Archaeological and Anthropological Sciences (2019) 11:6689–6704
https://doi.org/10.1007/s12520-019-00934-0

ORIGINAL PAPER

Osteological evidence of violence during the formation of the Chinese northern nomadic cultural belt in the Bronze Age

Qun Zhang[1,2] · Xuezhou Li[3] · Qian Wang[4] · Hui-Yuan Yeh[2] · Hong Zhu[1] · Yanguo Qin[5] · Quanchao Zhang[1]

Received: 6 December 2018 / Accepted: 28 August 2019 / Published online: 21 October 2019

Abstract

This paper presents the analyses of skeletal remains of the fifth century BC nomads from Jinggouzi Cemetery on the frontier of northern China. The mortality and trauma prevalence of the population are investigated with two projectile injuries with arrowhead embedded on the ilium and vertebra analyzed in detail. The demographic and traumatic profiles show a high risk of mortality at a young age. Macroscopic and microscopic observations on the projectile injuries show no signs of healing, which indicate that they were perimortem trauma and probably the cause of death. Radiography and computed tomography reconstruction provides detailed information about the shape of the arrowhead and the mechanism of the injuries. The bronze arrowheads can be classified as a tri-winged socketed arrowhead and both of the injuries could be not fatal. Based on the shape of the arrowheads and the cultural period, the injured individuals may represent the nomadic invader to the region who fought with locals. During the Late Bronze Age in northern Asia, the immigration due to the climatic changes and demographic pressures may be causally linked to the social conflict in this region and accelerated the formation of the Chinese northern nomadic cultural belt which initiated the beginning of a new era in Chinese history. The analysis of the skeletal remains from Jinggouzi Cemetery enriches the understanding of the process of integration in northern China and cumulatively provides valuable evidence for the reconstruction of the history of east Eurasia.

Keywords Arrowhead injury · Computed tomography · Northern China · Nomadic cultural belt · Conflict · Bronze Age

Introduction

The northern China frontier is an important geographical unit in Chinese history, which covers the eastern section of the Eurasia steppes. During the Bronze Age, agricultural civilizations developed in the south-central Eurasia, while cultures of the North remained nomadic. The ancient northern Chinese frontier was the boundary between these two cultural groups, several nomadic ethnic groups, such as the Huns, the Sushen (transliterated from Chinese textual record), and the Donghu (transliterated from Chinese textual record) who lived in this area and have always played important roles throughout Chinese history. During the Eastern Zhou Period (770–256 BCE), due to climatic changes, the shrinking of natural resources and the increase of demographic pressure led to southbound immigration of the northern nomads along with their nomadic culture. Meanwhile, with the improvement of agricultural technology and productivity in the Central Plains and the increase of population, the northern principalities of the central regime expanded their territories to the north (Ge et al. 1993). As a result, the northern principalities of the central regime, such as Zhao, Qin, and Yan, built the Great Wall along their northern frontier to defend themselves against the invasions of these nomadic populations. This region is termed the ancient Great Wall region and has been defined as a zone of interaction between politically and economically

✉ Yanguo Qin
qinyanguo0987@gmail.com

✉ Quanchao Zhang
anthropology239@163.com

1 School of Archaeology, Jilin University, 2699 Qianjin Ave, Changchun 130012, Jilin, China

2 School of Humanities, Nanyang Technological University, 48 Nanyang Ave, Singapore 639818, Singapore

3 Department of Orthopedics, Qilu Hospital of Shandong University, 107 Wenhua West Road, Jinan 250012, Shandong, China

4 Department of Biomedical Sciences, Texas A&M University College of Dentistry, 3302 Gaston Ave, Dallas, TX 75246, USA

5 Department of Orthopedics, The Second Hospital of Jilin University, 218 Ziqiang St., Changchun 130041, Jilin, China

opposing cultures: nomadic pastoralists and sedentary Chinese agriculturalists (Lattimore 1940; Davis-Kimball et al. 1995; Cosmo and Wyatt 2003; Cosmo 2004; Zheng 2004; Yang 2004). The mixture of these different cultures in this region leads to the formation of the Chinese northern nomadic cultural belt which acts as a vital cultural unit different from the main Central Plains civilization throughout the Chinese history.

Among the nomadic ethnic groups who lived in this region, Donghu are described as nomad warriors who had existed since the Shang Dynasty (c. 1600–1046 BCE) and thrived during the Zhou Dynasty (1046–256 BCE). Donghu invaded the frontiers of principalities of the central regime, such as the Yan and the Zhao to the south during the Warring States Period in Chinese history (Barfield 2006), and had a significant influence on the process of Chinese history. They were then defeated by the Huns in 206 BC and then disappeared in the historical records after having existed for about 1300 years. The survivors scattered and divided into some secondary tribes, such as the Wuhuan (transliterated from Chinese textual record) and the Xianbei (transliterated from Chinese textual record)—the latter of which were the origins of the Khitan and the Mongols.

Currently, there are very few archaeological materials and written records in this region, limiting our understanding of the population history in this region. Therefore, the reconstruction of the process of migration and integration of the different populations in this region can benefit from a multidisciplinary comprehensive research. Through analyzing the skeletal remains unearthed from a suspected Donghu cemetery, the aim of this study is to reveal the demographic structure, trauma prevalence, and mortality risk of this vital ancient population for the reconstruction of the population history from the osteological perspective and, finally, gain a better understanding of the population integration process and pattern during the formation of the Chinese northern nomadic cultural belt.

Material and methods

The description of the Jinggouzi Cemetery

The Jinggouzi Cemetery in Linxi County, Chifeng City, Inner Mongolia Autonomous Region, in northern China (Fig. 1), is located on the north bank of the Xar Moron River and south to the extension of the Greater Khingan Mountains. The surviving spring near the cemetery indicated that the natural environment in this area was suitable for human living. Between 2002 and 2003, with the permission of the State Administration for Cultural Heritage, 58 nomad tombs were excavated by the Research Center for Chinese Frontier Archaeology of Jilin University. According to the clear archaeological strata, and similar tomb structure and funerary styles, this cemetery is considered as a contemporary cemetery designed and constructed intentionally in a short period. After being contextualized under the large archaeological chronological framework of the same region, the funerary styles indicate that the estimated age of this cemetery is approximately 550 BCE, which is supported by the radiocarbon dating of a charcoal sample from one of the tombs (tomb 57) as 2485 ± 45 BP (Wang et al. 2010). A total of 153 individuals were identified among all the 58 tombs, and more than half of the tombs contained multiple individuals (58.6%), in which males, females, and subadults appear mixed and buried at the same time. Besides, although the tombs were thought to be primary interments, almost all of the tombs (92.7%) were intruded and destroyed shortly after they were buried. The human remains especially the torso parts were severely disturbed and distributed on the bottom, indicating early robbery activities (Wang et al. 2010).

The burial objects consisted of bone artifacts, pottery, and bronze wares, among which the fine arrowheads made of deer antler and rough bronze ornaments accounted for the vast majority. Two bronze daggers and nine bronze arrowheads were the only bronze weapons found in this cemetery (Wang et al. 2010). Almost every tomb had livestock skeletons; the main species were classified as horse (*Equus caballus*, 42.86%), cattle (*Bos taurus*, 22.45%), and sheep (*Ovis aries*, 21.43%), and there were other animals like donkey (*Equus asinus*) and canine (*Canis familiaris*) as well. No agricultural tools or swine bones were found in the cemetery, which indicates that the population did not live an agrarian life (Zheng 2004). Multidisciplinary studies indicate that the exotic cultural elements regarding the manner of burial, pottery styles, ornaments, and weapons in Jinggouzi Cemetery are different from the other local archaeological cultures of its age, showing more similarities to elements from the tombs found in Baikal region and northern Asia (Wu 2005; Lin 2003; Cui 2007). Besides, the physical anthropological and ancient genetic studies indicate that the Jinggouzi population showed characteristic traits of northern Asians, distinguishable from the local eastern Asians, while having more genetic similarities with northern nomadic populations (Zhu 2015; Zhu and Zhang, 2007; Wang et al. 2012). All these demonstrate that the Jinggouzi population made an abrupt appearance in this region and were probably to be the intrusive nomads that migrated from a region further north.

