International Journal of Osteoarchaeology
Int. J. Osteoarchaeol. (2015)
Published online in Wiley Online Library
(wileyonlinelibrary.com) **DOI**: 10.1002/oa.2506

Reconstructing Diet of the Early Qin (ca. 700–400 BC) at Xishan, Gansu Province, China

Y. MA,[a*] B. T. FULLER,[b] L. CHEN,[c] C. ZHAO,[c] Y. HU[b,d] AND M. P. RICHARDS[a,e]

[a] *Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany*
[b] *Department of Scientific History and Archaeometry, University of Chinese Academy of Sciences, Beijing, PR China*
[c] *Institute of Archaeology, Northwest University, Xi'an, Shaanxi, PR China*
[d] *Laboratory of Human Evolution, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, PR China*
[e] *Department of Anthropology, University of British Columbia, Vancouver, BC, Canada*

ABSTRACT Here we report the bone collagen carbon and nitrogen isotopic results of humans ($n = 33$) and animals ($n = 58$) to reconstruct the dietary practices of an early Qin population dating to the Zhou Dynasty (Late Western–Early Eastern period ca. 700–400 BC) at the Xishan site in Gansu Province, China. The humans have a very large range of $\delta^{13}C$ (−23.3‰ to −7.1‰) and $\delta^{15}N$ (4.3‰ to 10.9‰) values which reflects extraordinarily diverse diets and included individuals with predominately C_3 as well as those with exclusive C_4 diets. This wide span of isotopic results produced a subtle linear trend ($R^2 = 0.62$) in the human data, which paralleled the animals across the C_3 and C_4 environmental gradient. However, the majority of the individuals had a predominately C_4 diet based on millet with $\delta^{15}N$ results only slightly elevated above the animals, except for the pigs and cattle. This is evidence that many of the animals were likely used for their secondary products, labour or as sacrificial offerings and that pork and beef were the main sources of animal protein for the population. High status individuals had elevated $\delta^{15}N$ values (10.2 ± 0.6‰) compared to medium (8.9 ± 0.3‰) and lower status (8.8 ± 0.8‰) individuals, possibly related to increased animal protein in the diet. Differences related to gender were also found with females having elevated $\delta^{13}C$ (−11.2 ± 1.9‰) and $\delta^{15}N$ (9.4 ± 0.8‰) values compared to the males ($\delta^{13}C$ = −14.1 ± 4.2‰; $\delta^{15}N$ = 7.9 ± 1.9‰), but these results necessitate caution given the large number of individuals that could not be sexed. The results of this study support the view that the early Qin people were a more sedentary society focused on millet agriculture and animal husbandry, and that they were influenced by the pre-existing populations of the central Gansu region. Copyright © 2015 John Wiley & Sons, Ltd.

Key words: Western Zhou Dynasty; Eastern Zhou Dynasty; millet; social status; dietary diversity

Introduction

Named after the first emperor of China (Qin, 221–206 BC), the Qin Dynasty is considered one of the most important and influential periods in all of Chinese history (Sima, 1962; Li, 1984). However, before the Qin people successfully unified China they were one of several feudal states 'zhuhou guo'(诸侯国) vying for control of the region during the Zhou Dynasty (1046–221 BC) (Li, 1975). Because the Qin people are viewed as the direct ancestors which founded Imperial China, scholars have devoted large amounts of research to learning more about their early history, culture, and formation as a society to better understand how these people successfully rose to power (Duan, 1982; Ma, 1982; Xu, 2003).

The Qin people are believed to have originated in East China as the 'Yi' (夷) people around 1000 BC. At some point during the early Zhou Dynasties (ca. 890 BC), one group of Qin moved to the western part of China (what is now eastern Gansu Province) and lived among the nomadic 'Rong' (戎) groups (Zou, 1980; Duan, 1982; Liu, 2003). Recent archaeological excavations have confirmed this, and identified Li County in eastern Gansu Province as the earliest place where the Qin settled in this region (Liang *et al.*, 2008) (Figures 1a,b). These excavations yielded many important cemeteries (e.g. Dabaozi and Yuandingshang) and architectural

* Correspondence to: Ying Ma, Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, D-04103 Leipzig, Germany. e-mail: maying_121@126.com

Received 24 June 2015
Revised 6 September 2015
Accepted 9 October 2015

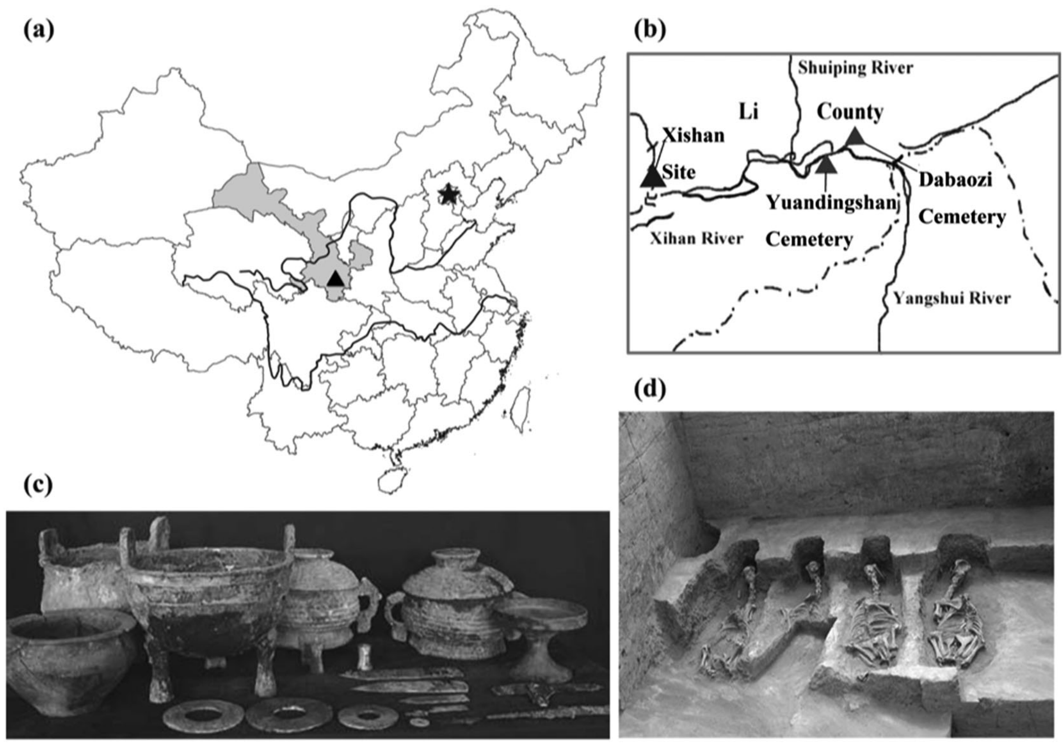


Figure 1. a) Map of China showing the location of the Xishan site (▲) in Gansu Province (shaded). Note (★) represents Beijing. b) Expanded map showing the location of the Xishan site in Li County. c) Picture of the grave goods recovered from burial M2003. d) Picture showing the sacrificial horse pit K404.

remains which have been used to identify unique customs and aspects of the Qin culture, dating from the late phase of the Shang Dynasty (1400–1046 BC) through the Zhou Dynasty (1046–256 BC) (Liang *et al.*, 2008).

Previous studies that examined the subsistence strategy of early Qin populations have produced conflicting results, and this topic remains an active area of debate (Zhang, 2001; Wang, 2007). Many historians believed that the early Qin population adopted a nomadic pastoral lifestyle and diet when they migrated to eastern Gansu, because ancient texts, such as *Shiji* (Sima, 1962), describe many activities relating to animal herding and hunting for the early Qin. In contrast, some archaeologists hold the view that the early Qin population adopted a more sedentary lifestyle based on farming, as indicated by the archaeological evidence from pottery vessels used for storing grains and tools related to farming. A single limited study of isotopic results and dental health patterns determined that people in Xishan had a diet that was a mix of stockbreeding and agriculture (Wei, 2008; Wei *et al.*, 2009). Unfortunately, no faunal isotope results were measured so it was impossible to determine the types of animals or plant protein that was consumed by the people of Xishan. In addition, there have been only two previously published isotopic studies of Qin sites (both did not contain faunal results) and these were from Shaanxi Province to the east and were from later time periods (Ling *et al.*, 2010a; 2010b). While historical sources and archaeological evidence indicate that the early Qin period consisted of different cultural groups with a complex social structure and order, previous research was not able to explore if there were possible differences related to status. Here we present a detailed application of stable isotope ratio analysis of human ($n = 33$) and faunal remains ($n = 58$) from the Xishan site. We selected available human skeletal remains from different contexts as well as faunal samples to establish the isotopic baseline with which to compare to the humans. We aimed to reconstruct the picture of daily life of the early Qin population in this region and to examine if social status and gender were possibly reflected in the different diets of the individuals.

