengdu Plain, Southwest China. The biological and pathological data collected in this work provide an important data base for future anthropological research.

Nevertheless, it is important to point out that the evidence of palaeopathology in the ancient residents of Wangyuancun site may be under-represented due to the fragmented nature of the skeletal assemblage. The sample of 16 individuals in this work is certainly a very small one from which to draw general conclusions reflecting the entire living population from which it came. Certainly biological, cultural, and other selective biases are present in this skeletal series as in almost any archaeological sample. Due to the scarcity of supporting material many questions about cliff burials remain difficult to answer. For example, the identity of the majority of those buried in cliff tombs is unknown, nor do we know how the funeral protocol for cliff tomb burial was conducted, and whether there was practice of secondary burials. We hope to expand the sample size at Wangyuancun site and from other related sites, and combined with isotope and other related studies in future, to better understand the life history of these ancient people and their social conditions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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