The osteological materials from Jinggouzi Cemetery

The specimens of this study were the skeletal remains from all the identified 153 individuals. Among them, two bronze arrowhead projectile injuries on the right ilium and the first lumbar vertebra, respectively, from two individuals were analyzed in detail. The sample coded as 02JLM46:B has been recorded previously but has not been analysed (Eng and

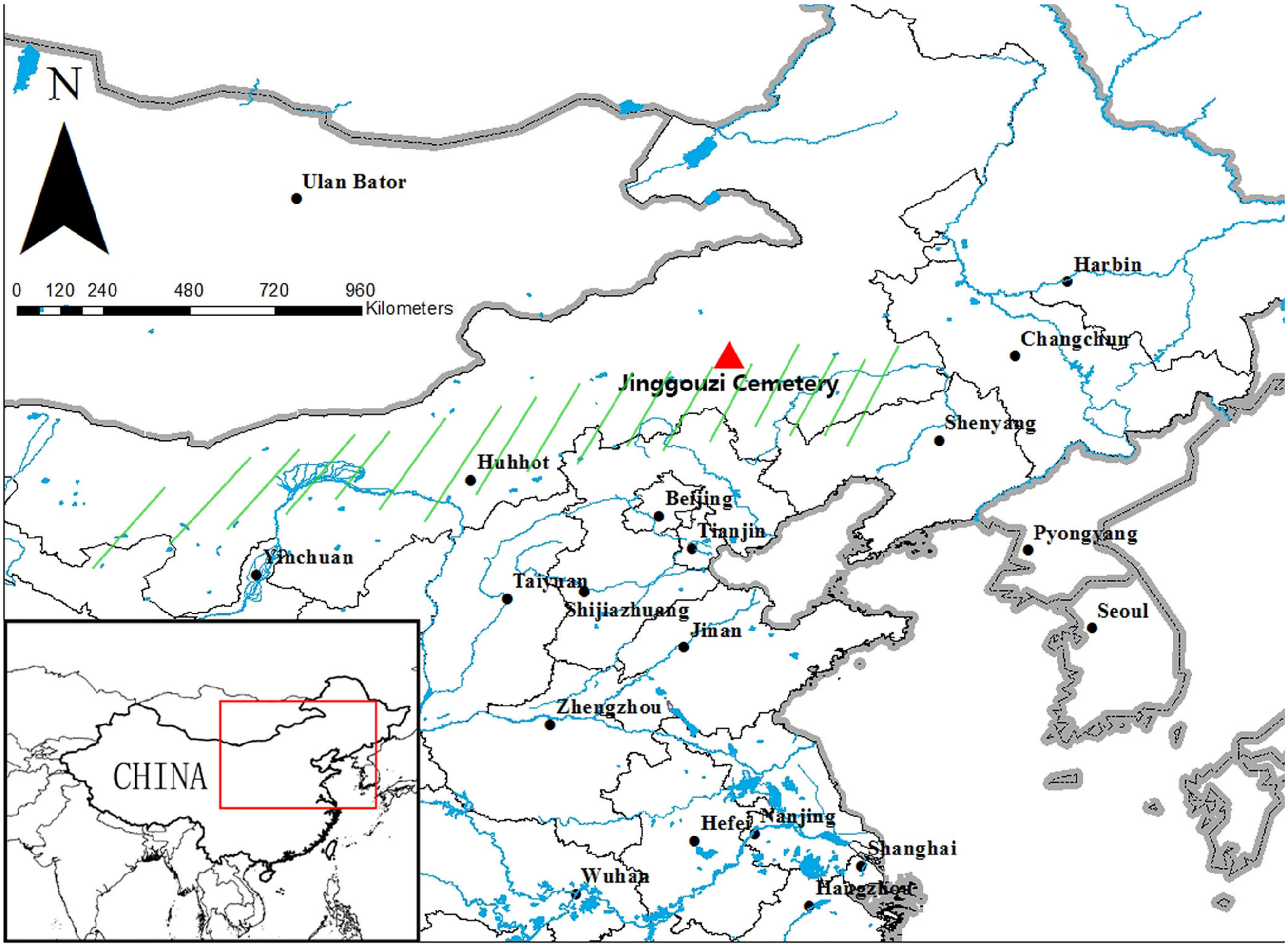


Fig. 1 Geographic location of the Jinggouzi Cemetery. The ancient Great Wall region is marked with green lines

Zhang 2013), and the one coded as 02LJM47:B was newly found among the collections.

Tomb 02LJM46 and tomb 02LJM47 were both vertical pits in shape and did not show any difference from the other tombs. The burial objects were as common as in the other tomb, consisting of pottery jar, several small bronze ornaments, tools, antler arrowheads, and livestock bones except for the bronze arrowheads. Both the two tombs contained multiple individuals which were buried at the same time. Tomb 02LJM46 contained three young males and one child, and tomb 02LJM47 contained one young male, one young female, one child, and an adult of unknown sex. Except for the two individuals with projectile injury, the other individuals showed no traumatic evidence on their skeletal remains. The skeletal remains of the two individuals were incomplete and badly disturbed. The skeletal remains of 02LJM46:B consisted of cranium, clavicles, parts of vertebrae and ribs, pelvis, femora, and left fibula; the skeletal remains of 02LJM47:B consisted of cranium, clavicles, scapulae, vertebrae, ribs, upper limbs, pelvis, femora, and tibiae. 02LJM46:B is a male who died at the age of approximately 20 years old and 02LJM47:B is a female who died at the age of approximately 25–30 years old (Wang et al. 2010).

Comparative contemporaneous populations in this region

The demographic profiles of six contemporaneous populations in this region were selected for comparison. These populations lived in the eastern and middle section of the ancient Great Wall region during the Eastern Zhou Period (770–256 BCE). Archaeological pieces of evidence show that the Maoqinggou Cemetery, the Yinniugou Cemetery, and the Shuiquan Cemetery were multicultural cemeteries, in which the different funerary styles were presented within the same cemetery (Sun 2017; Chen 2008), while the Xindianzi Cemetery and Guoxianyaozi Cemetery were single culture burials (Chen 2008; Zhang 2010). All these populations lived with a mixed subsistence pattern, while herding played an important role in their life. Exceptionally, the Dashanqian Site contained a cemetery and house remains, which belonged to a farming population with secondary lifestyle (Rohn and Barnes 2003).

Methods

The sex and age determinations of the individuals were derived from the on-site identification results in the original report (Wang et al. 2010). The mortality of the Jinggouzi population was calculated in each age cohort and the demographic profiles of the other six contemporaneous populations in this region were cited for comparison. The osteological trauma of the whole population was diagnosed referring to Ortner's (2003) descriptions, and the trauma prevalence was calculated through individual observation. The skeletal traumatic specimens with arrowhead embedded were examined using various scientific techniques. Macroscopic observation focused on the shape, dimensions, location, and state of the trauma, while microscopic observation focused on the edges on the margin of the wound, attempting to detect the extent of healing, if any. The detail of the osteological wound on ilium was observed directly using a three-dimensional (3D) deep-field microscope (VHX-2000 series, Keyence, Japan). Various radiological methods—X-ray (DR KONICA-150) examination and computed tomography (CT) (Philips, Brilliance CT; GE Discovery High Definition 750 CT scanner) scan—were used to obtain the bone radiopacity for new bone differentiating and to ascertain the internal situation of the trauma. Two sets of the modern human CT data were collected from the database of the hospital where the corresponding author is affiliated with under informed consent. 3D reconstruction of the specimens was utilized and superimposed to the normal ilium 3D model to evaluate the relative locations of the arrowheads and the projectile routes and it was further evaluated whether the injury was suffered before death (antemortem), around the time of death (perimortem), or after death (postmortem) (Cattaneo 2007; Lovell 1997; Maples 1986; Sauer 1998). To analyze the arrowheads in a 3D model and further measure their size, we separated the arrowheads from the surrounding bones based on the different grayscale values between the bronze arrowhead and bone tissue. Statistical analyses were performed using SPSS Statistics 20 software (IBM Corporation, Armonk, NY, USA) and Excel 2010 (Microsoft Corp., Redmond, WA).

Results

The mortality of the Jinggouzi population

The demographic pattern of the Jinggouzi population was calculated and compared with the other populations as shown in Table 1 and Fig. 2 (Wang et al. 2010; Tian 2007). The demographic age profile of the Jinggouzi population deviates strongly from that of the comparative populations under study. The mortality of a subadult is as much as 45.1%, accounting for the largest proportion of the entire population. The mortality in young adult period and middle adult A period is 19 and 19.6%, respectively. The mortality in middle adult B period is as low as 3.3%, and no individual survived into old adult age. Compared with other contemporaneous populations in this region, the peak mortality in the other populations are middle adult B, while the proportion of subadults in the Jinggouzi population is extremely high, followed by young and middle adults, demonstrating that the age of death of the entire population is very young.

