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Human isotopic evidence from the Guanzhong Basin casts light on a century of agricultural and pastoral interactions at medieval metropolitan Chang'an during sixth century AD

Pengfei Sheng[1,2,6], Edward Allen[2,6], Tian Ma[2,6], Yiyuan Dao[3], Jianlin Zhang[4], Daiyun Liu[4], Sheng Han[3], Hailiang Meng[5]✉ & Shaoqing Wen[1,2,5]✉

Noble and commoner in the medieval China capital of Chang'an (modern-day Xi'an) engaged in an intricately intertwined agricultural and pastoral economy. The period represents the peak of the integration of nomadic and agricultural populations in early China. Here we firstly reported human collagen $\delta^{13}C$ and $\delta^{15}N$ values for eight middle age nobles whose lifespans cover roughly a century (AD 503–604) and who include a Northern Zhou, Emperor Wu (北周武帝) and his consort, Empress A'shina (阿史那皇后). We also consider stable isotopic evidence from nine individuals in commoner burials in the Chang'an region, likewise dating to the sixth century. This century-long dietary profile provides direct archeological evidence for dietary variability at this core metropolitan population. Constructing a comparative model using existing historical human isotopic data ($n = 1233$) from northern China and its northern Steppe, we find a marked regional divergence in noble and commoner dietary patterns. We trace this back to the considerable variety of agricultural and pastoral dietary practices, likely pointing to different economic and geographic backgrounds of the individuals under study. We argue that a two-way relationship between shifting pastoral and agricultural practices was reflected to separate degrees at the elite and commoner level. This study offers an improved understanding of the multiplicity of dietary patterns and associated lifeways for the metropolitan societies of medieval northern China.

[1] Institute of Archaeological Science and MOE Laboratory for National Development and Intelligent Governance, Fudan University, 200433 Shanghai, China. [2] Department of Cultural Heritage and Museology and Center for the Belt and Road Archaeology and Ancient civilizations, Fudan University, 200433 Shanghai, China. [3] Department of History, Fudan University, 200433 Shanghai, China. [4] Shaanxi Institute of Cultural Relics and Archaeology, 710000 Xi'an, China. [5] Ministry of Education Key Laboratory of Contemporary Anthropology, Department of Anthropology and Human Genetics, Fudan University, 200433 Shanghai, China. [6] These authors contributed equally: Pengfei Sheng, Edward Allen, Ma Tian. ✉email: mmmhl@126.com; wenshaoqing1982@gmail.com

Introduction

Interactions between Han and non-Han elite groups and between agricultural and pastoral peoples were both integral elements of China's Northern Dynasties (北朝, AD 386–581). In both cases a degree of "hybridization" is argued to have occurred (Chen, 2002). Despite a clear ethnic demarcation of Han (agricultural) and non-Han around the third and fourth centuries, the emergence of Xianbei (pastoral/nomadic) identity that challenged Han dominance in the Central Plains marked a turning point in conceptualizing ethnicity in northern China and indeed geography of the Chinese realm (Felt, 2017). The Northern Wei (北魏, AD 386–534) and its descendant polities were a critical juncture in this process. In Dien's words, during this time peoples exhibiting a "wide range of regional cultural differences" (Dien, 2007) interacted in war and peace—and with frequent reconstitution of elite groups and polities. Chen Yinke (陈寅恪) argued for a counter-view of Han-ization (*Han hua*汉化) when trying to encapsulate the ethnic changes of this period—a non-Han, Xianbei (鲜卑) elite adopted the trappings of Han civilization, acquiring Chinese writing, administration and methods of government (Chen, 1931, 2002). "Xianbei-ization" (*Xianbei hua* 鲜卑化), later emphasized by Dien (Dien, 2007), argued that Xianbei culture was for its part also consciously promoted, Xianbei surnames maintained among the elites, and Han peoples occasionally Xianbei-ized through surname adoption. Beyond defining hybridization, recent scholarship has also examined the ethnic diversity of this period from the "multicultural" perspective (Corradini, 2004).

Archeology, however, which lends itself to the study of ethnicity and identity (Jones, 1997), has made limited contributions to this debate. Yet what has been written suggests the risks of taking either side of the Dien/Chen debate. Examining the frequency of Xianbei or Han elements in regional burials, Wu stresses that alternating processes of Xianbei-ization or Han-ization operated in specific contexts and periods (Wu, 2010). Overall, the lack of quantitative archeological work is surprising given the dramatic shifts in Northern Dynasty capitals, tomb culture and general manifestation of archeological evidence that would provide further insight.

This essay is the first effort to use robust scientific-archeological data for medieval foodways to provide quantitative dietary data on this controversial subject. Set against the backdrop of the Northern Wei relocation to the Central Plains from the near-steppe region of Pingcheng (平城) in AD 493, we examine dietary variation in both elite and commoner populations in the Chang'an (长安) area around the sixth century AD. By improving our knowledge of changing foodways and ethnic identities at both elite and non-elite levels, we apply a new archeological narrative to the conceptualization of Han and non-Han Northern Dynasties identity. In doing so, we reveal a more complex process of hybridization at separate elite and commoner levels, with movement from Han to Xianbei lifeways and vice-versa dependent on social levels and often hinging on distinct life trajectories.

This essay uses the carbon (C) and nitrogen (N) stable isotope analysis of osteoarcheological materials during around Northern Zhou period (北周, AD 557–581). Isotope analysis is a scientific-archeological technique that allows inferences on the diets of prehistoric or archeological-historical individuals (e.g. Hu, 2018; Liu et al., 2021). This makes stable isotope analysis, in combination with faunal and floral evidence, a powerful tool in the reconstruction of dietary stability as well as social practice (e.g., Eriksson, 2013). Over the past decades, stable C, N isotopic measurement has been performed on several Xianbei humans recovered from the burials of unidentified individuals in Shanxi and Inner Mongolia, dated fourth–fifth centuries AD (e.g., Zhang et al., 2015, 2017). The subsistence strategies of these groups (Tuoba Xianbei (拓跋鲜卑), among others) have been identified as demonstrating a marked shift from a primarily pastoral/hunting to a predominantly agricultural lifestyle, following large-scale migrations from the northeast Asian steppe to the Loess highlands and Central Plains of northern China (Zhang and Yi, 2022). However, stable isotope analytical work that might reflect the complexity of dietary profiles among special status groups, such as the emperors, empresses and other noble individuals who occupied the highest echelons of society, resident in the medieval capital of Chang'an (in modern-day Xi'an), a crucial century in the history of medieval China, has been distinctly lacking.