Stable isotope ratio analysis and palaeodiet

Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope ratio analysis of bone collagen is a well-established method used to reconstruct the diet of modern past populations and has been widely applied to address questions of subsistence practices, animal husbandry strategies, health and nutrition, and social status (e.g. van der Merwe and Vogel, 1978; Sealy *et al.*, 1987; Richards *et al.*, 1998; Fuller *et al.*, 2004; Müldner and Richards, 2007; Hu *et al.*, 2009; Choy *et al.*, 2010; Bourbou *et al.*, 2011; Commendador *et al.*, 2013; Cui *et al.* 2015). Based on the principle that the various body tissues are derived from dietary intake, isotope ratios obtained from bone collagen reflect the average isotopic composition of an individual's dietary protein intake over the entire lifetime including a significant amount of collagen from the period of adolescences (Stenhouse and Baxter, 1979; Hedges *et al.*, 2007).

The $\delta^{13}C$ results can distinguish between diets composed primarily of C_3 (plants adapted to temperate ecosystems, including most vegetables, fruit and wheat) and C_4 (plants adapted to hot and arid ecosystems, including maize, millet and some grasses) photosynthetic pathway plants, as well as the animals that consumed these (DeNiro and Epstein, 1978; Krueger and Sullivan, 1984; Schwarcz, 1991; Ambrose and Norr, 1993; Kellner and Schoeninger, 2007). The $\delta^{15}N$ results can be used to examine the trophic level, because body tissues show an approximately 3–5‰ enrichment in $\delta^{15}N$ relative to diet (DeNiro and Epstein, 1981; Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984; Bocherens and Drucker, 2003; Hedges and Reynard, 2007). Isotopic ratios can also detect the contribution of marine protein in the diet, because both the carbon and nitrogen isotope values vary between marine and terrestrial ecosystems in a predictable manner (Chisholm *et al.*, 1982; Schoeninger *et al.*, 1983; Richards and Hedges, 1999). However, a comprehensive discussion about how stable isotope ratios can be used to reconstruct dietary patterns in archaeological populations is beyond the scope of this study, and the reader is directed to the following excellent reviews for more information (Schwarcz and Schoeninger, 1991; Schoeninger, 1995; Katzenberg, 2000; Lee-Thorp, 2008; Reitsema, 2013).

The Xishan site, Gansu Province, China

The Xishan site is one of the most important archaeological sites in eastern Gansu Province, and is located on a hillside in the eastern portion of Li County. Excavations have yielded a cemetery, ritual sacrifice pits and ruins of a fortified wall, indicating it was a central settlement for the early Qin population during the late Western Zhou (1046–771 BC) to the Eastern Zhou periods (770–221 BC). In particular, 49 graves with various burial contexts were recovered, providing materials to better understanding the daily life in the early Qin period and Qin society in general. Six of the tombs were dated to the Late Western Zhou period, and were clearly separated into two clusters according to location and burial custom. Three tombs were oriented W–E and located on the top of the hill with the interred lying face up with arms crossed over the body, accompanied with rich grave goods, and as well as sacrificial victims and dogs. For example, individual M2003 was buried in a decorated wooden coffin that contained plentiful artifacts, including jade, bronze ritual objects (three tripod and two Gui '簋' style vessels; Gui is a bowl-shaped ancient Chinese ritual bronze vessel used to hold food offerings) likely related to the upper *Shi* (士) orders indicating it was a very high status grave (see Figure 1c). The other three tombs, oriented N–S, were located to the south of the hillside with very few grave goods. The remaining 43 tombs dated to the Eastern Zhou period, and these burials were positioned in the W–E direction. Most of the individuals from those tombs were buried with a flexed posture, and the accompanying grave goods included: pottery vessels, bronze weapons, jade, with variations in number and quality for each tomb.

Materials and methods

Fifty-eight faunal bone samples found either in a ritual sacrifice pit, the fill of the cemetery during excavation or inside of a tomb were collected and available for analysis (Table 1). The identification of faunal species was conducted by the Institute of Archaeology, CASS (Yu *et al.*, 2011), and represented eight species, including sheep, horse, deer and dog, which makes it possible to reconstruct the past food web, and provides the necessary baseline for understanding the human isotope values. In addition, 33 human skeletal remains were available for analysis, and prior to isotope analysis, age estimation and sex determination for each individual (where possible) were undertaken by one of the authors (L. Chen). However, a number of the tombs were looted in the past, and the bones of these individuals were scattered, disarticulated and commingled, and identification was not possible (Table 2), but as only ribs or long bones were sampled it is believed that all specimen represent separate individuals.

Bone collagen was extracted by the protocol described in Richards and Hedges (1999) with the addition of an ultrafiltration step as recommended by Brown *et al.* (1988) and Jørkov *et al.* (2007). Each bone sample was cleaned by air abrasion and then put into

Table 1. Isotopic results and sample information for all fauna from the Xishan site, Gansu Province, China

ID #	Species	Period	Burial Location	% Yield	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C/N
M1007	Horse	Zhou Dynasty (Late Western–Early Eastern)	Tomb	0.1	−19.5	7.3	45	15.7	3.3
K102	Horse	Zhou Dynasty (Late Western–Early Eastern)	Sacrifice Pit	0.6	−18.4	6.5	44	15.5	3.3
K102	Horse	Zhou Dynasty (Late Western–Early Eastern)	Sacrifice Pit	1.5	−18.3	6.9	44.4	15.8	3.3
H1053	Deer	Late Neolithic	Fill	2.1	−21.7	5.1	44.4	15.9	3.3
T0205(5)	Deer	Late Neolithic	Fill	3.2	−21.9	7.9	45.8	16.1	3.3
H1063(2)	Deer	Zhou Dynasty (Late Western–Early Eastern)	Fill	2.7	−21.1	4.2	45.2	16.1	3.3
T0105(2)	Deer	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.6	−21.2	3.6	44.7	15.7	3.3
T0102(3)	Deer	Zhou Dynasty (Late Western–Early Eastern)	Fill	0.7	−20	3.8	44.6	15.8	3.3
M2004	Deer	Zhou Dynasty (Late Western–Early Eastern)	Tomb	1.2	−16.4	6.6	44.6	15.8	3.3
H1063(2)	Deer	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.9	−20.5	4.7	44.4	15.9	3.3
H1137	Deer	Zhou Dynasty (Late Western–Early Eastern)	Fill	1.8	−21.8	5.7	44.8	16.1	3.3
YPW	Sika Deer	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.7	−20.1	4.0	45.3	16.2	3.3
M2004	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Tomb	6.2	−12	5.1	45.1	16.3	3.2
M2003	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Tomb	5.5	−17	6.6	45.3	16.4	3.2
T0204(2)	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Fill	2.8	−23.1	3.6	44.8	16	3.3
T0203(2)	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Fill	0.6	−22.9	3.7	44.2	15.7	3.3
T0102(2)	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Fill	0.5	−14.4	6.0	44.3	15.6	3.3
T0202(9)	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Fill	2.5	−17.7	6.5	44.6	15.9	3.3
H1004	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.5	−13.7	6.2	44.8	16.2	3.2
M1007	Sheep	Zhou Dynasty (Late Western–Early Eastern)	Tomb	4.6	−17.6	7.0	44.7	16.1	3.3
H1170	Sheep	Zhou Dynasty (Late Western–Early Eastern)	Fill	0.6	−18.9	5.3	44.1	15.7	3.3
T0205	Sheep	Zhou Dynasty (Late Western–Early Eastern)	Fill	2.2	−19.4	9.4	44.3	16.2	3.2
H1004(2)	Sheep	Zhou Dynasty (Late Western–Early Eastern)	Fill	4.7	−18.1	6.2	44.7	15.7	3.3
H1063(5)	Sheep	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.7	−18	5.4	46.9	16.1	3.4
H1167	Goat	Late Neolithic	Fill	0.6	−18.6	5.3	40.9	14.2	3.4
H4028	Goat	Zhou Dynasty (Late Western–Early Eastern)	Fill	2.9	−18.1	6.1	44.6	15.9	3.3
M1007	Goat	Zhou Dynasty (Late Western–Early Eastern)	Tomb	4.1	−19.5	7.3	45	15.7	3.3
H1091	Goat	Zhou Dynasty (Late Western–Early Eastern)	Fill	4.0	−18.5	5.9	45.5	16	3.3
H1170	Goat	Zhou Dynasty (Late Western–Early Eastern)	Fill	1.0	−19.5	8.1	44.4	15.8	3.3
H1107	Dog	Late Neolithic	Fill	0.7	−12.5	8.0	44.7	15.5	3.4
H1102	Dog	Late Neolithic	Fill	0.8	−14.4	8.5	44.4	14.9	3.5
M2003	Dog	Zhou Dynasty (Late Western–Early Eastern)	Tomb	4.1	−14	6.8	44.8	16	3.3
H1004(2)	Dog	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.5	−10.4	10.2	45	15.9	3.3
H4002(3)	Dog	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.2	−13.1	8.9	44.9	16.1	3.3
H1063 STC	Dog	Zhou Dynasty (Late Western–Early Eastern)	Fill	1.3	−9.4	8.1	44.6	15.7	3.3
H1063(2)	Dog	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.9	−9.9	8.8	45.1	16	3.3
H1063(2) ZT	Dog	Zhou Dynasty (Late Western–Early Eastern)	Fill	4.9	−8.1	8.9	45.8	16.3	3.3
M1002	Dog	Zhou Dynasty (Late Western–Early Eastern)	Tomb	2.7	−11.4	10.9	43.7	15.8	3.2
H1002	Pig	Late Neolithic	Fill	1.5	−14.5	7.8	45	15.7	3.4
H1063 BSTC	Pig	Zhou Dynasty (Late Western–Early Eastern)	Fill	2.1	−11	8.1	44.7	15.6	3.3
H1063(2)	Pig	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.6	−8.7	7.5	44.9	15.8	3.3
T0205(2)	Pig	Zhou Dynasty (Late Western–Early Eastern)	Fill	1.3	−11.8	7.9	44.7	15.5	3.4
H1041	Pig	Zhou Dynasty (Late Western–Early Eastern)	Fill	0.9	−17.7	4.9	44.3	15.5	3.3
T0204(2)	Pig	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.1	−9.9	7.8	44.6	15.6	3.3
H1063(2)	Pig	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.1	−9.5	6.5	45	15.8	3.3
H1049	Pig	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.7	−18.8	5.2	45.1	16	3.3
H4029	Pig	Zhou Dynasty (Late Western–Early Eastern)	Fill	4.2	−17.5	5.2	45.2	15.9	3.3
H4002(3)	Bear	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.3	−19.7	2.0	44.9	15.9	3.3
H1003(7)	Unidentified	Zhou Dynasty (Late Western–Early Eastern)	Fill	3.3	−7.3	10.1	45.1	16.1	3.3
H4002(4)	Unidentified	Zhou Dynasty (Late Western–Early Eastern)	Fill	5.1	−18.7	6.7	45.1	16	3.3
T0905(9)	Unidentified	Zhou Dynasty (Late Western–Early Eastern)	Fill	1.5	−12.8	8.5	43.3	15.6	3.2
T0204(3)	Unidentified	Zhou Dynasty (Late Western–Early Eastern)	Fill	0.6	−18.9	7.0	43.4	15.4	3.3
Samples below failed to produced collagen									
T0302	Horse	Zhou Dynasty (Late Western–Early Eastern)	Fill		—	—	—	—	—
M1	Horse	Zhou Dynasty (Late Western–Early Eastern)	Tomb		—	—	—	—	—
M3001P	Deer	Zhou Dynasty (Late Western–Early Eastern)	Tomb		—	—	—	—	—
H3011	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Fill		—	—	—	—	—
H0308(3)	Cattle	Zhou Dynasty (Late Western–Early Eastern)	Fill		—	—	—	—	—
T0102(4)	Pig	Late Neolithic	Fill		—	—	—	—	—