Table 1 Demographic statistics of the populations in the ancient Great Wall region during the late Bronze Age. The figure represents the number of individuals, and the percentage represents the proportion

	Location	Subadult (< 14)	Young adult (15–23)	Middle adult A (24–35)	Middle adult B (36–55)	Old adult (> 55)	Adult (> 18)
Jinggouzi ($n = 153$)	East section	69 45.1%	29 19.0%	30 19.6%	5 3.3%	0 0.0%	20 13.0%
Maoqinggou ($n = 26$)	Middle section	0 0.0%	5 19.2%	1 3.8%	15 57.7%	5 19.2%	0 0.0%
Yinniugou ($n = 23$)	Middle section	1 4.4%	3 13.0%	3 13.0%	13 56.5%	3 13.0%	0 0.0%
Guoxianyaozi ($n = 20$)	Middle section	3 15.0%	3 15.0%	4 20.0%	6 30.0%	0 0.0%	4 20.0%
Shuiquan ($n = 91$)	Middle section	9 9.9%	12 13.2%	33 36.3%	30 33.0%	0 0.0%	7 7.7%
Dashanqian ($n = 34$)	East section	7 20.6%	5 14.7%	5 14.7%	15 44.1%	1 3.0%	1 3.0%
Xindianzi ($n = 43$)	Middle section	4 9.3%	7 16.3%	13 30.2%	12 27.9%	0 0.0%	7 16.3%

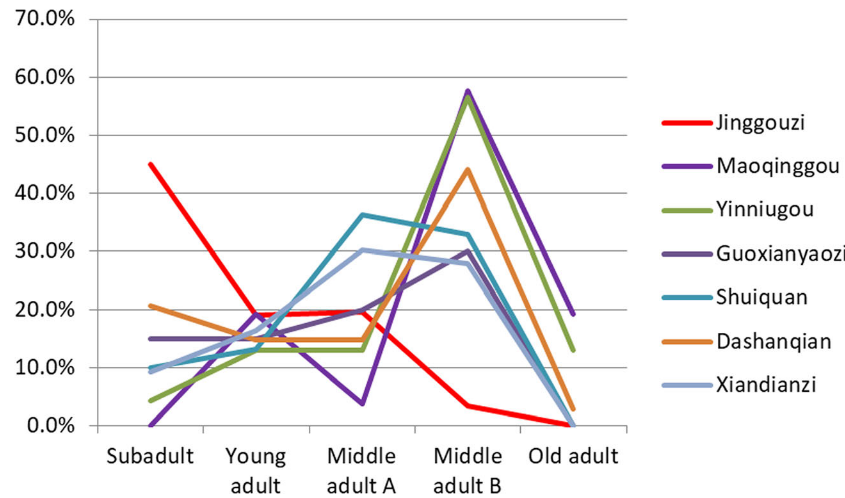


Fig. 2 Mortality distribution of the samples in the ancient Great Wall region

Trauma prevalence in the Jinggouzi population

The basic trauma prevalence of the Jinggouzi population provides us a direct evidence for the understanding of the prehistoric social life in the site. Table 2 shows the details of the individual trauma in the population. A total of 17 individuals in this population can be observed with trauma among the 153 individuals, including 6 males, 10 females, and a subadult with a blunt trauma to the head. In terms of prevalence, among the individuals determined as male, 14.6% showed trauma; among individuals determined as female, 35.7% were injured. The

Table 2 Description of the individuals with trauma in the Jinggouzi population

Label	Sex	Age	Location	Condition
M3:A	Male	25	Right ulna fracture	Healed
			Right tibia fracture	Healed
M15	Male	> 18	Left tibia fracture	Healed
			Left fibula fracture	Healed
			Left ulna fracture	Healed
M46:B	Male	22	Right ilium projectile trauma	Unhealed
M49:A	Male	18–20	Left humerus fracture	Healed
M56:A	Male	22	Right femur fracture	Healed
M58:A	Male	30	Right rib fracture	Healed
M4	Female	35	Right tibia fracture	Healed
M11:A	Female	25	Left ulna fracture	Healed
M17:B	Female	30–35	Right parietal sharp force trauma	Healed
M18	Female	20–25	Left frontal sharp force trauma	Healed
M19:A	Female	25–30	Right femur fracture	Healed
M22:B	Female	25	Left parietal blunt force trauma	Healed
			Left parietal blunt force trauma	Healed
			Left parietal blunt force trauma	Healed
M30:A	Female	25	Left femur and tibia fracture	Healed
M31:B	Female	25–30	Parietal and occipital sharp force trauma	Unhealed
M36:A	Female	> 18	Left rib fracture	Healed
M47:B	Female	25–30	Left parietal blunt force trauma	Healed
			Lumbar vertebra projectile trauma	Unhealed
M12:D	Unknown	2–5	Right parietal blunt force trauma	Unhealed

The bone side of individual M4 is contrary to the description in Eng and Zhang (2013). It was double checked and corrected in the present study. The individual labels are in accordance to the original records

Table 3 Statistics of the prevalence of trauma by individual in the Jinggouzi population

	Male		Female		Unknown		Total	
	Obs./*N*	%	Obs./*N*	%	Obs./*N*	%	Obs./*N*	%
Subadult (< 14)	/	/	/	/	1/69	1.5	1/69	1.5
Young adult (15–23)	3/14	21.4	1/11	9.1	0/4	0	4/29	13.8
Middle adult A (24–35)	2/15	13.3	8/10	80	0/5	0	10/30	33.3
Middle adult B (36–55)	0/3	0	0/2	0	0/0	0	0/5	0
Old adult (> 55)	0/0	0	0/0	0	0/0	0	0/0	0
Adult (> 18)	1/9	11.1	1/5	20	0/6	0	2/20	10
Total	6/41	14.6	10/28	35.7	1/84	1.2	17/153	11.1

Note: Chi-square test: males vs. females, $X = 4.151$, $df = 1$, $P = 0.042$. The females had significantly higher frequency than males

females had a significantly higher trauma prevalence than males (chi-square test: $X = 4.151$, $df = 1$, $P = 0.042$) (Table 3).

Most of the males with trauma died at the young adult and middle adult A phases. However, among females, the traumatic rate of individuals in the middle age A period reaches 80%. In terms of the type and location of the trauma, most of the injured males had traumas on long bones except one in the ilium and one in the rib. Among females, cranial trauma and long bone fractures are the most frequent type in addition to one vertebral projectile injury and one rib fracture, and even some individuals suffered from multiple traumas. Overall, not only is the individual trauma rate higher in females, but the cranial trauma is also more common in females.

Macroscopic and microscopic analyses of the projectile trauma specimens

The projectile trauma of 02LJM46:B is located on the right ilium. A bronze arrowhead is observed embedded into the anterior side of the right ilium immediately between the anterior superior iliac spine and the anterior inferior iliac spine (Fig. 3). The edges of the wound are 27.4 mm from the auricular surface and 73.6 mm from the crista iliaca. The embedded arrowhead is at an oblique angle to the surface of the ilium and has entered the ilium directly in an anterior–posterior direction, descending from the right to slightly left. The wound shows a peeling at the mesial edge, and the cortical bone and trabecular are exposed around the wound. The fragment lost at the mesial edge of the defect suggests that the sharp force penetrated the ilium in a ventral-dorso direction, but not completely perpendicular, with the trajectory relatively oblique with respect to the ilium surface.

The projectile trauma from 02LJM47:B is found on the vertebral column. The arrowhead is located between the 12th thoracic vertebra and the first lumbar vertebra with its tip embedded in the lumbar vertebral body (Fig. 4). The arrowhead has entered the vertebral body posterior–anteriorly, slightly downwards and slightly to the right. The left surface of the spinous process of the 12th thoracic vertebra and the left upper articular surface of the first lumbar vertebra are damaged due to the projection, and the bronze stain can be observed around the trauma. The bone defect and the spongy bone are visible on the upper surface of the lumbar vertebral body around the arrowhead. The two arrowheads outside the

Fig. 3 Macroscopic observation of the injury on the ilium of 02LJM46:B

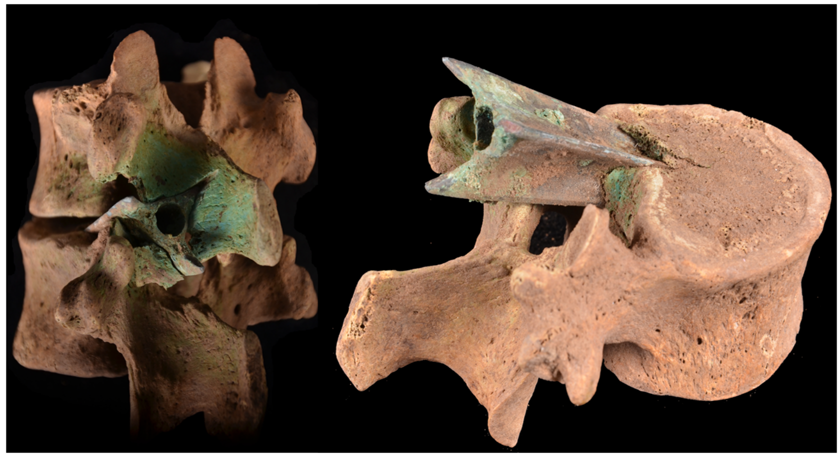


Fig. 4 Macroscopic observation of the injury on vertebrae of 02LJM47:B. Left: The 12th thoracic vertebra and the first lumbar vertebra in original condition; right: the first lumbar vertebra with arrowhead embedded

bone show a similar tri-winged shape with a hole on the axis for installing a shaft. The wings of the arrowhead are sharp-edged and well casted.