Our project began with work on skeletal material pertaining to the Northern Zhou Emperor Wu (北周武帝) and his consort, Empress A'shina (阿史那皇后), who were originally from the Mongolian Steppe. These remains were examined alongside material from six other non-Han and Han nobles (Fig. 1). We extracted the collagen required for stable isotopic analysis from these eight noble individuals and three domesticated animals buried with Emperor Wu (Table S1), and included in our study nine contemporaneous commoner burials from the Jichang II ($n = 6$), near Chang'an (Fig. 1; Table S2), as well as Zhaijiasi ($n = 2$) and Sunjianantou ($n = 1$) cemeteries located in the west of the Guanzhong Basin (Fig. 1; Table S2). To broaden the geographical and dietary range of this study, we then proceeded to compile a secondary database of human stable isotopic data ($n = 1233$) from across north China and neighboring regions (Fig. 2; Table S3) for the period 550 BC–1200 AD (2570–820 B.P.). This combination of original and collected data, we anticipated, would provide insight into the long-term dietary practices of Northern Zhou royals, nobles and commoners resident around Chang'an, which had become a core region of medieval Imperial China around the sixth century AD. These results would speak to our understanding of the degree social and cultural diversity and interaction (e.g., Xianbei-ization or Han-ization). In turn this would demonstrate how medieval Chang'an contributed to the character of the subsequent imperial capital of the Sui and Tang dynasties during the critical sixth century.

Archeological background

The medieval capital of Chang'an lies beneath the modern city of Xi'an in the Guanzhong Basin, southern Shaanxi. This area served as a capital regions from Western Wei (西魏) through the Sui and Tang Dynasties (AD 535–907). Thousands of tombs, spanning the Northern Dynasties through Tang Dynasty (AD 439–907), have been excavated in the area in recent decades. These include 70 large or noble burials since the year 2000 alone (Liu, 2015). The present study works with materials from eight noble and nine commoner individuals found at burials in the Guanzhong Basin, as well as three domesticated herbivores sacrificed in the tomb of Emperor Wu and Empress A'shina (Figs. 1, 3, 4; Tables S1 and S2), all dating to medieval Chang'an's Northern Zhou and Sui period, *circa*. sixth century AD.

The Xiao Mausoleum of the Emperor Wu of the Northern Zhou Dynasty

The tomb of Emperor Wu of the Northern Zhou Dynasty, Yuwen Yong (宇文邕) (AD 543–578) and Empress A'shina (阿史那皇后) (AD 551–582) lies in Chenma County (34.47°N, 108.82°E), Xianyang, north of Xi'an (Fig. 1). First identified in 1993, this Imperial Mausoleum was excavated by the Shaanxi Provincial Institute of Archeology and Xianyang City Archeological Institute from 1994–1995. Oriented south and running a total length of 68.4 meters (Fig. 3), the Xiao Mausoleum was found to contain

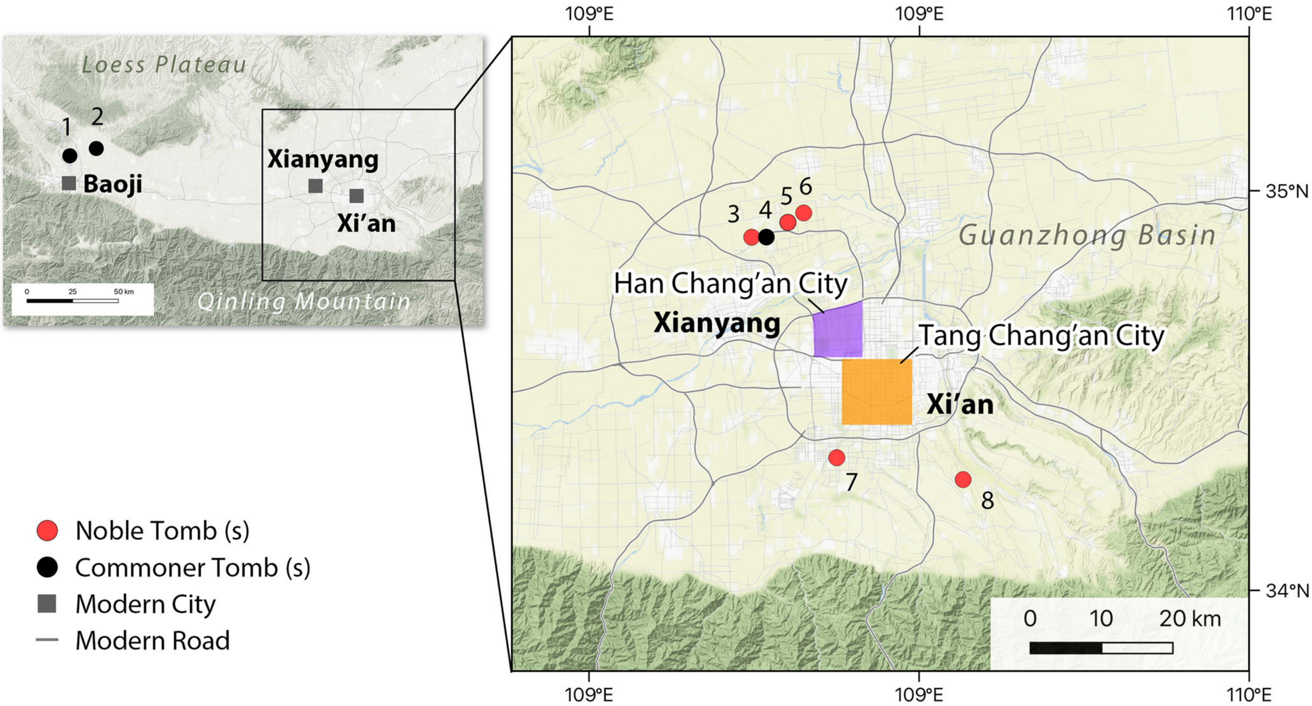


Fig. 1 Location of the noble and commoner cemeteries used in this study. 1. Sunjianantou cemetery 2. Zhaijiasi cemetery; 3. Tomb of Yuan Wei and Yu Yirong; 4. Jichang II cemetery; 5. Tomb of Dugu Bin; 6. Xiao Mausoleum of Emperor Wu (Yuwen Yong) and Empress A'shina; 7. Tomb of Li Yu; 8. Tomb of Princess Huihua and General Qifu Xiaoda.

diverse and valuable burial objects, including 150 pottery figurines, 35 pottery models, 2 bronzes and 2 tomb epitaphs (Fig. 4; SPIA & XIA, 1997). Yuwen Yong was the third Emperor of Northern Zhou. Known as a resolute and wise leader, during his 19 year reign (Fig. 4a) Yuwen married Empress A'shina, daughter of Muhan Khagan of the Göktürks, A'shina Yandu (木杆可汗阿史那燕都), thereby securing Göktürk military support against the Northern Qi to the east. Discovery of the Emperor Yuwen Yong's epitaph (Fig. 4b, c) and the Gold Seal of the Tianyuan Empress Dowager (Fig. 4d) on-site provided positive identification of their joint burial, as recorded in the *Book of Zhou* (Linghu, 1971). The Xiao Mausoleum, a typical Northern Zhou royal tomb, provides an important reference for other noble burials explored in this study.