0.5 M HCl solution at 4 °C for ~2 weeks, with acid changes every 2 days. Demineralized samples were gelatinized at 70 °C in a pH = 3 solution for 48 h. After purification with a 5-μm EZEE© filter, the solution was concentrated by Amicon© ultrafilters (<30 kDa), and then was frozen and freeze dried for 2 days.

Table 2. Isotopic results and sample information for all humans from the Xishan site, Gansu Province, China

Sample	Phase ca. 700–400 BC	Sex	Age	% Yield	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N	Grave goods	Inferred status
M1009	Zhou Dynasty (Late Western)	F	40–44	1.4	−10.2	9.8	40.3	14.4	3.3	Common pottery	Low
M1014	Zhou Dynasty (Late Western)	F	Adult	0.5	−8.1	9.0	41.8	15.0	3.3	Jade Gui (玉圭)	Medium
M2003 1[a]	Zhou Dynasty (Late Western)	F	15–16	1.0	−12.4	9.3	44.1	15.5	3.3	Sacrificed victim including a dog buried inside of a separate wooden box	Low
M1001	Zhou Dynasty (Early Eastern)	?	Adult	1.8	−16.2	7.3	44.8	16.2	3.2	Tomb looted	?
M1002	Zhou Dynasty (Early Eastern)	M	20–25	2.7	−11.4	10.9	43.7	15.8	3.2	Thirty-two grave goods including: bronze weapons, jade, common pottery, bone artifacts and a sacrificed dog	High
M1010	Zhou Dynasty (Early Eastern)	F	40–45	1.5	−11.8	10.6	43.6	15.6	3.3	Tomb looted	?
M1013	Zhou Dynasty (Early Eastern)	F	Adult	1.8	−13.6	7.3	42.7	15.5	3.2	Unknown	?
M1016A	Zhou Dynasty (Early Eastern)	M	Adult	1.9	−23.3	5.5	43.4	15.6	3.3	Unknown	?
M1016 B	Zhou Dynasty (Early Eastern)	F	40–45	2.0	−13.1	9.2	43.8	15.7	3.3	Assorted calaite, jade and stone artifacts, plus common pottery	Medium
M1020	Zhou Dynasty (Early Eastern)	M	45–50	4.9	−8.6	9.0	45.1	16.2	3.2	Common pottery	Low
M1021	Zhou Dynasty (Early Eastern)	?	8–10	2.2	−19.2	4.6	43.3	15.7	3.2	Tomb partially looted but some grave goods were still present: seven stone Gui (石圭), bronze artifacts and a sacrificed dog	High?
M1023	Zhou Dynasty (Early Eastern)	?	11–12	1.9	−8.1	8.5	43.6	15.6	3.3	Common pottery	Low
M1024	Zhou Dynasty (Early Eastern)	M	35+	0.7	−11.3	8.6	42.0	15.0	3.3	Stone Gui (石圭), common pottery and a sacrificed dog.	Medium
M1027 2[a]	Zhou Dynasty (Early Eastern)	?	11–12	1.6	−13.7	7.3	43.2	15.4	3.2	Sacrificed victim that was buried with a sacrificed dog	Low
M3001	Zhou Dynasty (Early Eastern)	M	20–25	2.4	−15.9	5.7	43.1	15.5	3.2	Tomb partially looted but some grave goods were still present: four bone arrowheads, stone artifacts and common pottery	Medium?
LXD M4002	Zhou Dynasty (Early Eastern)	?	Adult	2.6	−7.1	9.0	43.4	15.6	3.2	?	?
M4004	Zhou Dynasty (Early Eastern)	F	15–16	1.4	−10.1	9.6	44.4	16.0	3.2	Tomb looted	?
LXD M4004 A	Zhou Dynasty (Early Eastern)	?	Adult	0.7	−9.0	8.6	45.0	15.7	3.3	Tomb looted	?
LXD M4004B	Zhou Dynasty (Early Eastern)	?	Adult	0.9	−10.1	9.3	44.1	15.8	3.3	Tomb looted	?
M4005	Zhou Dynasty (Early Eastern)	M	Adult	1.1	−15.6	5.5	44.4	16.0	3.2	?	?
LXD H1070	Zhou Dynasty (Early Eastern)	?	Adult	0.9	−13.9	7.5	43.3	15.5	3.3	Tomb looted	?
LXD H1149	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	1.1	−18.4	7.6	44.6	15.9	3.3	Tomb looted	?
LXD T0203(5)	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	1.4	−22.6	5.8	44.0	15.8	3.3	Tomb looted	?
LXD T70905(9)	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	0.3	−15.3	4.9	43.1	14.7	3.4	Tomb looted	?
LXD H4006	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	2.9	−13.4	8.5	43.9	15.9	3.2	Tomb looted	?
LXD T0201	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	0.6	−12.4	8.5	44.0	15.0	3.4	?	?
LXD T0203A	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	1.9	−13.6	5.3	43.8	15.8	3.2	?	?
LXD T0105	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	0.3	−10.5	9.7	42.0	14.7	3.3	?	?
LXD T0203B	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	0.7	−19.5	4.3	43.4	15.6	3.3	?	?
LXD T0105(3)	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	0.3	−10.7	9.2	41.3	14.1	3.4	?	?
LXD T0409(2) A	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	3.7	−15.6	5.5	43.0	15.6	3.2	?	?
LXD T0409(2) B	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	2.9	−17.6	7.0	46.6	16.0	3.2	?	?
LXD H1166	Zhou Dynasty (Late Western–Early Eastern)	?	Adult?	3.2	−21.0	4.5	45.1	15.8	3.3	Tomb looted	?

(*Continues*)

Table 2. (Continued)

Sample	Phase ca. 700–400 BC	Sex	Age	% Yield	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	%C	%N	C:N	Grave goods	Inferred status
[b]M2003 2[a]	Zhou Dynasty (Late Western)	F	30	—	−12.2	9.7	42.8	15.5	3.2	Sacrificed victim, buried in a wood chest with six shells, and a jade Han (玉晗).This suggests a close relationship with the tomb owner	High
[b]M2004	Zhou Dynasty (Late Western)	M	17–19	—	−12.6	9.0	42.7	15.5	3.2	Common pottery	Low
[b]M1011	Zhou Dynasty (Early Eastern)	M	60+	—	−13.7	8.8	41.9	15.1	3.2	Tomb looted	?
[b]M1015	Zhou Dynasty (Early Eastern)	M	18–19	—	−14.1	7.7	43.0	15.6	3.2	Five pieces of common pottery	Low
[b]M1017	Zhou Dynasty (Early Eastern)	F	25–30	—	−11.8	9.4	42.3	15.4	3.2	Common pottery	Low
[b]M1022	Zhou Dynasty (Early Eastern)	F	51–60	—	−13.2	8.7	41.6	14.8	3.3	Common pottery	Low
[b]M1027	Zhou Dynasty (Early Eastern)	F	45–50	—	−9.1	10.0	41.2	15.1	3.2	Tomb owner buried with two sacrificed victims, a sacrificed dog, two cattle skulls and other assorted animals. Fifteen pieces of common pottery, nine jade pieces (1 Jue 玉玦 and 8 Han 玉晗) and three shells.	High
[b]M1027 1[a]	Zhou Dynasty (Early Eastern)	F	16–17	—	−8.9	9.6	42.0	15.4	3.2	Sacrificed victim buried in wooden coffin	Low

[a]Sacrificial victim.
[b]Data from Wei (2008).