The microscopic observation of the ilium wound provides additional detailed information (Fig. 5). On the mesial side of the margin, an incised wound with bevelled edges toward the great sciatic notch is observed, while the cortical bone and trabecular bone are clearly exposed. Additionally, on the superior side, a piece of cortical bone is disengaged outward, while the margin of the wound is sharp and distinct. After the examination of the details on the traumatic margin, it is possible to identify a clearly defined irregular traumatic incision around the outline of the arrowhead from where it entered the ilium. It exhibits no apparent healing signs normally observed postinjury, such as tiny bony spurs or a smooth, rounded bone surface. The sharp margins with visible trabecular around the edges show no sign of bone healing, suggesting that the individual died in a short time after the injury.

X-ray examination and CT analysis

From the X-ray (Fig. 6a), it can be observed that the arrowhead on the ilium is embedded and the bone structure is uniform. There are no erosion or osteoporosis of the bone and no callus formation around the arrowhead. The CT scans of the

Fig. 5 Microscopic observation on the details of the injury on the ilium. Upper: Medial edge view; below: inferior edge view

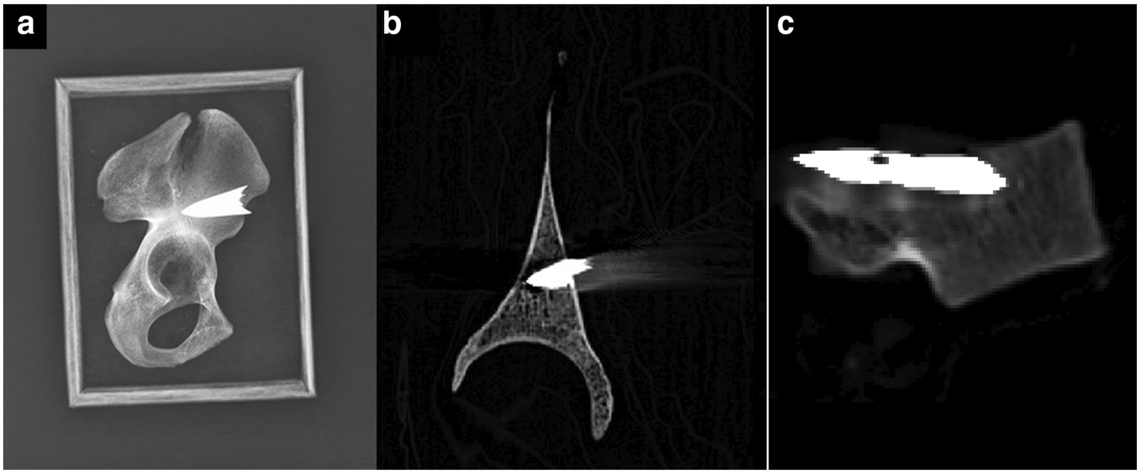


Fig. 6 The X-ray (**a**) and the CT scan image of the ilium (**b**) and vertebra (**c**)

ilium and vertebra (Fig. 6b, c) show that the arrowheads did not fully penetrate the ilium and vertebral body, and the bone density around the arrowheads is homogeneous. No sign of bone absorption and callus formation is observed.

With the CT DICOM data of the scanned specimens, the 3D models are reconstructed by Mimics 16.0 software. In the model for the ilium injury, the main artery is also reconstructed (as shown in Fig. 7). The arrow did presumably not damage the external iliac artery, and this result is conformed to the 2D CT scan contours (Fig. 9). Therefore, this injury may not have caused immediate death. In the model for the vertebral injury (Fig. 7), the arrowhead projected into the vertebral body through the back muscles and spinal canal and may not have caused immediate death as well.

The 3D models of the arrowheads are reconstructed as shown in Fig. 8, and the tri-winged arrowheads' shape is in accordance with the classic style in this region, which was casted and widely used by the local sedentary populations (Shi 2006).

Clinical evaluation of the projectile injuries

Clinically, the injury on the ilium belongs to a penetrating wound caused by a sharp arrowhead through the abdominal wall (Fig. 9). The entrance is located in the right lower quadrant, just medial to the anterior superior iliac spine of the right ilium. The arrowhead penetrates the skin, the external oblique muscle, the internal oblique muscle, the transverse oblique muscle, the transverse fascia, the parietal peritoneum, the iliacus muscle, and the ilium. The important internal organs, such as the cecum or the ascending colon, were very likely injured. This type of wound would have resulted in devastating complications, most likely fatal. To begin with, the penetrating injury would have led to

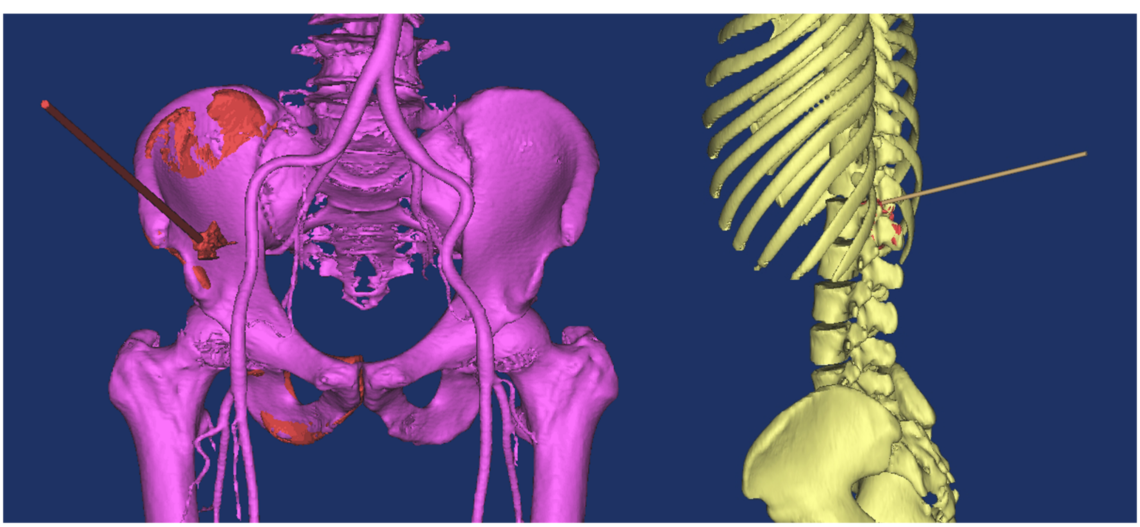


Fig. 7 Reconstruction images of the ilium and vertebra superimposed to the modern model. The red parts are the original specimen