The Tomb of Princess Huihua and Qifu Xiaoda

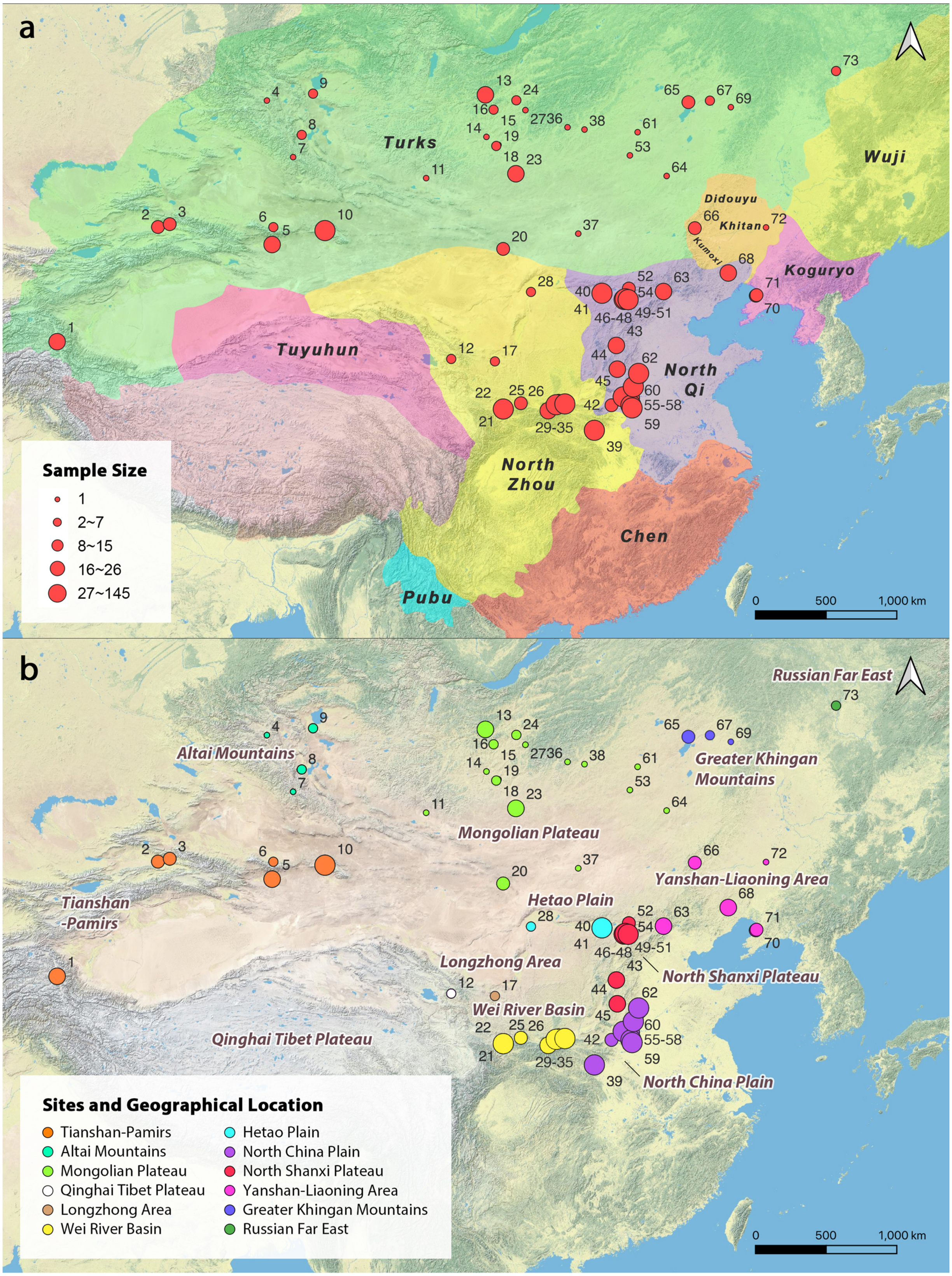
From 2014–2015, the tomb of Tuyuhun Princess Huihua (晖华公主) (AD 503–541) and her husband, Senior General Qifu Xiaoda (乞伏孝达), was uncovered at Guozhuang Village in Dazhao Sub-district of Chang'an District of Xi'an (34.15°N, 109.06°E), and excavated by the Shaanxi Provincial Institute of Archeology (SPIA et al., 2019) (Fig. 1). At 42.3 m in length, the tomb contains four ventilation shafts, four openings and a single niche (Fig. 3). The excavation report includes 141 pottery figurines, 7 pottery models, 5 pottery wares, 5 bronze wares, 1 iron object, 7 porcelains and 2 epitaph stones (Fig. 4e), evidence for the tomb occupant's high status. These epitaphs declare Princess Huihua as the fourth daughter of Mingyuan, King of Tuyuhun (吐谷浑王明元) (Luo, 2020). Her husband, Qifu Xiaoda, titled Cavalry Generalissimo of the Rouran (茹茹骠骑大将军), was highly regarded by King Mingyuan, who acquiesced to Qifu's marriage with the Princess during Qifu's period of service with the Tuyuhun. The couple returned to life among the Rouran (who occupied the Mongolian Steppe during the mid-fourth to the mid-sixth century AD) for an extended period prior to their relocation to and brief ensconce at Chang'an, where the Princess died. Princess Huihua and General Qifu can be considered representative of a high nobility with extensive steppe backgrounds. Theirs is the first Tuyuhun tomb dated to the Western Wei period found in the Xi'an region. Skeletal material from these individuals provides crucial archeological materials for understanding the dietary history of elite pastoralists during the Northern Dynasties.

The Tomb of Yuan Wei and Yu Yirong

The joint burial of Yuan Wei (元威) (AD 538–590) and his wife Yu Yirong (于宜容) (AD 544–601), excavated by the Shaanxi Provincial Institute of Archeology and Xianyang Archeological Institute in 2010, is located at Buli Village in Dizhang District, Xianyang (34.44°N, 108.75°E) (Fig. 1). The tomb is 23.2 m long, and features a ramped entrance and three ventilation shafts (Fig. 3). The section of a stone epitaph, along with a few pieces of pottery, porcelain, iron objects, shells, bronze mirrors, and bronze coins in typical Sui Dynasty style, were recovered from the tomb (SPIA & XIA, 2012). Yuan Wei is recorded as a Xianbei minister who served the Northern Wei and Sui, and a descendant of Emperor Zhaocheng (昭成) of Northern Wei, Tuoba Shiyijian (拓跋什翼犍) (Fig. 4g). His wife, Yu Yirong, descended from Northern Wei nobility. Despite this noble pedigree and residence in the Guanzhong Basin, Yuan Wei held only a middling (Third/Fourth tier) official rank.

The Tomb of Dugu Bin

The tomb of Dugu Bin (独孤宾) (AD 504–571), excavated by the Shaanxi Institute of Archeology in 2007 (SPIA, 2011), is located at the Longzao Village in Dizhang town, Weicheng District, Xianyang City (34.46°N, 108.81°E) (Fig. 1). This tomb has a 14.5 m ramped entrance and three ventilation shafts, and runs for a total length of 32.7 meters (Fig. 3). Looted several decades back, only



28 funerary objects were recovered from the tomb by archeological workers. The newly unearthed epitaph of Dugu Bin (Fig. 4f), combined with literary evidence on the *Book of Zhou*, shows that Dugu Bin was originally Gao Bin (高宾), a traditional Han family name. Precocious and adept at both literature and military affairs, Dugu spent his early career in the employ of the Eastern Wei before he fled to the Western Wei with his life threatened. Gao was then awarded the Xianbei surname Dugu. His son, Gao Jiong (高颎), rose to the rank of Prime Minister in the early Sui Dynasty (Linghu, 1971; Wei, 1973).