Approximately 0.5 mg of extracted collagen was weighted for carbon and nitrogen analysis, using a Flash EA 2112 coupled to a Delta XP mass spectrometer (Thermo-Finnigan, Bremen, Germany). The results are reported in 'per mil' (‰) relative to the standards VPDB for $\delta^{13}C$ and AIR for $\delta^{15}N$. The analytical precision is ±0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$.

Results and discussion

The mean $\delta^{13}C$ and $\delta^{15}N$ results were calculated using duplicate measurements of each sample, and the C:N, %C, %N values were also measured (Tables 1,2). All of the humans (33 out of 33) and 52 out of 58 of the faunal samples produced collagen that met the published quality criteria for well-preserved collagen (DeNiro, 1985; van Klinken, 1999).

Faunal isotope data

The fauna samples exhibit a wide range of $\delta^{13}C$ (~16‰) and $\delta^{15}N$ (~9‰) results that spanned a complete C_3 to C_4 dietary range (Figure 2). The majority of the animals date from the Zhou Dynasty (Late Western–Early Eastern period ca. 700–400 BC), but six animals are believed to date earlier, from the late Neolithic, based on the levels at which they were discovered. However, no noticeable isotopic differences are observed between these six specimens and the other samples (Table 1) so all will be treated as reflecting the likely isotopic baseline of the humans during the Zhou Dynasty.

The herbivores (horse, deer, sheep, goat, cattle, bear; $n = 30$) omnivores (dog, pig; $n = 18$) and unidentified faunal ($n = 4$) $\delta^{13}C$ values range from −23.1‰ to −7.3‰ and the $\delta^{15}N$ values range from 2.0‰ to 10.9‰. The horses ($n = 3$) have a mean ± sd $\delta^{13}C$ value of 18.7 ± 0.7‰ and mean ± sd $\delta^{15}N$ value of 6.9 ± 0.4‰. The sheep ($n = 5$) have a mean ± sd $\delta^{13}C$ value of −18.4 ± 0.7‰ and mean ± sd $\delta^{15}N$ of 6.7 ± 1.7‰, while the goats ($n = 5$) have mean ± sd $\delta^{13}C$ value of −18.8 ± 0.6‰ and a mean ± sd $\delta^{15}N$ value of 6.5 ± 1.1‰. These results indicate these three species fed on similar diets that were predominately based on C_3 plants (Figure 2). One of the sheep has an elevated $\delta^{15}N$ signature which might reflect nursing as it was identified as a juvenile between 6 and 28 months old (Balasse and Tresset, 2002).

The deer ($n = 9$) have mean ± sd $\delta^{13}C$ (−20.5 ± 1.7‰) and $\delta^{15}N$ (5.1 ± 1.4‰) values reflecting a nearly exclusive C_3 diet. However, a single individual (M2004) plots away from the group and shows a

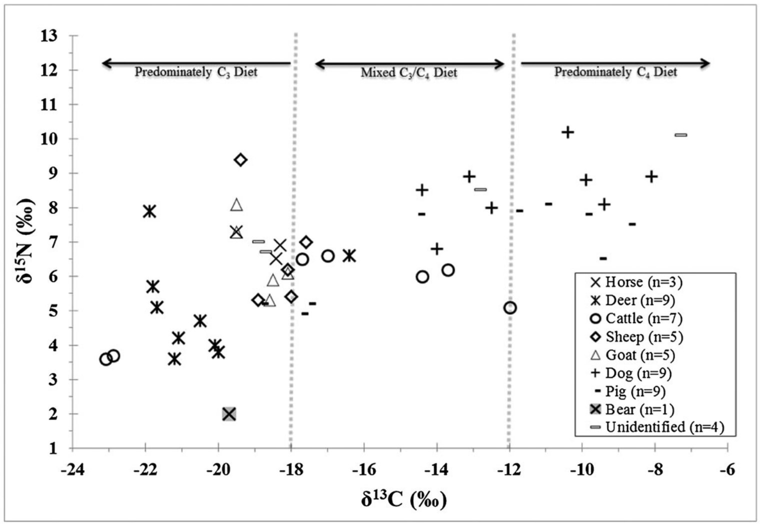


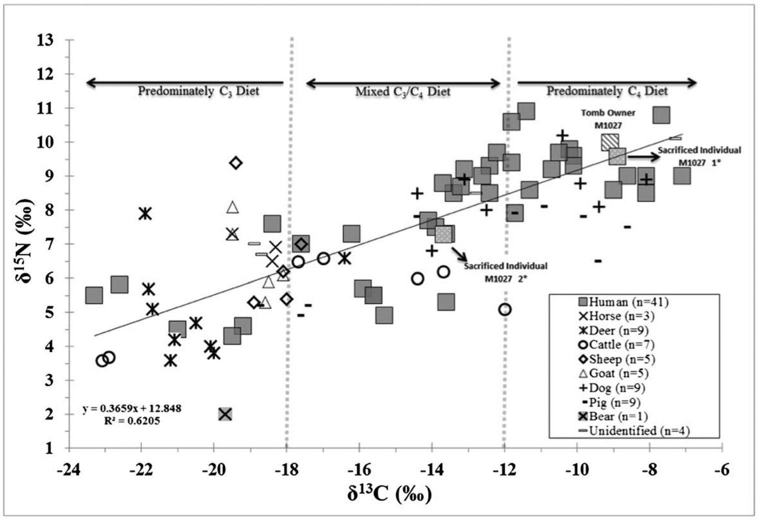
Figure 2. $\delta^{13}C$ and $\delta^{15}N$ faunal results from the Xishan site Gansu Province, China. It is estimated that values > −12‰ reflect a predominately C_4 diet, values between −12‰ and −18‰ indicate a mixed C_3/C_4 diet, and values < −18 reflect a predominately C_3 diet in China according to the work of Pechenkina et al. (2005) and Barton et al. (2009).

significant ^{13}C-enrichment, indicating it was having substantial amounts of C_4 foods (likely millet) in its diet (Table 1; Figure 2). This could reflect that this deer was kept as a pet or sacrificial animal and fed by humans at the site. The cattle ($n = 7$) have mean ± sd $\delta^{13}C$ (−17.3 ± 4.4‰) and $\delta^{15}N$ (5.4 ± 1.3‰) values and display a wide range of $\delta^{13}C$ (−23.1‰ to −12.0‰) and $\delta^{15}N$ (3.7‰ to 6.6‰) values, indicating that they consumed a much more diverse range of foods at Xishan. Two of the cattle have isotopic results close to the horse and sheep/goat assemblage indicating similar animal husbandry strategies were used with this cluster of animals (Figure 2). In addition, two cattle have the most ^{13}C-depleted results of all the species studied, and these individuals had exclusive C_3 diets that could reflect that they were wild and grazing in a closed forested habitat because of the canopy effect (France, 1996; Vera, 2000; Drucker *et al.*, 2008). The final three individuals have ^{13}C-enriched values that plot below the dogs and reflect that these cattle were likely cared for in or near the settlement and foddered with significant amounts of millet. The isotopic results of the single bear reflect that it was having a herbivorous C_3 diet and a similar pattern has been observed in Europe (Bocherens *et al.*, 1994; Bocherens *et al.*, 1997).