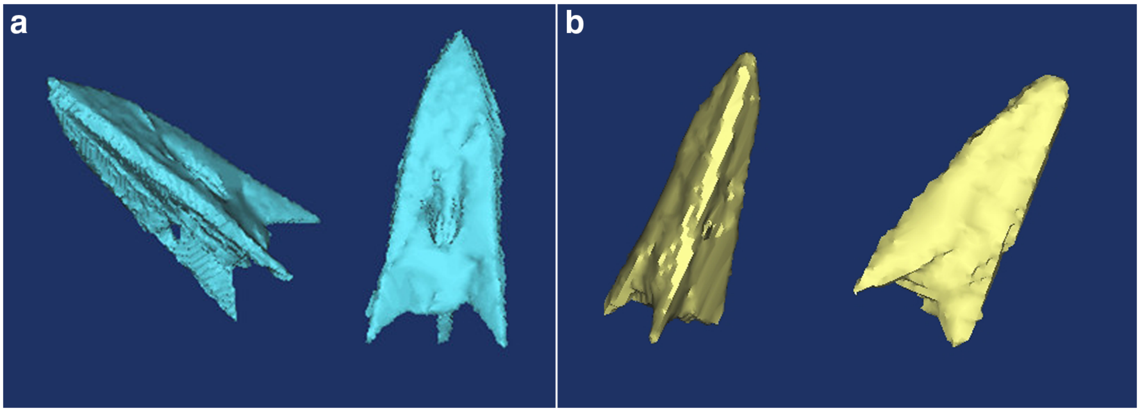
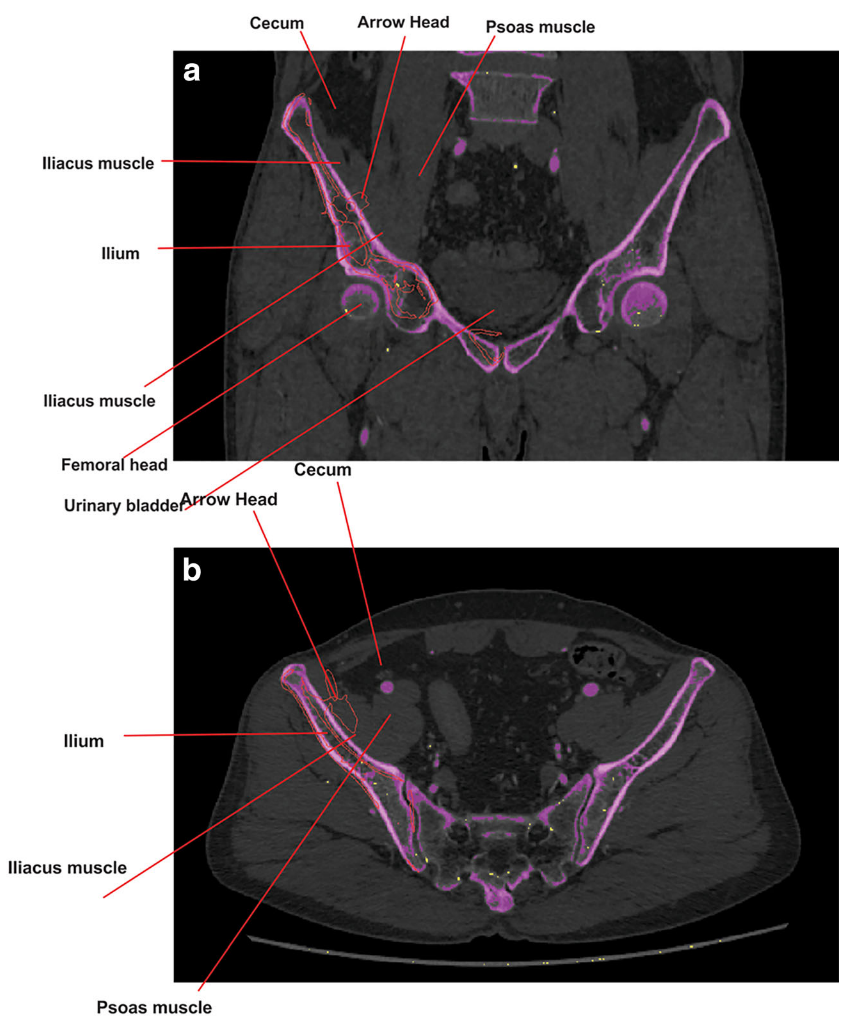


Fig. 8 The reconstructed arrowheads in the 3D model. **a** The arrowhead from the ilium injury. **b** The arrowhead from the vertebral injury

bleeding, and the tissues would have been sore and swollen. A wound infection might have spread quickly from the wounded skin and deep tissues in adjacent regions (cellulitis). Blood, fat debris, intestinal contents, and fluids would have accumulated and remained undrained in the lower abdominal and pelvic cavity, leading to continuing infection through the vascular system (sepsis). Sepsis arguably would have been the primary cause of death in an age without antibiotics. In this case, this injury alone would have led to sepsis within a couple of days, and death would have happened as soon as 3 days thereafter (Zuev et al. 2006). The open abdominal wound and injured

Fig. 9 Injury shown on the 2D CT scan contours image (**a** coronal plane, **b** transverse plane). The red contours are the original specimen



iliacus muscle (the flexor of the thigh) would prevent the inflicted person from moving around. The period from injury to death probably lasted no more than a week. Admittedly, other fatal injuries without involvement of bones might exist yet could not be considered for the scenario with confidence.

The injury on the vertebrae also belongs to a penetrating wound with the entrance located on the lower back but is clearer regarding the wound mechanism (Fig. 10). The arrowhead penetrated the skin, the thoracolumbar fascia, the erector spinae, the multifidus, and the interspinous ligament and finally reached the vertebral body. The spinal cord (lumbar enlargement), the arachnoid mater, and the internal vertebral venous plexus are definitely damaged. Clinically, the simple spinal cord injury is rarely fatal. The symptoms of spinal cord injury depend on the severity of the injury and the location of the damage, including partial or complete loss of the sensory function or limb control. Since the injury is located between the 12th thoracic vertebra and the first lumbar vertebra, the lumbar muscle strength could be generally weakened and the lower limb could be paralyzed. The internal oblique, the lower transversus abdominis, and the sphincters of the bladder and rectal could not be controlled autonomously along with the sensory dysfunction in the lower limbs, groin, haunch, and perineum. The patellar reflex, Achilles tendon reflex, and plantar reflex may have disappeared. Uncommonly, the cerebrospinal fluid leakage due to spinal arachnoid damage can cause cerebral palsy.

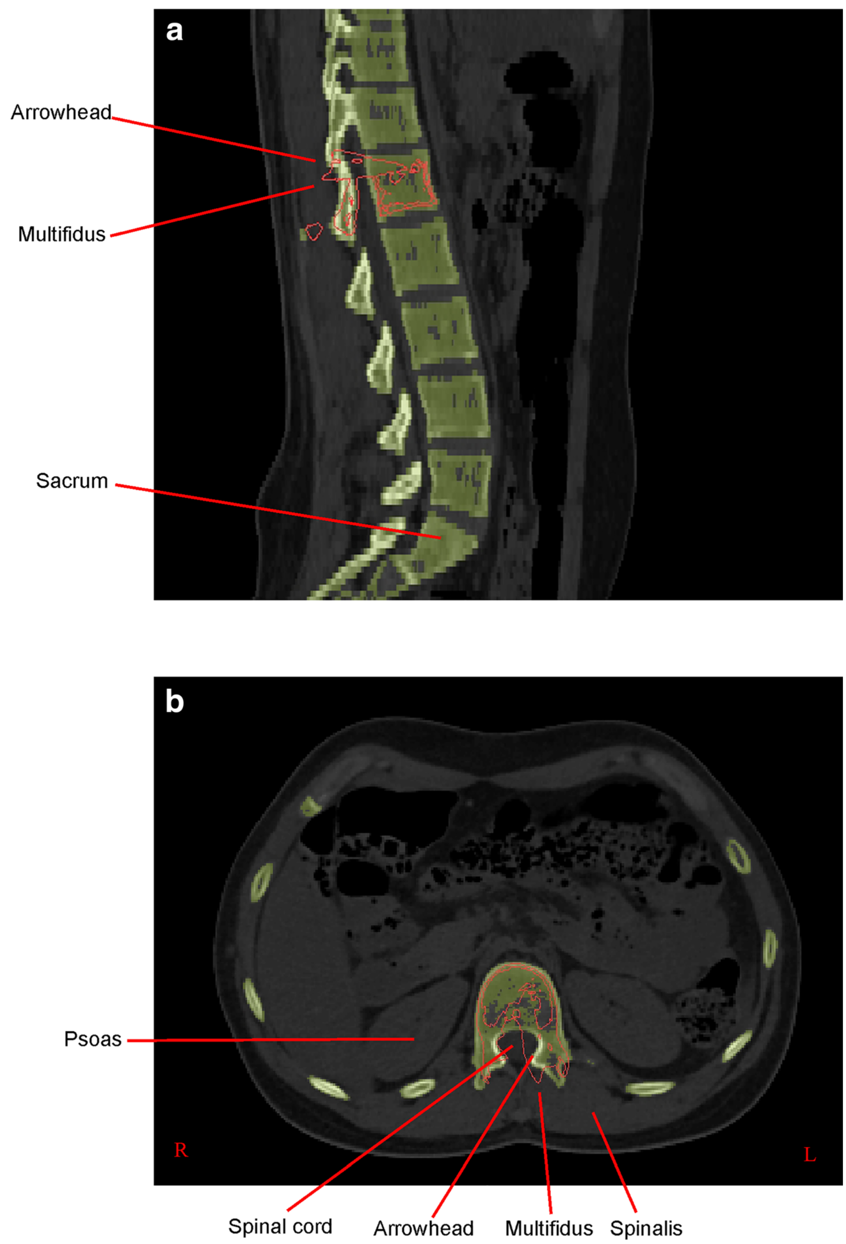


Fig. 10 Injury shown on the 2D CT scan contour image (**a** sagittal plane, **b** transverse plane). The red contours are the original specimen

Discussion

Analysis of the skeletal remains facilitates a better understanding of the ancient society. Demography reflects the risk of mortality and the trauma on the bones provides us with direct evidence for analyzing the confrontation and violence through this pivotal period in history. Based on previous research, accidental injuries are generally related to the daily living, while the intentional violence-related injuries reflect the confrontation to some extent (Jordana et al. 2009; Buzon and Richman 2007; Larsen 1997; Lovell 1997; Walker 2001). Considering trauma from the sociocultural perspective is essential. The confrontation between the central regime and the Eurasian Steppe nomads was the main theme of ancient Chinese history. The traumatic sample discovered in the northern frontier of ancient China reflects the interaction between pastoral and settled people, nomadic tribes (unsettled pastoralist), and central states (principalities of the central regime).