Fig. 2 Sites yielding human C, N isotopic data in different areas of northern China and surrounding regions, 550 BC–AD 1200 (2570–820 B.P.). a Map of the extents of different states in early China around AD 572, the red circles are the location of analyzed sites (see Table S3); **b** Location of sites and geographical location (1. Jirzankal; 2. Goukou; 3. Qiongkeke; 4. Atsyn Gol; 5. Yanghai; 6. Shichengzi; 7. Khoit Tsenkher, Tarvagatain Am; 8. Shombuuzin Belchir; 9. Chandman Mountain; 10. Heigouliang; 11. Bayankhongor aimag; 12. Shangsunjia; 13. Egiin Gol; 14. Emeel Tolgoi; 15. Burkhan Tolgoi; 16. Tamityn Ulaan Khoshuu; 17. Huangwan; 18. Uguumur; 19. Ikh Tokhoirol; 20. Bayanbulag; 21. Lixian; 22. Xishan; 23. Baga Gazaryn Chuluu; 24. Buural Uul; 25. Jianhe; 26. Fenggeling; 27. Atsyn Am; 28. Nalintaohai; 29. Guanzhong Jianyu; 30. Jichang; 31. Guandao; 32. Guangming; 33. Lintong; 34. Shanren; 35. Liyi (Wanli); 36. Jargalantun Hundii; 37. Sant Uul; 38. Duulga Uul; 39. Shenmingpu; 40. Tuchengzi; 41. Dabaoshan; 42. Tumen; 43. Xiaonanzhuang; 44. Tunliu Yuwu; 45. Xuecun; 46. Dongxin Square; 47. Huayu Square; 48. Nanjiao; 49. Yuchang Jiayuan; 50. Shuibosi; 51. Datong cemetery; 52. Bagou cemetery; 53. Delgerkhaan Uul; 54. Sandaowan cemetery; 55. Changxinyuan; 56. Xinzheng City; 57. Xiyasi; 58. Xinghong; 59. Dashengzhao; 60. Laodaojing; 61. Naimaa Tolgoi; 62. Gu'an Tomb; 63. Xitun; 64. Baruun Khovdiin AM; 65. Zhalainuoer cemetery; 66. Linxi Dajing; 67. East Wuzhuer cemetery; 68. Lamadong; 69. Tuanjie cemetery; 70. Bayuquan; 71. Tianrui Cement Plant; 72. Tuerji Mountain Tomb; 73. Mohe).

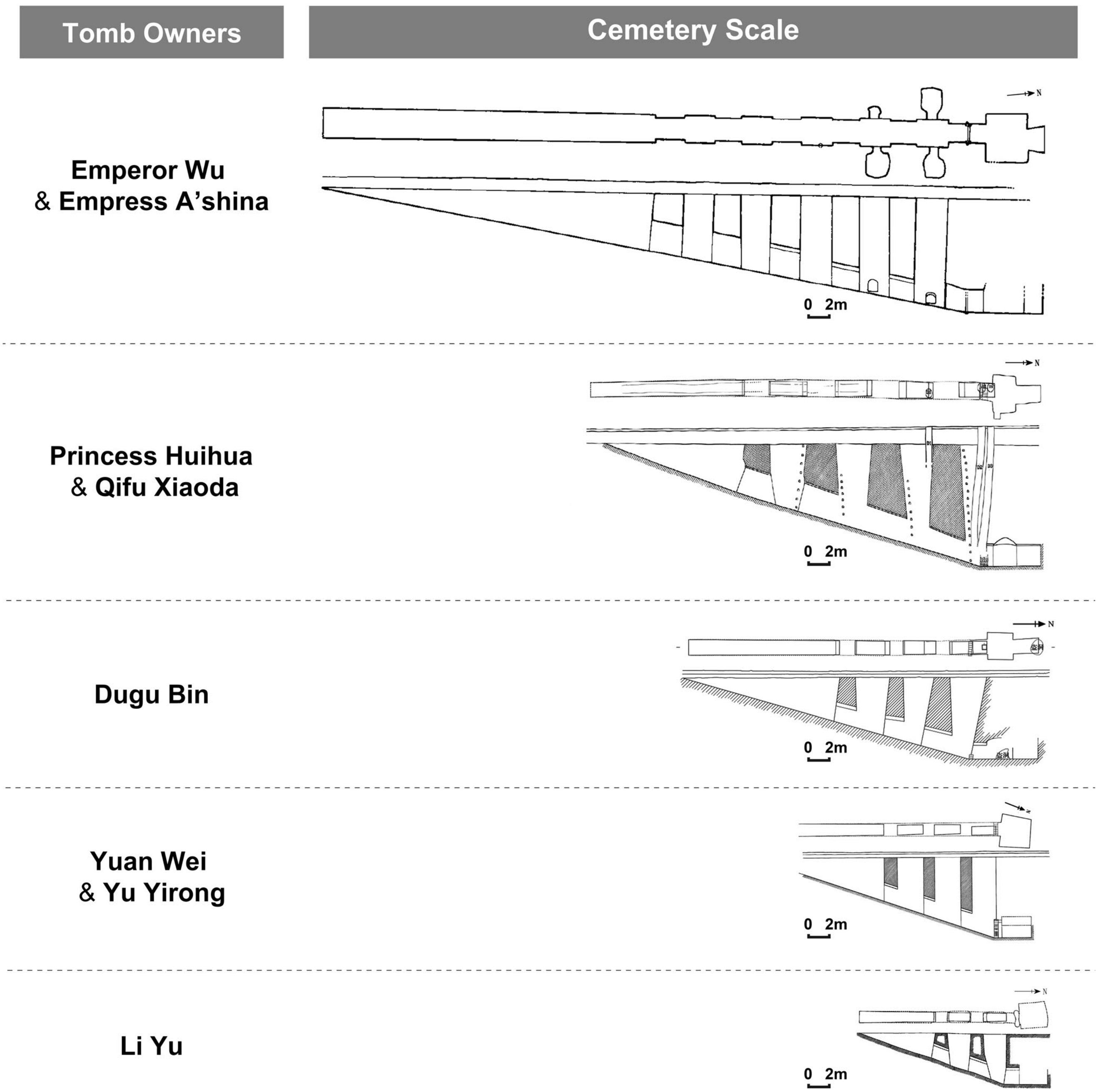


Fig. 3 The dimensions of noble cemeteries seen this study.