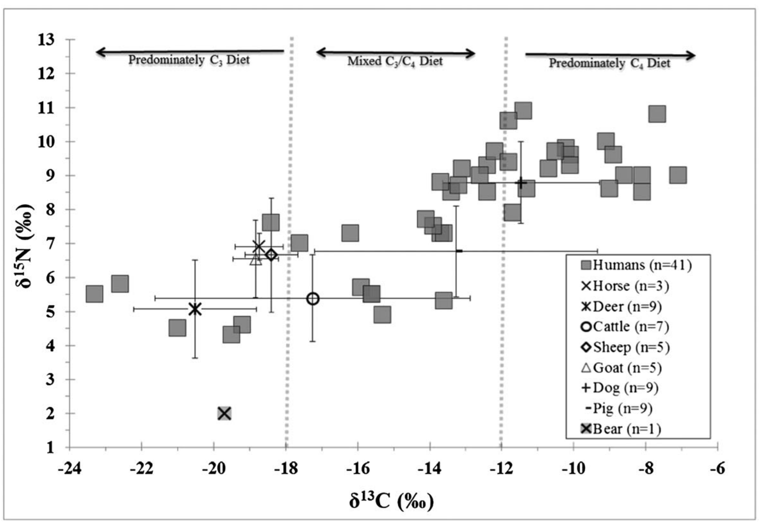
The mean ± sd $\delta^{13}C$ (−13.3 ± 3.9‰) and $\delta^{15}N$ (6.8 ± 1.3‰) values of all the pigs ($n = 9$) cluster in two groups (Figure 2). However, three pigs have mean ± sd $\delta^{13}C$ (−18.0 ± 0.6‰) and $\delta^{15}N$ (5.1 ± 0.1‰) values that are near some of the cattle, horses and sheep/goats, suggesting that these animals were all cared for and fed in a similar manner. It is also possible that these C_3 pigs might be wild boar as suggested by past research (Pechenkina *et al.*, 2005; Barton *et al.*, 2009). The rest of the pigs have $\delta^{13}C$ values that range between −14.5‰ and −8.7‰ (mean ± sd; −10.9 ± 2.1‰) and $\delta^{15}N$ values that range between 6.5‰ and 8.1‰ (mean ± sd; 7.6 ± 0.6‰). These pigs were eating a predominately C_4 diet (millet), and the elevated $\delta^{15}N$ values suggest that they were fed scraps or refuse by the humans and thus domesticated. The dogs (n=9) have some of the most ^{13}C-enriched (mean ± sd; −11.4 ± 2.2‰) and ^{15}N-enriched (mean ± sd; 6.8 ± 1.3‰) values of all the animals, suggesting a significant and regular consumption of C_4 protein in their diet, which is a common pattern observed in isotopic studies of domesticated dogs in north China (Chen *et al.*, 2012; Hou *et al.*, 2013; Si, 2013).

Human isotope data

The isotopic results and information for the humans measured in this study are presented in Table 2 and plotted in Figures 3a and 3b. In addition, eight human $\delta^{13}C$ and $\delta^{15}N$ results from the work of Wei (2008) are also listed in Table 2 and shown in Figures 3a and 3b so that there are a total of 41 humans that can be isotopically examined and discussed from the Xishan site. Like the animals, the humans show a wide range of $\delta^{13}C$ (−23.3‰ to −7.1‰) and $\delta^{15}N$ (4.3‰ to 10.9‰) results. This reflects that the diet of the early Qin at Xishan was extraordinarily diverse and included



a



b

Figure 3. a) Human and faunal $\delta^{13}C$ and $\delta^{15}N$ results from the Xishan site Gansu Province, China. Highlighted are the three individuals found in tomb M1027, consisting of the tomb owner (M1027) and two sacrificed individuals (M1027 1* and M1027 2*). It is estimated that values > −12‰ reflect a predominately C_4 diet, values between −12‰ and −18‰ indicate a mixed C_3/C_4 diet, and values < −18 reflect a predominately C_3 diet in China according to the work of Pechenkina et al. (2005) and Barton et al. (2009). b) Human and faunal mean ± sd $\delta^{13}C$ and $\delta^{15}N$ results from the Xishan site Gansu Province, China. It is estimated that values > −12‰ reflect a predominately C_4 diet, values between −12‰ and −18‰ indicate a mixed C_3/C_4 diet, and values < −18 reflect a predominately C_3 diet in China according to the work of Pechenkina et al. (2005) and Barton et al. (2009).

individuals with a nearly complete C_3 diet as well as those with an exclusive C_4 diet. In addition, a subtle but clear linear trend ($R^2 = 0.62$) is observed for the humans which parallels the faunal results. However, in many cases the humans plot with or only slight above the animals (an exception being the C_4 pigs and cattle) indicating the animals were not regularly consumed, but likely used for their labour or secondary products (Figures 3a,b), and this is observed at other sites in China (e.g. Li *et al.*, 2014).

The subsistence patterns of the early Qin population

The data presented here indicate that the early Qin population at Xishan had a diverse diet that spanned a range of complete C_3 to C_4 resources. However, the majority of the population (35 out of 41 individuals) were eating a predominately C_4 (> −12‰) or mixed C_3/C_4 diet (> −18.0‰) (Pechenkina *et al.*, 2005; Barton *et al.*, 2009). This is clear evidence that millet farming was highly important to the Qin people. Flotation studies confirm the presence of carbonized millet grains, and broomcorn millet (*Panicum milaceum*) is considered to have been the main C_4 plant in this region (Wang, 2006; Chen, 2007; Li *et al*., 2007; Zhou *et al*., 2011). Thus, millet was an integral part of the diet, culture and history either through direct consumption and/or by the consumption of animals fed on millet. Given that millet grows quickly and requires little human assistance to produce a yield, it is an ideal crop for a possible nomadic/pastoral population such as the Qin (Chen, 2007). However, the isotopic results, indicating that large quantities of millet were consumed by the inhabitants coupled with the low trophic level of the humans compared to the animals (see below), are compelling evidence that the Qin were a settled agriculture population at the Xishan site.

However, the human $\delta^{15}N$ results are nearly identical or only slightly elevated above the fauna (Figures 3a,b), and this provides strong support that most of these domestic animals were not readily consumed but also used for their secondary products, labour or sacrificial importance. Exceptions to this include the pigs and cattle, as many of the individual humans are clearly elevated in $\delta^{15}N$ by comparison (Figure 3a), and this agrees with the historical accounts. In particular, written records mentioned six kinds of animals such as pig, dog, cattle, sheep/goat, horse and chicken as being very important domestic breeds in the pre-Qin period (Yang, 2008; Flad *et al*., 2009; Yuan, 2012). They were widely used for protein food sources (e.g. pig), sacrificial or ritual killing (e.g. dog, pig and horse), vehicle and farming labour (e.g. horse and cattle), and also for military purposes (horse). An abundance of pits which contained slaughtered animals were found at the Xishan site, including seven horse pits, one cattle pit and three pits with dog and other assorted fauna pits, indicating the wide range of domesticated animals that were available in the early Qin period. Only two other isotopic studies have been published on Qin sites (Sunjianantou and Jianhe), and both of these were from the neighbouring Province of Shaanxi and date to later periods (Ling *et al*., 2010a; 2010b). When the results presented here from Xishan are compared to the Sunjianantou and Jianhe sites, we see similar patterns (Figure 4) with individuals at all three sites having a heavy reliance on millet and similar $\delta^{15}N$ values. However, there is clearly more dietary diversity at Xishan. It is difficult to make more detailed comparisons as no faunal remains were analyzed at the Sunjianantou and Jianhe sites, but it is possible that the sources of animal protein were similar at the three sites, and more isotopic work on both humans and animals is necessary from additional Qin sites. To summarize, we infer from the results of this study that the early Qin population brought a millet agriculture system with them when they immigrated to Xishan, and simultaneously adopted and exploited a stockbreeding and animal husbandry regime that was influenced by

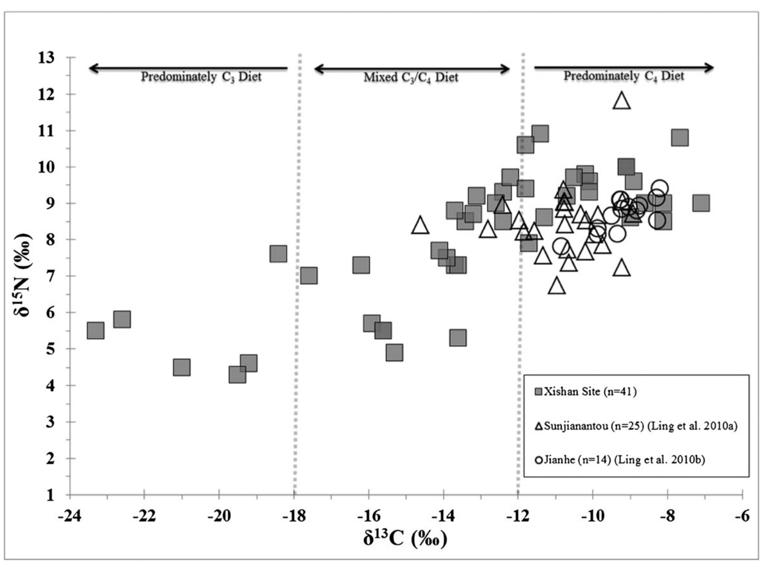


Figure 4. Comparison of the human $\delta^{13}C$ and $\delta^{15}N$ results from the Qin sites of Xishan, Sunjianantou (Ling et al., 2010a) and Jianhe (Ling et al. 2010b). All three sites show that individuals were consuming large amounts of millet but that Xishan had the largest dietary diversity. It is estimated that values > -12‰ reflect a predominately C_4 diet, values between -12‰ and -18‰ indicate a mixed C_3/C_4 diet, and values < -18 reflect a predominately C_3 diet in China according to the work of Pechenkina et al. (2005) and Barton et al. (2009).

the pre-existing populations of the central Gansu region. This discovery supports the archaeologist's view that the early Qin people were a more sedentary and agriculture-based society at the Xishan site.