The risk of mortality among the Jinggouzi population

In medicine, trauma refers to an accidental or inflicted injury caused by "harsh contact with the environment" (Stedman 1982). Osteological trauma can reflect the warfare and violence in the past human societies (Milner 1999; Novak 2000; Walker 2001; Redfern 2017). The Jinggouzi population suffered an overall traumatic prevalence of 11.1% with a higher proportion in females. Most of the traumas were antemortem and occurred on long bones. Cranial traumas were more commonly found in females. Previous studies have analyzed the high prevalence of cranial trauma among females and inferred that this might be related to domestic violence, internal village tensions, or intrapopulation conflict (Webb 1995; Martin 1997; Walker 1997; Wilkinson 1997; Jackes 2004). In the Jinggouzi population, disadvantaged females and subadults were speculated to have suffered high risk of attack. Multiple cranial traumas were found on some female individuals and the cranial blunt force trauma could be observed even on a subadult at the age of 2–5 years old.

The tough survival condition could also be supported by demographic data. Among the whole population, subadults accounted for the largest proportion (45.1%), while the peak mortality rates in adult male and female groups were between 15 and 35 years old; no individual lived into the old adult phase. The age at death among the entire population is rather young. In contrast to the other populations that lived in this region during the Bronze Age, the mortality of subadult in Jinggouzi is extremely high, while the proportion of the elder is low.

The gross morphology on the margins of the two projectile injuries and the X-ray and CT images demonstrate no sign of the new bone formation process, which strengthens the inference that the wounds were perimortem (Berryman and Haun 1996; Brothwell 1981; Kanz and Grossschmidt, 2005; Galloway 1999). The clinical consequences of these two projectile injuries on the abdomen and lower back were serious, and these vital regions are vulnerable and they are inferred to be targeted intentionally. Although most of the other observed traumas were antemortem, considering the high mortality among the young, the morphological features of the perimortem injury on the torso, and the sharp bronze arrowheads, it allows us to hypothesize that at least these deadly injuries were received during an interpopulation conflict.

Currently, a comparative framework of the trauma prevalence among the populations in the ancient Great Wall region during the late Bronze Age period is unavailable due to the lack of trauma prevalence data from the comparative populations. Eng and Zhang (2013) investigated the trauma frequencies at Jinggouzi Cemetery and the other three ancient populations in northern China. Nileke Cemetery and Yanghai Cemetery were nomadic burials located in the remote northwestern China during the Early Iron Age, while the Lamadong Cemetery was a more central agropastoral population during the dynastic period. Compared with these populations, Jinggouzi showed a higher trauma prevalence. Admittedly, due to the early disturbances of the cemetery and the postmortem taphonomic damages especially on the subadult skeletons, the observed trauma in the present study may not represent the actual prevalence of trauma in this population. The phenomenon that some males were found headless could also lead to the underestimation of the cranial traumatic prevalence in males. We also cannot exclude that some fatal traumas did not leave any signs on the bones.

The possibility of conflict between populations

In consideration of the traumatic pattern in the Jinggouzi population, the identification of the enemy side in the conflict plays an important role in explaining the cause of the conflict. With regard to the weaponry found in the tombs of Jinggouzi, we found that the fine tri-winged arrowheads were special compared with other rough grave goods among the burial artifacts. Only nine bronze arrowheads were found in seven tombs out of the 58 tombs; eight of them were tri-winged socketed arrowheads and one was a dual-winged tanged arrowhead (Table 4). These tombs with bronze arrowheads found were similar to the other tombs, which consisted of both single individual burial and multiple individuals burials. The bronze arrowheads were much fewer in number and were scattered or close to the torso. However, the most frequent weapons found in these tombs were the arrowheads made from antlers (Fig. 11). A total of 251 were found; bunches of them were placed beside the skulls or torsos in an orderly manner as was shown in the tombs which were less disturbed. This phenomenon may demonstrate that the antler arrowheads were intentionally placed as the burial artifacts, while the bronze arrowheads remained inside the body during burial by accident.

Table 4 The description of the tombs with bronze arrowhead

Tomb No.	Arrowhead length (cm)	Arrowhead condition	Location	Bone arrowhead amount	Individuals	
					Sex	Age at death
M20	2.2	Incomplete	Scattered	16	Male	25–30
M24	3.0	Incomplete	Scattered	5	Male	25–30
M26	3.4	Complete	Scattered	13	Unknown	12–17
					Unknown	0.5±
M46	1.5	Incomplete	Scattered	3	Male	22±
					Male	20±
	5.1	Complete	Embedded		Male	20–25
					Unknown	1.5±
M47	4.2	Complete	Embedded	3	Male	14–16
					Female	25–30
					Unknown	Adult
					Unknown	7±
M51	3.5	Complete	Scattered	6	Male	25±
					Unknown	20±
					Unknown	10±
	3.6	Complete	Scattered		Unknown	6–7
					Unknown	Infant
					Unknown	Infant
M55	3.6	Complete	Scattered	14	Male	22±
					Female	15–16
					Unknown	1±
					Unknown	1±
					Unknown	0.5±

The differences between the antler arrowhead and the bronze arrowhead in material, shape, and location demonstrate that the bronze arrowheads may come from another population who fought with the Jinggouzi population.

Of all the bronze wares found in the cemetery, 95% of them were ornaments, 4% of them were tools, and only 1% of them were weapons, including two bronze daggers and nine bronze arrowheads. The metal elements and lead isotope analysis showed that almost all the ornaments and tools were Cu–Sn–Pb alloy, which is significantly different from the materials from the local contemporary copper mine (Li 2015). Although the specimens included in this study were not being analyzed, the analysis of one of the arrowheads found in the same tomb as the specimen M46:B showed that it was Cu–Sn–As alloy and contained a significant amount of silver, which is consistent with the local metal composition. The lead isotope analysis also supported its local casting (Li 2015). It demonstrates that the simple ornaments for everyday use were not locally casted, but the very small amounts of the arrowheads were probably sourced locally.

Based on the gross examination of the external shape and the 3D reconstruction of the embedded bronze arrowheads, this type of bronze tri-winged socketed arrowhead had a special identity and was mainly prevalent along the eastern section of the ancient Great Wall region during the Bronze Age (Shi 2006, 2015) at the exact location of the Jinggouzi Cemetery (Fig. 11). These local populations belong to another cultural group called "upper culture of Xiajiadian" which were widely distributed in the eastern part of Inner Mongolia and western Liaoning. Their funerary styles were completely different from the Jinggouzi Cemetery. Their tombs were southeast-oriented with stone coffins, and the exquisite bronze wares and weapons were extremely abundant (Jin 1987). Even bronze helmets and the stone molds for bronze arrowhead casting were found in some of the cemeteries (Liu 2000; Chen 2014). This leads us to suggest that the bronze arrowheads may belong to the local inhabitants who lived in the eastern section of the ancient Great Wall region and acted as the enemy of Jinggouzi inhabitants.