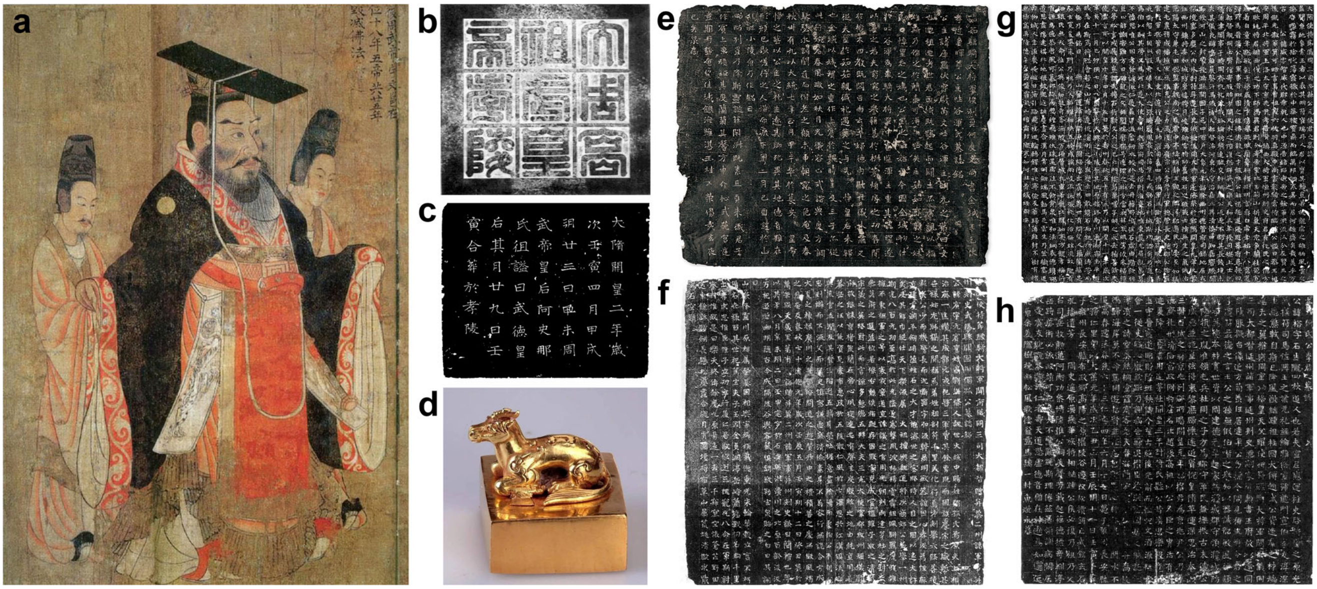


Fig. 4 Portrait and burial objects with written records from sampled noble tombs in the Guanzhong Basin during around the sixth century. a Portrait of Emperor Wu; **b** Epitaph seal-cover of Emperor Wu; **c** Epitaphs of Empress A'shina; **d** Gold Seal of Tianyuan Empress Dowager (A'shina); **e** Epitaph of Princess Huihua; **f** Epitaph of Dugu Bin. **g** Epitaph of Yuan Wei; **h** Epitaph of Li Yu.

The Tomb of Li Yu

The tomb of Li Yu (李裕) (AD 542–604), located at Guodu country, in the southern suburbs of Xi'an, lies seven kilometers from the former Sui capital at Daxing city (34.16°N, 108.87°E) (Fig. 1). Excavated by archeologists from the Shaanxi Provincial Institute of Archeology in 2006 (SPIA, 2009), the tomb is a single-chamber earthen cave tomb, with a passage 7.28 m in length, facing south and featuring a ramped entrance and a pair of ventilation shafts (Fig. 3). The epitaph (Fig. 4h) states that tomb-owner Li Yu saw duty as a Metropolitan Governor (京兆尹) and Duke of Yishi County during the Sui Dynasty. His grandfather, Li Bi (李弼) one of the "Eight Pillars of the Northern Zhou State" (北周八柱国), was an enormously successful general and right-hand man to Emperor Yuwen Tai himself (宇文泰). This ancestry probably guaranteed high office for Li, but his own political career was apparently uninspiring. Li Yu's tomb is relatively ordinary in form and scale—suggesting an average rather than high nobility.

Tombs of commoner

Sampled human bones of commoners living in the Guanzhong Basin during Northern Zhou to Sui-Tang period were collected from three cemeteries: Jichang (Airport) II cemetery ($n = 6$), Zhaijiasi cemetery ($n = 2$) and Sunjianantou cemetery ($n = 1$). The Jichang (Airport) II cemetery (34.44°N, 108.76°E) in Xianyang, near Chang'an (Fig. 1), was excavated during the 50 s and again at the turn of the 1980s, revealing in both cases a large number of Northern Zhou, Sui and Tang burials. Renewed excavations in from 1999–2000 and from 2008–2011 under the auspices of the Shaanxi Institute of Cultural Relics and Archeology also revealed high-ranking and commoner Northern Zhou, Sui and Tang burials. Further excavation in 2020–2021 uncovered a handful of burials from the pre-Northern Dynasties Period, along with 77 Northern Dynasties burials and a total of 17000 artifacts. The number of burials at Jichang II and the consistent use of this site suggests information from the cemetery is representative of commoner and elite burial culture at the capital region during these centuries.

The Zhaijiasi cemetery (34.51°N, 107.40°E) is located in around Zhaijiasi Village, Fengxiang County, Baoji, in the west Guanhzong Basin (Fig. 1). Here archeologists from the Shaanxi Institute of Cultural Relics and Archeology excavated ten small-sized commoner burials in 2011. Of these, eight tombs were identified as dating from the Northern Zhou to Sui and Tang dynasties, based on the cultural styles of the burial objects. The Sunjianantou cemetery (34.48°N, 107.24°E) lies in the modern village of Sunjiatanantou, Fengxiang County, Baoji City (Fig. 1). 191 ancient tombs and chariot-and-horse burial pits were excavated by a joint archeological team consisting of Shaanxi Institute of Cultural Relics and Archeology, the Archeological Team of Baiji City and the Fengxiang Museum from 2003–2004. The main archeological findings consisted of small and medium-sized commoner burials from the Zhou, Qin and Han dynasties and later historical periods.

Methods

Isotopic analysis. We collected a total 23 human skeletal samples from the Guanzhong Basin (Table S4). These samples, which included eight nobles and nine commoners dated from the period *circa*. 500–600 AD, and were used to extract our stable C, N isotopic measurements. We extracted collagen using protocols outlined in Richards and Hedges (1999). We modified the protocol to include a final stage of ultrafiltration prior to lyophilization, as outlined in Brown et al. (1988). The purified collagen was measured at the Environmental Stable Isotope Laboratory (ESIL), Institute of Environment and Sustainable Development of Agriculture, Chinese Academy of Agricultural Sciences (CAAS), using an IsoPrime 100 IRMS (Elementar, UK) coupled with an Elementar Vario (Elementar, UK), and calibrated with USGS40, USGS41a as reference materials. The isotope results were analyzed as the ratio of the heavier isotope to the lighter isotope ($^{13}C/^{12}C$ or $^{15}N/^{14}N$) and expressed as 'δ' in parts per mil (‰), following internationally defined standards (Lee-Thorp, 2008). For carbon (Vienna Pee Dee Belemnite, VPDB) and gaseous nitrogen (Ambient Inhalable Reservoir, AIR), we used two-point calibration. Measurement errors were under ± 0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$ values.