Dietary variation relating to social status

Both textual and archaeological evidence imply that the early Qin society was characterized by considerable social complexity with a range of status differences (Ge, 1992; Dai, 2006). If we assume that the upper class individuals had more access to wealth, power and the means of production, they may have set themselves apart from the majority by consuming foods that were perhaps more nutritious, exotic or rarer to obtain. The most direct evidence to determine wealth and status differences among individuals is from the mortuary analysis (Table 2). Unfortunately, only 16 individuals could be assigned a clear status level (low, medium and high) as the others had tombs that were partially or completely looted in the past. However, examination of these isotopic results shows that while all classes had similar $\delta^{13}C$ values, the $\delta^{15}N$ results of the high status (10.2 ± 0.6‰) individuals were significantly elevated over the medium (8.9 ± 0.3‰) and lower status (8.8 ± 0.8‰) individuals (one-way ANOVA test; $p = 0.039$; Figure 5). This could indicate that high status individuals were having more pork (or other high nitrogen isotope protein sources) in their diet compared to the common people, but this is only a preliminary conclusion as the number of samples in this population with known status is small.

Tomb owners vs. sacrificial victims

Four cases of human sacrifice were found at Xishan (Chen, 1989; Liang *et al.* 2008), and this confirms the presence of pronounced social differences within the population. It is unknown how these individuals were killed as no obvious signs of trauma were observed, but historical sources indicate that the Qin would sometimes poison, hang or bury individuals alive that were to be sacrificed, and that most were unwilling participants, but that some viewed it as an honour to be buried with their master (Wen and De, 1998; Gan, 2008). For burial M2003, only the two sacrificed victims (M2003 1* and M2003 2*) could be analyzed as the skeleton of the tomb owner was missing. The $\delta^{13}C$ and $\delta^{15}N$ values of M2003 1* and M2003 2* are nearly identical and indicate that both had similar diets even though the status of M2003 2* is inferred to be high based on the number and value of the associated grave goods (Table 2). In contrast, the two sacrificial victims (M1027 1* and M1027 2*) of burial M1027 have different $\delta^{13}C$ and $\delta^{15}N$ values even though both are considered low class (Figure 3a, Table 2). The tomb owner (M1027; $\delta^{13}C = -9.1‰$, $\delta^{15}N = 10.0‰$) has similar isotopic result to one of the sacrificed individuals (M1027 1*; $\delta^{13}C = -8.9‰$, $\delta^{15}N = 9.6‰$) with both of these individuals consuming a predominately C_4 diet which included pork (Table 2). However, M1027 2* has significantly lower $\delta^{13}C$ (−13.7‰) and $\delta^{15}N$ (7.3‰) values indicating a significantly different diet that was based more on a mixture of C_3/C_4 foods, possibly including beef (Figure 3a, Table 2).

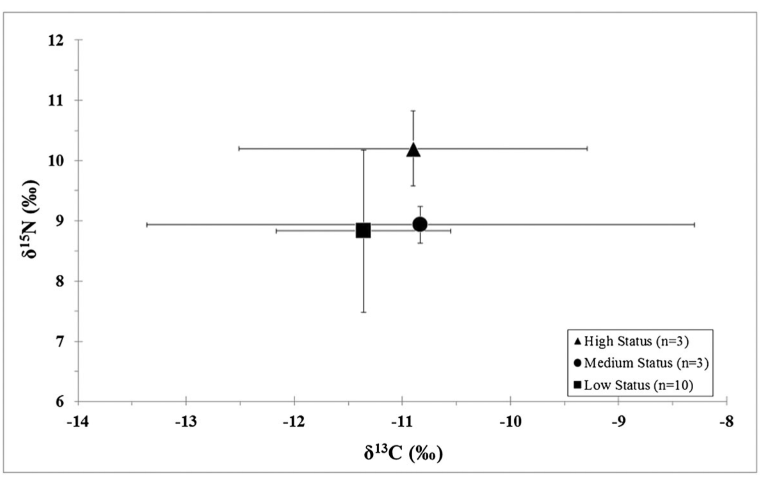


Figure 5. The mean ± sd $\delta^{13}C$ and $\delta^{15}N$ results for individuals that could be assigned status based on associated grave goods recovered from tombs at the Xishan site Gansu Province, China. High status individuals had $\delta^{15}N$ values that were significantly different (10.2 ± 0.6‰) than medium (8.9 ± 0.3‰) and low status (8.8 ± 0.8‰) individuals (one way ANOVA test; $p = 0.039$).

There is the intriguing possibility that the isotope data can further illuminate the identity of these sacrificial victims. Written records indicate that the life and diet of the sacrificed was determined by their owner (Chen, 1989; Wen and De, 1998; Gan, 2008). Those individuals that had a similar dietary preference with their tomb master may not have necessarily had an inferior life history, and on the contrary could reflect individuals who had a close relationship with their master, such as concubines, retainers and liegeman (Ling *et al.*, 2010a). In contrast, different dietary patterns compared to a tomb owner may suggest a more distant or subordinate relationship with their master, possibly a slave. This could have been the case for tomb M1027 where the tomb owner (an older female) might have had a close everyday relationship with the first sacrificed individual (M1027 1*—younger female; possible servant girl), but the second sacrificed individual (M1027 2*—unsexed young individual) was treated more as a slave for menial or undesirable work (Figure 3a, Table 2). Unfortunately, there is a scarcity of complete data for the other tombs, and the current sample size is too small to draw any larger conclusions from these comparisons. Further studies of the early Qin from other more undisturbed sites will help us to understand the dietary differences related to social status between the main tomb occupants and the sacrificial victims buried with them.

Isotopic differences associated with sex

Historical writings indicate that the Qin were a male dominated society (e.g. Duan, 2005; Zhao, 2008). However, there is evidence that the Qin were somewhat more progressive and that females enjoyed some additional freedoms and rights compared to other contemporary states such as the Chu (Gu, 2003). For example, records indicate that it was common in some cases for a man to marry a woman and live with the family of his wife when she had more wealth, and in these instances, the woman was the most powerful individual of the household (Zu, 2012). In addition, historical sources mention that the Qin state had a group of female soldiers that made up part of the army (Dong, 1956; Liu, 1998). However, there is no information concerning possible dietary differences that existed between the sexes during the Qin period. Here we examine the isotopic results of the identified males ($n = 9$) and females ($n = 12$) at Xishan to examine if different diets were consumed. The mean ± sd $\delta^{13}C$ values of the males ($-14.1 \pm 4.2‰$) and females ($-11.2 \pm 1.9‰$) were found to be significantly different ($p = 0.047$) using a one-way ANOVA test (Figure 6). This indicates that the males consumed a mixed C_3/C_4 diet and that the females had a more C_4-based diet. In addition, the mean ± sd $\delta^{15}N$ values of the males ($7.9 \pm 1.9‰$) and females ($9.4 \pm 0.8‰$) were also determined to be significantly different ($p = 0.024$) using a one-way ANOVA test (Figure 6). It is particularly interesting that the males have lower $\delta^{15}N$ values compared to the females as past isotopic research usually finds the opposite results (e.g. Fuller *et al.*, 2006; Richards *et al.*, 2006; Quintelier *et al.*, 2014). These findings at Xishan suggest that the females were consuming a diet of more millet and pork while the males had a much more

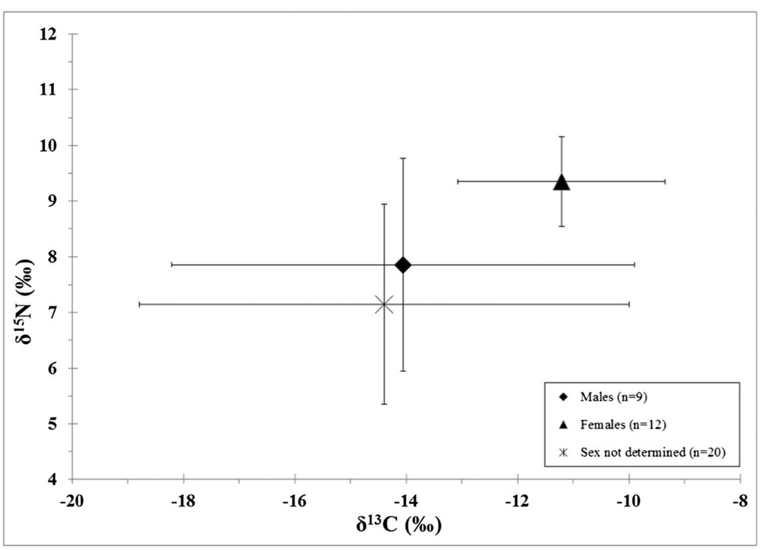


Figure 6. The mean ± sd $\delta^{13}C$ and $\delta^{15}N$ results for males, females and sex not determined at the Xishan site Gansu Province, China. Significant differences were found for the $\delta^{13}C$ ($p = 0.047$) and $\delta^{15}N$ values ($p = 0.024$) between the males and females using a one-way ANOVA test, but caution is suggested for these results given the high number of individuals where the sex was not determined.

diverse diet that was a mix of millet/rice/wheat and different animals both wild and domestic (Li *et al.*, 2007). The reasons for these differences are unclear and could suggest that males had greater access to dietary items through hunting or travel related to trade or warfare while the females had a more homogenous diet related to foodstuffs found in and around the settlement. However, the number of individuals that could be reliably sexed is small at Xishan, and it is possible that if the large number unidentified individuals (n=20) could have had their sex determined that these isotopic differences would disappear. Thus, we highlight the need for caution with these interpretations and recognize that additional isotopic studies from Qin populations are needed in the future.