Climate and socioeconomic background behind the conflict

Projectile injury caused by an arrow shot is a common skeletal evidence of interpersonal violence in archaeological populations around the world (Lambert 1997; Guilaine and Zammit

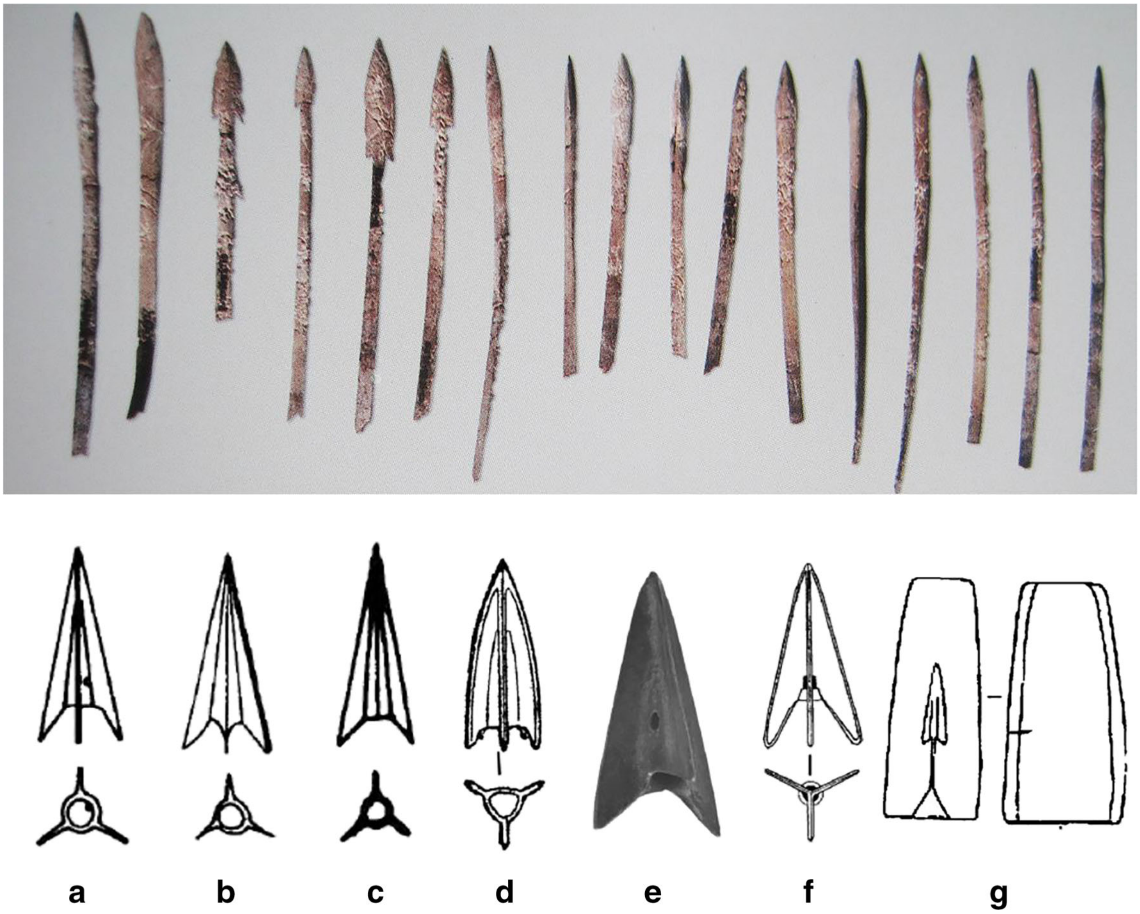


Fig. 11 The comparison of the antler arrowhead in Jinggouzi population and the common types of bronze arrowhead prevalent in the eastern section of the ancient Great Wall region. Upper: the antler of Jinggouzi; below: **a**–**f** represent the prevalent types of bronze arrowhead, and **g** is the stone mold for the arrowhead casting. Redesigned from Wang et al. (2010), Shi and Jia (2009), Shi (2015), and Chen (2014)

2005). From the perspective of cause, injuries and deaths caused by interpersonal violence can occur in many different social situations ranging from personal conflict to warfare between different populations due to territorial expansion, social dominance, or economic exploitation (Walker 2001).

Throughout human history, climate change has been responsible for population migrations (Buzter, 1983; Bridgeman 1983; Lamb 1982; Kohler et al. 2008; Kuckelman 2010). It caused conflicts with pre-existing populations. Numerous studies have focused on the relationship between climate change and violence, especially between temperature extremes and the increasing levels of conflict (Zhang et al. 2007, 2011; Hsiang et al. 2013; Redfern 2017). In ancient China, the correlation between climate change and conflicts was significant. When the climate cooled, the population pressure caused by the increase of population during the previous warm phase along with shrinking livelihood resources resulted in the higher frequency of conflicts between populations (Tian and Shi 1995; Zhang et al. 2006). There is a close relationship between climate change and historical migrations of the nomads in eastern central Asia and the southern Mongolian grasslands (Chen 1931; Zhao 1985; Zhang et al. 2006; Fang and Guo 1992).

Climatological data indicate that the Eurasian Steppe experienced climate change to a cooler and drier environment during the Bronze Age (Geel et al. 1996, 1998; Shelach 1994). Moreover, geological studies on the thickness variations of the past 2600 years in annual layers of stalagmite in northern China also indicate that both northern and eastern Asia experienced a cold period between 665 and 510 BC, which happens to be the period of the Jinggouzi (Tan et al. 2003). This climate variation led to the immigration of the nomad population toward the south in the pursuit of better meadows.

The process of the migration and integration in the ancient Great Wall region

The ancient Great Wall region played an important role during the process of ancient Chinese history. As an important area connecting the northern Eurasian Steppe and the East Asian agricultural area, it witnessed migration, integration, and conflict between different populations throughout the history. Historians have long recognized the strong association between the developments of the northern principalities of the central regime and the northern nomads throughout the Bronze Age with a concomitant conflict and warfare (Di Cosmo 1999; Underhill and Habu, 2006). Not only the ancient Chinese historical records recount the frequent conflict between the intrusive nomads, but the recent investigations on the ancient Great Wall ruins also confirmed the existence of the interaction in this region (Heritage Editorial Board 1981). The Great Wall built by the Yan State was just about 100 km southeast of the Jinggouzi Cemetery. Over the past years, archaeological and anthropological pieces of evidence of the integration indicate that several different archaeological cultures prevailed in this area, and even different funerary styles and populations can be found to appear in the same contemporary cemetery. Thus, it is generally thought that the integrations of different populations during this period were gradual and moderate in some regions (Zhang and Zhu 2010).

However, the reconstruction of the integration process cannot only rely on the archaeological cultures, written historical records, and cranial morphology, while neglecting the lines of evidence from the skeletal traumatic remains themselves. As the earliest North Asian appeared in this region, the relationship between the Jinggouzi population and the locals provides valuable evidence for the reconstruction of human historical process in east Eurasia history. The high risk of mortality of the young and the intense conflict show that multiple types of integrations existed during that period, not only the moderate types but also some intense types. The diverse pattern of population integration processes laid the foundation for the final formation of the Chinese northern nomadic cultural belt which initiated the beginning of a new era in Chinese history.

Conclusions

The skeletal remains are the mirror of history. The mortality, trauma prevalence, and the arrowhead injuries presented here provide a path for us to reconstruct the history in the region even with the lack of any written record. From the combined pieces of evidence, we conclude that the Jinggouzi population is the southbound nomads and was in conflict with the aboriginals that lived in the east section of the ancient Great Wall belt. This research not only provides osteological evidence of the interpersonal conflict but also helps to further illuminate the complex relationships among different groups living during the formation of the Chinese northern nomadic cultural belt in the Bronze Age, as an important part of the Eurasian process.

Acknowledgments Thanks are extended to Cheng K.L from the China-Japan Union Hospital of Jilin University for the CT scan of the vertebrae specimens. We are grateful to Tyler E. Dunn from the University of Illinois at Urbana-Champaign and Kara Adams for grammar editing and the two anonymous reviewers for their constructive suggestions and elaborative review.