In addition, three domesticated animal samples (Table S4) including sheep, cattle and horse long bones buried in the Xiao Mausoleum of the Emperor Wu and Empress A'shina of the

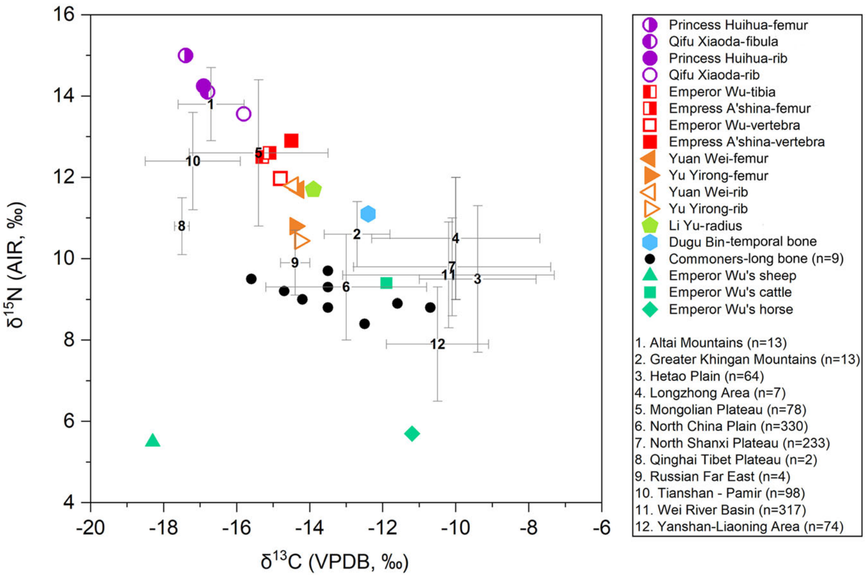


Fig. 5 New δ^{13}C and δ^{15}N values of human and animal samples recovered from the Guanzhong Basin and the mean ± SD δ^{13}C and δ^{15}N values of previous human samples from 73 sites in Northern China and surrounding regions during around 550 BC–AD 1200 (2570–820 B.P.) (Atahan et al., 2014; Dong et al., 2007, 2017; Gu, 2007; Guo et al., 2020; Hou et al., 2012, 2017, 2019; Hou & Gu, 2018; Li et al., 2020; Ling et al., 2010, 2019; Ling, 2010; Liu et al., 2021; Ma et al., 2016a, b; Machicek, 2011; Pan et al., 2009; Sheng et al., 2020; Si et al., 2013; Tang et al., 2018; Tao et al., 2020a, b; Wang et al., 2016; Wang et al., 2018; Wilkin et al., 2020; Xue, 2015; Zhang, 2003; Zhang, 2006; Zhang & Li, 2006; Zhang et al., 2009; Zhang et al., 2010; Zhang et al., 2012; Zhang et al., 2013, 2015, 2017; Zhang Q et al., 2018; Zhang X et al., 2018; Zhang, 2019; Zhou, 2016; Zhou et al., 2017; Zhou & Mijiddorj, 2020; Zhou et al., 2020; Zhu et al., 2020).

Northern Zhou Dynasty were sent to Beta Analytic Inc., Miami, Florida, USA, for δ^{13}C and δ^{15}N isotopic analysis with C/N (%C, %N and C:N) measurement using standard method. Measurement errors were under ± 0.3‰ and ± 0.5‰ for δ^{13}C and δ^{15}N values, respectively.

Results

Our new stable C, N isotope results from our human and animal specimens ($n = 26$) are illustrated in Fig. 5 and detailed in Table S4. All human and animal bones produced good quality collagen, with C:N ratios ranging between 2.9 to 3.6 (DeNiro, 1985; Ambrose, 1990) encouraging further interpretation. We performed further deductions using previously established cut-off values of −18‰ and −12‰ for δ^{13}C, which represent a general threshold from a predominately C_3 to mixed C_3/C_4 diet, and mixed C_3/C_4 to fully C_4 diets (Wang, 2017), respectively.

The sheep bones collected from the tomb of the Emperor Wu and Empress A'shina yielded the lowest δ^{13}C and δ^{15}N (−18.3‰, 5.5‰), indicating that this herbivore fed on C_3 plants (primarily wild C_3 grasses and shrubs). In contrast, the cattle and horse bone samples recovered from the same archeological context exhibited a completely distinct dietary pattern. As shown in Fig. 5, both large domesticated herbivores all exhibited ^{13}C-enriched results (−11.9‰ and −11.2‰) indicative of a C_4 diet (mainly from millet crops). The cattle specimen had the most ^{15}N-enriched (9.4‰) results of all the animal studied (5.5‰ and 5.7‰). This individual is an outlier compared to the other two herbivorous animals, having consumed a more nutritious diet. These δ^{13}C and δ^{15}N values of domesticated animals provide us the isotopic baseline for better understanding human dietary lifeways of this period.

In general, the stable carbon and nitrogen isotope ratios of the long bones of humans (e.g., tibia and femur) provide evidence on the long-term diets of individuals for a decade and longer before death. Here, the eight elite individuals' bones exhibited a wide range of both δ^{13}C and δ^{15}N values (−17.4‰ to −12.4‰, mean ± SD = −15.0 ± 1.5‰; 10.8‰; to 15.0‰;, mean ± SD = 12.4 ± 1.4‰; Table S4). This was evidence of a predominantly mixed C_3/C_4-based diet. Along with the marked discrepancy in δ^{15}N values among the three noble couples, this evidence suggests a variety in protein intake across these elite diets, with elevated δ^{15}N levels mainly indicating ingestion of meat and milk products in this context. In contrast, the six commoners from the Xi'an area exhibited relatively low δ^{15}N values (8.5‰–9.5‰, mean ± SD = 9.1 ± 0.3‰; Table S4). A 3.3‰ difference was detected in mean ^{15}N isotope values between the lower-value commoner and higher-value noble group. Similarly, three commoner individuals from the Baoji area in the west of Guanzhong Basin also yielded low δ^{15}N values (8.8‰–9.7‰, mean ± SD = 9.1 ± 0.4‰; Table S4). We therefore estimated that the commoner population in this study experienced considerably poorer nutrition compared to elite groups. While limited discrepancy in commoner δ^{15}N values may also indicate low protein intake, this population displayed wide-ranging δ^{13}C values (−15.6‰ to −10.7‰, mean ± SD: −13.3 ± 1.4‰), suggesting diets would have been oriented around both C_4-based (essentially millet crops) and mixed C_3/C_4-based (probably wheat/barley crops) foods respectively.