Conclusion

This study represents the largest and most detailed assessment of stable isotope ratio results from an early Qin population in China, the site of Xishan. The results found that millet was an important food resource in the diets of most of the humans and their livestock, but that the population had a very diverse diet that spanned nearly complete C_3 to C_4 diets for some individuals. A subtle linear trend ($R^2 = 0.62$) is observed for the humans, which parallels the trend for the fauna. However, in many cases the humans plot with or only slightly above the animals (an exception being the C_4 pigs and cattle) indicating that they were not regularly consumed, but likely used for their labour, secondary products or sacrificial importance. Examination of the human isotopic results by status found that high status individuals had significantly elevated $\delta^{15}N$ results compared to the low or middle status individuals, possibly reflecting increased pork consumption. However, the small sample size means that caution is warranted for these interpretations, and more work is needed from other non-looted early Qin sites. Significant differences related to gender were also found with females having elevated $\delta^{13}C$ and $\delta^{15}N$ values compared to the males, but we strongly recommend caution in the interpretation of these results as a large number of individuals could not be sexed. We suggest that while the early Qin undertook a mixed subsistence strategy, they were mainly focused on millet agriculture and stockbreeding, and that the population was settled rather than a nomadic or pastoral based society; supporting the views of the archaeologists that excavated Xishan. This study adds to the growing body of isotope data from China and shows the importance of both millet agriculture and animal husbandry in the formation of early Chinese state society.

Acknowledgements

The authors would like to thank Northwest University and the Gansu Provincial Institute of Cultural Relics and Archaeology for providing samples and archaeological information, and the Institute of Archaeology, CASS for identifying the faunal samples. Special thanks go to Dawei Tao for his very helpful comments on the manuscript. This research was funded by the Max Planck Society and the CAS President's International Fellowship for Postdoctoral Researchers 2013Y1JA0004.

References

Ambrose SH, Norr L. 1993. Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate. *Prehistoric Human Bone: Archaeology at the Molecular Level*, JB Lambert, G Grupe (eds.). Springer Verlag: Berlin, 1–37.

Balasse M, Tresset A. 2002. Early weaning of Neolithic domestic cattle (Bercy, France) revealed by intra-tooth variation in nitrogen isotope ratios. *Journal of Archaeological Science* **29**: 853–859.

Barton L, Newsome SD, Chen FH, Wang H, Guilderson TP, Bettinger RL. 2009. Agricultural origins and the isotopic identity of domestication in northern China. *Proceedings of the National Academy of Sciences* **106**: 5523–5528.

Bocherens H, Drucker D. 2003. Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: Case studies from recent and ancient terrestrial ecosystems. *International Journal of Osteoarchaeology* **13**: 46–53.

Bocherens H, Marc F, André M. 1994. Diet, physiology and ecology of fossil mammals as inferred from stable carbon and nitrogen isotope biogeochemistry: implications for Pleistocene bears. *Palaeogeography Palaeoclimatology Palaeoecology* **107**: 213–225.

Bocherens H, Billiou D, Patou-Mathis M, Bonjean D, Otte M, Mariotti A. 1997. Paleobiological implications of the isotopic signatures (^{13}C, ^{15}N) of fossil mammal collagen in Scladina Cave (Sclayn, Belgium). *Quaternary Research* **48**: 370–380.

Bourbou C, Fuller BT, Garvie-Lok SJ, Richards MP. 2011. Reconstructing the diets of Greek Byzantine populations (6th–15th centuries AD) using carbon and nitrogen stable isotope ratios. *American Journal of Physical Anthropology* **146**: 569–581.

Brown TA, Nelson DE, Vogel JS, Southon JR. 1988. Improved collagen extraction by modified Longin method. *Radiocarbon* **30**: 171–177.

Chen S. 1989. Human sacrifice and funerary objects of Qin during Eastern Zhou. *Cultural Relics of Central China* **2**: 22–27. (in Chinese)
Chen W. 2007. *China Agricultural History: Volume of Xia, Shang, Zhou, Spring and Autumn Period*. China Agriculture Press: Beijing. (in Chinese)
Chen X, Yuan J, Hu Y, He N, Wang C. 2012. Palaeodiet reconstruction of domestic animals in Taosi site, China: an investigation of Neolithic animal feeding strategy. *Kaogu* **9**: 75–82. (in Chinese)
Chisholm BS, Nelson DE, Schwarcz HP. 1982. Stable carbon isotope ratios as a measure of marine versus terrestrial protein in ancient diets. *Science* **216**: 1131–1132.
Choy K, Jeon OR, Fuller BT, Richards MP. 2010. Isotopic evidence of dietary variations and weaning practices in the Gaya Cemetery at Yeanri, Gimhae, South Korea. *American Journal of Physical Anthropology* **142**: 74–84.
Commendador AS, Dudgeon JV, Finney BP, Fuller BT, Esh KS. 2013. Stable isotope ($\delta^{13}C$ and $\delta^{15}N$) perspective on human diet on Rapa Nui (Easter Island) c.a. 1400–1900 AD. *American Journal of Physical Anthropology* **152**: 173–185.
Cui Y, Song G, Wei D, Pang Y, Wang N, Ning C, Li C, Feng B, Tang W, Li H, Ren Y, Zhang C, Huang Y, Hu Y, Zhou H. 2015. Identification of kinship and occupant status in Mongolian noble burials of the Yuan Dynasty through a multidisciplinary approach. *Philosophical Transactions R. Soc. B* **370**: 2013.0378.
Dai L. 2006. Diet and rank character in Pre-Qin period. *Journal of Nanning Polytechnic* **1**: 5–8. (in Chinese)
DeNiro MJ. 1985. Post-mortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* **317**: 806–809.
DeNiro MJ, Epstein S. 1978. Influence of diet on the distribution of carbon isotopes in animals. *Geochimica et Cosmochimica Acta* **42**: 495–506.
DeNiro MJ, Epstein S. 1981. Influence of diet on the distribution of nitrogen isotopes in animals. *Geochimica et Cosmochimica Acta* **45**: 341–351.
Dong S. 1956. *Qi Guo Kao: Study on the History of Seven States during Warring States Periods*. Zhonghua Book Company: Beijing. (in Chinese)
Drucker DG, Bridault A, Hobson KA, Szuma E, Bocherens H. 2008. Can carbon 13 in large herbivores reflect the canopy effect in temperate and boreal ecosystems? Evidence from modern and ancient ungulates. *Palaeogeography Palaeoclimatology Palaeoecology* **266**: 69–82.
Duan L. 1982. Study on the migration of Yi and the deviation of Qin. *Journal of Humanities* **5**: 166–175. (in Chinese)
Duan T. 2005. Difference in gender estate and status under the mourning apparel system in Pre-Qin times. *Journal of Sichuan University (Social Science Edition)* **3**: 105–110. (in Chinese)
Flad RK, Yuan J, Li S. 2009. On the source and features of the Neolithic domestic animals in the Gansu and Qinghai Region, China. *Archaeology* **5**: 80–86.
France R. 1996. Carbon isotope ratios in logged and unlogged boreal forests: examination of the potential for determining wildlife habitat use. *Journal of Environmental Management* **20**: 249–255.
Fuller BT, Fuller JT, Sage NE, Harris DA, O'Connell TC, Hedges REM. 2004. Nitrogen balance and $d^{15}N$: why you're not what you eat during pregnancy. *Rapid Communications in Mass Spectrometry* **18**: 2889–2896.
Fuller BT, Molleson TI, Harris DA, Gilmour LT, Hedges REM. 2006. Isotopic evidence for breastfeeding and possible adult dietary differences from late/sub-Roman Britain. *American Journal of Physical Anthropology* **129**: 45–54.
Gan X. 2008. Discussing the Sati system characteristics of Qin Dynasty. *Journal of Xi'an University of Finance and Economics* **21**: 14–17. (in Chinese)
Ge C. 1992. The Hierarchical Society of Ancient China. Shaanxi People's Publishing House, Xi'an. (in Chinese)
Gu J. 2003. Comparison on customs of the Chu and Qin state during middle and late Warring States Periods. *Journal of Central China Normal University (Humanities and Social Sciences)* **4**: 67–72 (in Chinese).
Hedges REM, Reynard LM. 2007. Nitrogen isotopes and the trophic level of humans in archaeology. *Journal of Archaeological Science* **34**: 1240–1251.
Hedges REM, Clement JG, Thomas CDL, O'Connell TC. 2007. Collagen turnover in the adult femoral mid-shaft: modeled from anthropogenic radiocarbon tracer measurements. *American Journal of Physical Anthropology* **133**: 808–816.
Hou L, Li S, Hu Y, Hou Y, Lv P, Cao L, Hu B, Song G, Wang C. 2013. Preliminary study on domestic animal feeding strategy during Proto-Shang Period. *Huaxia Archaeology* **2**: 130–139. (in Chinese)
Hu Y, Shang H, Tong H, Nehlich O, Liu W, Zhao C, Yu J, Wang C, Trinkaus E, Richards MP. 2009. Stable isotope dietary analysis of the Tianyuan 1 early modern human. *Proceedings of the National Academy of Sciences* **106**: 10971–10974.
Jørkov MLS, Heinemeier J, Lynnerup N. 2007. Evaluating bone collagen extraction methods for stable isotope analysis in dietary studies. *Journal of Archaeological Science* **34**: 1824–1829.
Katzenberg MA. 2000. Stable isotope analysis: a tool for studying past diet, demography and life history. *Biological Anthropology of the Human Skeleton*, MA Katzenberg, SA Saunders (eds.). Wiley-Liss: New York, 305–328.
Kellner CM, Schoeninger MJ. 2007. A simple carbon isotope model for reconstructing prehistoric human diet. *American Journal of Physical Anthropology* **133**: 1112–1127.
van Klinken GJ. 1999. Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* **26**: 687–695.
Krueger HW, Sullivan CH. 1984. Models for carbon isotope fractionation between diet and bone. Turnlund, J.E. and Johnson, P.E. (eds.), Stable Isotopes in Nutrition American Chemical Society Symposium Series 258, pp. 205–222.