Considering that the stable C, N isotopic values of human skeleton associated with a high metabolic rate (e.g., ribs and vertebrae) can record the diets of humans around 3–5 years before death, we analyzed the δ^{13}C and δ^{15}N values of these the ribs or vertebrae remains of these noble couples (Yuwen Yong, A'shina, Qifu Xiaoda, Huihua, Yuan Wei and Yu Yirong) to understand the late life diets of these aristocratic individuals. Utilizing isotopic data from different bones, we were able quantitatively reconstruct the transitions in the dietary practices of these different classes of nobles from early to late life. As can be seen in Fig. 5, there was no marked difference in the C, N isotope data of long bones and ribs among the low-rank nobles Yuan Wei and Yu Yirong. This suggests that their diets probably did not change significantly during their lifetimes. However, two middle-rank nobles of Princess Huihua and Qifu Xiaoda probably adjusted their dietary patterns from early to late life. Specifically, the visibly ^{13}C-enriched results of Huihua and Qifu' ribs suggest that they consumed more C_4 foods (essentially from millet agriculture) with age, and accordingly, the lower δ^{15}N values show evidence of reduced protein consumption, indicating some likely change in dietary lifestyle. Similarly, vertebrae samples from Emperor Wu and Empress A'shina were found to have lower δ^{13}C values compared to long bone samples. This indicates the diets consumed by the highest class of noble individuals were notably influenced by C_4-based proteins (essentially from millets). As for the δ^{15}N values of the emperor and empress, only Yuwen Yong shows a slight decline (0.5‰) in the isotope value of vertebrae, meaning Yong may have consumed less protein in his later years. The slight increase in stable N isotopic values of Empress A'shina implies that her consumption habits of meat and milk foods was consistent through later life.

Additionally, all previously published human collagen C and N isotopic data ($n = 1233$) during 550 BC–1200 AD (2570–820 B.P.) recovered from 73 sites from 12 different geographical areas in northern China and nearby areas (Fig. 2) were plotted in Fig. 5, summarized in Table S5 and detailed in Table S3. In Fig. 5, we see that the 191 archeological human remains—sourced from the Altai Mountains, Mongolian Plateau, Qinghai-Tibet Plateau and Tianshan-Pamir region—yielded relatively low δ^{13}C values, alongside comparatively elevated δ^{15}N values, suggesting considerable intake of C_3-based foods (primarily wheat/barley-based) and animal proteins in the diets of these pastoral groups. On the other hand, the 695 humans from agricultural societies around the Hetao Plains, Longzhong Region, North Shanxi Plateau, Wei River Basin and Yanshan-Liaoning Region exhibit ^{13}C-enriched results and relatively low δ^{15}N values indicative of the consumption of C_4 diets (mainly millets)-based and less animal proteins. In addition, δ^{13}C and δ^{15}N values of 347 humans from the Great Khingan Mountains, Russian Far East and North China Plain suggested consumption of mixed C_3/C_4 diets with some animal protein intake, while 330 individuals from North China Plain exhibited relatively low δ^{15}N values, further hinting at a diet of crop-based foods. Overall, the large number of human isotopic data analyzed suggests the dietary patterns of these archeological site inhabitants in northern China and nearby areas could divide among agro-pastoral and agricultural groups, using the differences in collagen δ^{13}C values δ^{15}N values outlined above.

Discussion

Analyzing the medieval elite, non-elite and animal food networks in the Guanzhong Basin from the perspective of stable isotope analysis, our study shows the complexity of the relationship between food, social status and identity in the sixth century Chang'an region. Comparing our data to previously published historical human bone collagen C and N isotopic data from Northern China and the surrounding regions for the period 550 BC–1200 AD (2570–820 B.P.) also revealed considerable variation in the origins of studied noble and commoner groups (Fig. 5). Most all Xianbei noble dietary habits discussed in this study converged with those of Mongolian Plateau nomadic groups (Fig. 5), while commoner diet tended to converge with agricultural populations in traditionally cultivated regions such as the North China Plain (Fig. 5).

Diet and ethnic identity were connected in different ways between elite and commoner groups. We observed that all noble individuals exhibited significantly higher levels of nutrition compared with commoners (Fig. 5). Diets also varied between nobles: for example, Princess Huihua and Qifu Xiaoda, descended from the grassland steppe (SPIA et al., 2019), exhibited the lowest δ^{13}C values (−16.8‰ and −17.4‰) and highest δ^{15}N values (14.1‰ and 15.0‰), pointing to a high C_3-based plant (essentially wheat/barley crops) and high protein intake in their diets. For Xianbei nobles with longer residency in the Guanzhong Basin, such as Emperor Wu and his Turkic wife Empress A'shina of the Northern Zhou Dynasty (SPIA & XIA, 1997), we found that with increasing status this δ^{13}C value increased to −15.3‰ and −15.1‰, and δ^{15}N values declined from 12.5‰ and 12.6‰ (Fig. 5), suggesting a more millet-wheat/barley mixed diet. As for lower-ranked Xianbei nobles Yuan Wei, Yu Yirong, Li Yu, our new isotopic data indicate dietary patterns closer to Han nobles such as the Dugu Bin (according to unpublished ancient DNA data) and commoner groups resident in the Chang'an area (Fig. 5) (SPIA & XIA, 2012; SPIA, 2009, 2011) thus more in line with Han dietary principles (primarily agricultural). Nobles arriving in the agricultural regions of the Central Plains, while maintaining a primarily pastoral lifestyle, adjusted in the practice of their noble duties. The fluctuation from pastoral norms among the lower nobility may have been larger than for higher-ranking nobles and Emperors.

Differences in the new isotopic results for the three noble groups varied among couples (Fig. 5). Individuals from the same region should in principle exhibit identical base stable isotope values. Yet the δ^{15}N value of Princess Huihua was above that of her husband Qifu Xiaoda, despite both originating among the Tuyuhun (吐谷浑)—suggesting a higher protein intake and possibly higher status for the Princess (Luo, 2020). Moreover, as elite pastoralists from the steppe areas relocated to Chang'an in later life, the Princess Huihua and Qifu Xiaoda were accordingly influenced by a stronger degree of millet-based agricultural food production. Yuan Wei also demonstrates improved nutrition when compared with his wife Yu Yirong using these parameters. In contrast, despite the wide geographical variation in their origins, with Emperor Wu (Yuwen Yong) growing up in the Guanzhong Basin and Empress A'shina on the Mongolian Steppe, their dietary habits appear almost identical (Fig. 5). We know from historical records that Empress A'shina was received personally by Emperor Wu upon her arrival in the Guanzhong Basin and treated by the Emperor with great respect thereafter (Linghu, 1971). The elevated δ^{15}N value in the vertebrae of A'shina compared to the isotopic data of long bones, suggesting that she enjoyed and further improved her pastoral-based dietary lifestyle after living in Chang'an. Perhaps the textual and archeological evidence converge in this case, with dietary similarity and degree of proximity we could expect of a married couple going hand-in-hand. According to our new data, we also believe that the Xianbei emperor, Emperor Wu of the Northern Zhou, was profoundly influenced by a mixed pastoral-agricultural economy in terms of foodways, as his long residency in the Guanzhong Basin embracing and promoting the political and cultural system of the Han.