Lee-Thorp JA. 2008. On isotopes and old bones. *Archaeometry* **50**: 925–950.
Li Y. 1975. *The First Emperor of China*. International Arts and Sciences Press: New York.
Li X. 1984. *Eastern Zhou and Qin Civilizations*. Cultural Relics Press: Beijing. (in Chinese)
Li X, Zhou X, Zhou J, Dodson J, Zhang H, Shang X. 2007. The earliest archaeobiological evidence of the broadening agriculture in China recorded at Xishanping site in Gansu Province. *Science in China Series D: Earth Sciences* **50**: 1707–1714. (in Chinese)
Li Z, Brunson K, Dai L. 2014. The zooarchaeological study of wool exploitation from the early Bronze Age in the central plains. *Quaternary Sciences* **34**: 149–157. (in Chinese)
Liang Y, You F, Li Y, Mao R, Tian Y. 2008. *The Investigation Report of the Archeological Sites in the Upper Reaches of the Western Hanshui River*. Cultural Relics Publishing House: Beijing. (in Chinese)
Ling X, Chen L, Tian Y. 2010a. Carbon and nitrogen stable isotopic analysis on human bones from the Qin Tomb of Sunjianantou Site, Fengxiang, Shanxi Province. *Acta Anthropologica Sinica* **29**: 54–61. (in Chinese)
Ling X, Wang WS, Chen L, Sun L, Hu Y. 2010b. Stable isotope analysis of Qin human remains from the Jianhe cemetery at Baoji, China. *Archaeology and Cultural Relics* **1**: 95–98. (in Chinese)
Liu X. 1998. *Zhan Guo Ce (Strategies of the Warring States)*. Shanghai Classics Publishing House: Shanghai. (in Chinese)
Liu J. 2003. *The Study on the Proto-Zhou Culture*. Sanqin Publishing House: Xi'an. (in Chinese)
Ma F. 1982. *Union of Qin History*. Zhonghua Book Company: Beijing. (in Chinese)
van der Merwe NJ, Vogel JC. 1978. ^{13}C content of human collagen as a measure of prehistoric diet in Woodland North America. *Nature* **276**: 815–816.
Minagawa M, Wada E. 1984. Stepwise enrichment of ^{15}N along food chains: further evidence and the relation between ^{15}N and animal age. *Geochimica et Cosmochimica Acta* **48**: 1135–1140.
Müldner G, Richards MP. 2007. Stable isotope evidence for 1500 years of human diet in the city of York, UK. *American Journal of Physical Anthropology* **133**: 682–697.
Pechenkina EA, Ambrose SH, Ma X, RAB, Jr. 2005. Reconstructing northern Chinese Neolithic subsistence practices by isotopic analysis. *Journal of Archaeological Science* **32**: 1176–1189.
Quintelier K, Ervynck A, Müldner G, Van Neer W, Richards MP, Fuller BT. 2014. Isotopic examination of links between diet, social differentiation, and DISH at the post-Medieval carmelite friary of Aalst, Belgium. *American Journal of Physical Anthropology* **153**: 203–213.
Reitsema LJ. 2013. Beyond diet reconstruction: stable isotope applications to human physiology, health, and nutrition. *American Journal of Human Biology* **25**: 445–456.
Richards MP, Hedges REM. 1999. Stable isotope evidence for similarities in the types of marine foods used by late Mesolithic humans at sites along the Atlantic coast of Europe. *Journal of Archaeological Science* **26**: 717–722.
Richards MP, Hedges REM, Molleson TI, Vogel JC. 1998. Stable isotope analysis reveals variations in human diet at the Poundbury Camp Cemetery Site. *Journal of Archaeological Science* **25**: 1247–1252.
Richards MP, Fuller BT, Molleson TI. 2006. Stable isotope palaeodietary study of humans and fauna from the multi-period (Iron Age, Viking and Late Medieval) site of Newark Bay, Orkney. *Journal of Archaeological Science* **33**: 122–131.
Schoeninger MJ. 1995. Stable isotope studies in human evolution. *Evolutionary Anthropology* **4**: 83–98.
Schoeninger MJ, DeNiro MJ. 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta* **48**: 625–639.
Schoeninger MJ, DeNiro MJ, Tauber H. 1983. Stable nitrogen isotope ratios of bone collagen reflect marine and terrestrial components of prehistoric human diet. *Science* **220**: 1381–1383.
Schwarcz HP. 1991. Some theoretical aspects of isotope paleodiet studies. *Journal of Archaeological Science* **18**: 261–275.
Schwarcz HP, Schoeninger M. 1991. Stable isotope analyses in human nutritional ecology. *Yearbook of Physical Anthropology* **34**: 283–321.
Sealy JC, van der Merwe NJ, Lee-Thorp JA, Lanham JL. 1987. Nitrogen isotope ecology in southern Africa: implications for environmental and dietary tracing. *Geochimica et Cosmochimica Acta* **51**: 2707–2717.
Si Y. 2013. Feeding practices of domestic animals and meat consumption of ancient in the central plain of Chuna, 2500 BC~1000 BC. PhD Thesis. Department of Scientific History and Archaeometry, University of Chinese Academy of Sciences. (in Chinese)
Sima Q. 1962. *Shiji: The Records of the Grand Historian*. Zhonghua Press: Beijing. (in Chinese)
Stenhouse MJ, Baxter MS. 1979. The uptake of bomb ^{14}C in humans. *Radiocarbon Dating: Proceedings of the Ninth International Conference*, R Berger, HE Suess (eds.). The University of California Press: Los Angeles, 324–341.
Vera FWM. 2000. *Grazing Ecology and Forest History*. CABI Publishing: Oxon, New York.
Wang X. 2006. Regional features of food culture during Pre-Qin. *Qinghai Social Science* **4**: 99–104. (in Chinese)
Wang Z. 2007. *The Study on the Pre-Qin Culture*. Northwest University: Xi'an. (in Chinese)
Wei M. 2008. Oral health and diet pattern in early Qin people: a case study from the Xishan site, Gansu Province. Master Thesis. Department of Scientific History and Archaeometry, University of Chinese Academy of Sciences. (in Chinese)
Wei M, Wang T, Zhao C, Chen L, Wang C. 2009. Diet and oral hygiene of the people in early Qin Dynasty from the Xishan site, Gansu Province. *Acta Anthropologica Sinica* **28**: 45–56. (in Chinese)

Wen X, De S. 1998. The evolvement of human sacrifice in Qin. *Wenbo* **6**: 45–49. (in Chinese)
Xu R. 2003. *The Early Development History of Qin Dynasty*. Chinese Science Culture Press: Beijing. (in Chinese)
Yang J. 2008. Reconstruction of the meat structure of diet on ancient inhabitants. *Archaeology and Cultural Relics* **6**: 103–105. (in Chinese)
Yu C, Lv P, Zhao C. 2011. Research of animal bones unearthed from Xishan site in Gansu. *Relics from South* **3**: 73–79. (in Chinese)
Yuan J. 2012. Research on domestic animals in ancient China. *Quaternary Sciences* **30**: 298–306. (in Chinese)
Zhang T. 2001. Issues on the Pre-Qin sites excavated in Li County. *Wenbo* **3**: 67–74. (in Chinese)
Zhao D. 2008. A rough research on gender roles in pre-Qin dynasty. *Culture Journal* **2**: 5–10. (in Chinese)
Zhou X, Li X, Zhao K, Dodson J, Sun N, Yang Q. 2011. Early agricultural development and environmental effects in the Neolithic Longdong basin (eastern Gansu). *Chinese Science Bulletin* **56**: 762–771. (in Chinese)
Zou H. 1980. *Essays on Xia, Shang and Zhou archaeology*. Wenwu Press: Beijing. (in Chinese)
Zu J 2012. Concerning the survival condition of Qin women: as Shuihudi Qin bamboo is main research material. Master Dissertation. College of Humanities, Suzhou University of Science and Technology. (in Chinese)