Figure 5 shows the marked variation in δ^{13}C value of commoners in the Guanzhong region, from a minimum value of −15.6‰ to a maximum value −10.7‰, and an average value of −13.3 ± 1.4‰. This indicates a mixed C_3/C_4 diet, and indirectly points to widespread production of both millet and wheat/barley crops. The variation probably results from two separate phenomenon: the ongoing introduction of non-Han individuals and admixture of crops and dietary lifestyles in the centuries following the collapse of the Eastern Han, alongside shifting government policies towards sectors of the agricultural economy in the core regions of medieval Imperial China. Historical records mention the requisition of millets from four Guanzhong prefectures (*Bin, Jing, Dongqin,* and *Qi*) as victuals for the Western Wei army (Linghu, 1971), suggesting the contemporary predominance of millet crops. Theft of millets was specifically mentioned in a memorial during the reign of Emperor Ming (宇文毓, Yuwen Yu), which suggested that "all investigations should be invalidated now that an extended period of years and months has passed" (*nian yue ji yuan, yi bu xu wen*; Linghu, 1971). Both records point to a degree of government ownership over millet crops. Beset by multiple years of failed harvests in the early sixth century AD, however, Emperor Wu would re-instate private ownership of millet and wheat (Linghu, 1971). The mention of both millet and wheat/barley crops in this degree suggests their wide dispersal across the Guanzhong Basin. In other words, a large volume of non-native wheat/barley crops (C_3 plants) was introduced to the Wei River Basin in these centuries, possibly as a result of massive agro-pastoralist migration. this reached new heights of penetration in Guanzhong agriculture, previously dominated by millet-based farming (Liao et al., 2022). This strengthened the complex interplay of agropastoralism during this period at both an elite and commoner level.

The variation of dietary practices at both elite and commoner levels as shown in stable isotope evidence corroborates with a notion of complex, interlocking and fluid Xianbei/Han identity (Chen, 2002). This fusion was often a laboratory for conflict. When the Northern Wei Emperor Xiaowen (拓跋宏, Tuoba Hong) had first relocated to Luoyang in AD 495, resulting Han-Xianbei tensions are thought by some to have precipitated the dynasty's downfall. Expressing reverence for Confucianism and even attempting to suppress 'foreign' Buddhism, while granting Han individuals the right to enlist in the previously exclusively Xianbei ranks of the dynasty's army, Emperor Wu of the succeeding Northern Zhou continued to engage with Xianbei or pastoral lifestyle and cultural sensitivities, while defusing the tensions of Han/Xianbei conflict. Xianbei elite chose a multilayered Han-Xianbei identity at their political convenience and for the sake of survival—and with it found some success negotiating the tensions of competing Han and Xianbei worlds. Moreover, we have shown the variety of backgrounds and dietary practices of elite and non-elite worked to achieve a similar fusion on both elite and non-elite levels that may have been just as fluid, especially around the Chang'an capital. This inclusivity was underscored culturally by Xianbei/Han overtures towards the "Turks in the capital, who were treated with gifts, and those who ate meat and clothing were often lavished with gifts of thousands of cash"—as well as through continued intermarriage (Lewis, 2009). Our new isotopic data allows us to argue the Han-ization or Xianbei-ization as ethnic boundaries were both shifting and arguably recast by the intense political, social and spiritual interactions as well as between pastoralist and agriculturalist and between elite and commoner at more mundane levels, and suggests new processes in the porous ethnic borders in north China during this period.

Overall, despite maintaining the fundamentals of their pastoralist lifestyles, pastoralist elite migrants to the Chang'an region were affected by agricultural foodways, with lower elites seemingly experiencing more profound dietary changes. Commoners, on the other hand, who may have maintained agricultural and pastoral lifestyles previously, were introduced to mixed wheat and millet-based crop farming as a result of elite migration and policy making, with subsequent impacts on commoner dietary regime. Han and non-Han two-way interactions distinguish this period and make it a crucial century in the study of medieval China (Tanikawa, 2004). Whether noble, or commoner, if this hybridization laid a deep social foundation for the prosperity of the Sui and Tang, we argue that this base had much to do with dietary variation and the movements and integration of different ethnic groups that stood behind it, operating at both elite and commoner levels in the political center of medieval northern China.

Conclusion

The debate on Sinicization/Xianbei-nization in the Northern Dynasties originated with Chen Yinke's observation on the Han-ization of Xianbei elites, who migrated in large-numbers to form the Northern Wei capital. Our study of noble and commoner diets around Chang'an in the subsequent Northern Zhou period in the sixth century AD shows how vital understanding the foodways of Han and Xianbei can be for adding a spoonful of nuance to this debate. Xianbei nobles adopted a more agricultural diet to varying degrees, living on a spectrum from Han-ized to Xianbei-ized, and possibly reversing this approach in certain periods. Diets may have consciously tailored to match their newly acquired political status within a complex process of Xianbei and Han hybridization within an evolving Northern Zhou court. Commoners, whether through conscious decision and a strategy of engagement with a reinvigorated Silk Road economy, or through political events that uprooted large populations during these centuries, exhibited even greater variety in their dietary practice. The study of foodways thus both shows internal variety in the elite spectrum, while pointing to the dual-nature of hybridization at both the elite and non-elite level. With the observations and deductions in this essay, we may also begin to ask to what degree Sui-Tang culture—a key component of Chinese history—was grounded in the multilayered fusion and continued hybrid remolding of the Han/Xianbei element under a complex and diverse set of identities, one that later re-combined in the cosmopolitan, seventh century Tang.

Though stable isotope analysis has plenty to tell us about classic Sinological debates and is a promising avenue for future research combining archeological and historical approaches, our current approach stands in need of an expanded set of commoner data from the Chang'an area, particularly for the Sui-Tang period (AD 581–907). We also look forward to performing stable isotope analysis of a wide range of crops and animals that could reveal further variety in agricultural and pastoral practices in this fascinating transitional moment.

Data availability

Data will be made available on request. Analysis results are also provided in the Supplementary Information.

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Author contributions

Conceptualization: PS, EA, SW; methodology: PS, SW; Investigation: PS, JZ, DL, HM; Funding acquisition: SW, DL, PS; Project administration: SW, HM, PS; supervision: SW, HM, SH; Writing—original draft: PS, YD, TM, EA; Writing—review & editing: PS, EA, SW. All authors contributed to the article and approved the submitted version.

Competing interests

The authors declare no competing interests.

Ethical approval

We collected 23 ancient human bones and 3 animal bones from archeological sites in the Shaanxi Province of China (Table S4). Approval for their use was curated by co-authors and obtained with permission from the respective provincial archeology institutes in the Shaanxi Province of China (where the samples are collected) that managed these bone samples. The approval and oversight of this study were also provided by the institutional review board at the Ethics Committee for Biological Research at Fudan University.

Informed consent

Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Additional information

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Correspondence and requests for materials should be addressed to Hailiang Meng or Shaoqing Wen.