Funding information This work was supported by the Fok Ying Tung Education Foundation for Young Teachers (Grant No. 141111), Special Funds for the 'Compass Plan' of the State Administration of Cultural Heritage, and the NAP Start-Up Grant from Nanyang Technological University.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Barfield TJ (2006) Steppe nomadic culture and political organization. In: Aruz J, Farkas A, Fino EV (eds) The golden deer of Eurasia: perspectives on the steppe nomads of the Ancient World. Metropolitan Museum of Art, New York, pp 12–17

Berryman HE, Haun SJ (1996) Applying forensic techniques to interpret cranial fracture patterns in archaeological specimens. Int J Osteoarchaeol 6(1):2–9

Bridgeman HA (1983) Could climatic change have had an influence on the Polynesian migrations? Palaeogeogr Palaeoelimatol Palaeoecol 41:193–206

Brothwell DR (1981) Digging up bones, 3rd edn. British Museum (Natural History), London

Buzon MR, Richman R (2007) Traumatic injuries and imperialism: the effects of Egyptian colonial strategies at Tombos in upper Nubia. Am J Phys Anthropol 133:783–791

Buzter KW (1983) Human response to environmental change in the perspective of future, global climate. Quat Res 19:279–292

Cattaneo C (2007) Forensic anthropology: developments of a classical discipline in the new millennium. Forensic Sci Int 165:185–193

Chen C (2008) A study on the cemeteries in Daihai area during the Warring States Period. PhD dissertation, Jinlin University

Chen GY (1931) Chronology of natural disasters and wars in Chinese history, vol 2. Shanghai Book Bureau Press, Shanghai, pp 1691–1698 (in Chinese)

Chen HL (2014) A study on the issues of Xiaoheishigou site. Archaeol Northern Ethn 1:33–58

Cosmo ND, Wyatt DJ (2003) Political frontiers, ethnic boundaries and human geographies in Chinese history. Routledge Curzon, London, pp 1–15

Cosmo ND (2004) Ancient China and its enemies—the rise of nomadic power in East Asian history. Cambridge University Press, Cambridge, pp 13–43

Cui FX (2007) The archery culture among nomadic populations in ancient northern China. J Phys Educ Inst Shanxi Normal Univ 22(1): 69–71

Davis-Kimball J, Bashilov VA, Yablonsky LT (1995) Nomads of the Eurasian Steppes in the early Iron Age. Zinat Press, Berkeley, pp 315–319

Di Cosmo N (1999) The northern frontier in pre-imperial China. In: Loewe M, Shaughnessy EL (eds) The Cambridge history of ancient China: from the origins of civilization to 221 BC. Cambridge University Press, Cambridge, pp 885–966

Eng JT, Zhang QC (2013) Conflict and trauma among nomadic pastoralists on China's northern frontier. In: Pechenkina K, Oxenham M (eds) Bioarchaeology of East Asia: movement, contact, health. University Press of Florida, Gainesville, pp 213–245

Fang JQ, Guo L (1992) Relationship between climatic change and the nomadic southward migrations in eastern Asia during historical times. Clim Chang 22:151–169

Galloway A (1999) Broken bones: anthropological analysis of blunt force trauma. Charles C. Thomas, Springfield, IL

Ge JX, Cao SJ, Wu SD (1993) Brief history of immigration in China. Fujian People's Press, Fuzhou, pp 440–450

Geel BV, Buurman J, Waterbolk HT (1996) Archaeological and palaeoecological indications for an abrupt climate change in The Netherlands and evidence for climatological teleconnections around 2650 BP. J Quat Sci 11:451–460

Geel BV, Plicht JVD, Kilian MR, Klaver ER, Kouwenberg JHM, Renssen H, Reynaud-Farrera I, Waterbolk HT (1998) The sharp rise of D14C ca. 800 cal BC: possible causes, related climatic teleconnections and the impact on human environments. Radiocarbon 40:535–550

Guilaine J, Zammit J (2005) The origins of war: violence in prehistory. Blackwell, Oxford

Heritage Editorial Board (1981) The investigation report of the Chinese Great Wall. Cultural Relicas Press, Beijing

Hsiang SM, Burke M, Miguel E (2013) Quantifying the influence of climate on human conflict. Science 341(6151):1235367

Jackes MK (2004) Osteological evidence for Mesolithic and Neolithic violence: problems of interpretation. In: Roksandic M (ed) Violent interactions in the Mesolithic: evidence and meaning. Archaeopress, Oxford, pp 23–39

Jin FY (1987) Research on the "upper culture of Xiajiadian" and its origin. Acta Archaeol Sin 2:177–208

Jordana X, Galtes I, Turbat T et al (2009) The warriors of the steppes: osteological evidence of warfare and violence from Pazyryk tumuli in the Mongolian Altai. J Archaeol Sci 36(7):1319–1327

Kanz F, Grossschmidt K (2005) Head injuries of Roman gladiators. Forensic Sci Int 160:207–216

Kohler TA, Mark DV, Aaron MW, Kristin AK (2008) Mesa Verde migrations. Am Sci 96:146–153

Kuckelman KA (2010) The depopulation of Sand Canyon Pueblo, a large ancestral Pueblo village in southwestern Colorado. Am Antiq 75: 497–525

Lamb HH (1982) Climate, history and the modern world. Methuen, London, pp 131–230

Lambert PM (1997) Patterns of violence in prehistoric huntergatherer societies of coastal southern California. In: Martin DL, Frayer DW (eds) Troubled times: violence and warfare in the past. CRC, New York, pp 77–110

Larsen CS (1997) Bioarchaeology. Interpreting behaviour from the human skeleton. Cambridge University Press, Cambridge

Lattimore O (1940) Inner Asian frontiers of China. American Geographical Society, New York

Li LH (2015) Research on the bronze from the west cemetery in Jinggouzi, Liaoxi ChiFeng region. PhD dissertation, University of Science and Technology Beijing

Lin Y (2003) The formation process of the nomadic belt in Chinese northern Great Wall region during the Xia Dynasty to the Warring States Period. Yenching J Chin Stud 14:95–146

Liu GX (2000) Research on the bronzes of the "upper culture of Xiajiadian". Acta Archaeol Sin 4:451–500

Lovell NC (1997) Trauma analysis in paleopathology. Yearb Phys Anthropol 40:139–170

Maples WR (1986) Trauma analysis by the forensic anthropologist. In: Reichs KJ (ed) Forensic osteology: advances in the identification of human remains. Charles C Thomas, Springfield, IL, pp 218–228

Martin DL (1997) Violence against women in the La Plata River valley (A.D. 1000–1300). In: Martin DL, Frayer DW (eds) Troubled times: violence and warfare in the past. Gordon and Breach, Amsterdam, pp 45–75

Milner GR (1999) Warfare in prehistoric and early historic eastern North America. J Archaeol Res 7:105–151

Novak S (2000) Battle-related trauma. In: Fiorato V, Boylston A, Knüsel CJ (eds) Blood red roses: the archaeology of a mass grave from Towton, AD 1461. Oxbow Books, Oxford, pp 90–102

Ortner DJ (2003) Identification of pathological conditions in human skeletal remains (2nd edition). Academic, London, pp 119–162

Redfern RC (2017) Injury and trauma in bioarchaeology: interpreting violence in past lives. Cambridge University Press, Cambridge, p 17–60, 64–71

Rohn AH, Barnes E (2003) The reconstruction of the funerary behavior of the Dashanqian site. Res Chin Front Archaeol 2:337–352

Sauer NJ (1998) The timing of injuries and manner of death: distinguishing among antemortem, perimortem and postmortem trauma. In: Reichs KJ (ed) Forensic osteology. Advances in the identification of human remains. Charles C Thomas, Springfield, IL, pp 321–332

Shelach G (1994) Early Bronze Age cultures in North China. Asian Perspect 33:261–292

Shi Y (2006) Researches on bronze arrows before Qin Dynasty in northern China. PhD dissertation, Jinlin University

Shi Y (2015) Research on the bronze arrowhead from Inner Mongolian Great Wall region during the East Zhou Period. Northern Cultural Relics 2:24–30

Shi Y, Jia SJ (2009) Research on the bronze arrowhead from Northeast China during Pre-Qin Period. Northern Cultural Relics 3:3–8

Stedman TL (1982) Steadman's medical dictionary. William & Wilkins, Baltimore

Sun JS (2017) Research on the issues on the East Zhou cemeteries in Daihai region. Steppe Cultural Relics 1:69–75

Tan M, Liu TS, Hou JZ et al (2003) Cyclic rapid warming on centennial-scale revealed by a 2650-year stalagmite record of warm season temperature. Geophys Res Lett 30(12):1617–1620

Tian GJ, Shi PJ (1995) A primary study on the environmental archaeology in the China northern Great Wall region. Steppe Cultural Relics: 44–51

Tian Y (2007) The demographic comparative analysis of the populations in central and eastern Inner Mongolia in Pre-Qin Period. Master dissertation, Jinlin University

Underhill A, Habu J (2006) Early communities in East Asia: economic and sociopolitical organization at the local and regional levels. In: Stark MT (ed) Archaeology of East Asia. Blackwell, London, pp 121–148

Walker PL (2001) A bioarchaeological perspective on the history of violence. Annu Rev Anthropol 30:573–596

Walker PL (1997) Wife beating, boxing, and broken noses: skeletal evidence for the cultural patterning of violence. In: Martin DL, Frayer DW (eds) Troubled times: violence and warfare in the past. Gordon and Breach, Amsterdam, pp 145–175

Wang HJ, Chen L et al (2012) Genetic data suggests that the Jinggouzi people are associated with the Donghu, an ancient nomadic group of North China. Hum Biol 84(4):365–378

Wang LX, Ta L, Zhu YG (2010) Lin Xi Jinggouzi: archaeological report and comprehensive research on the Late Bronze Age cemetery. Science Press, Beijing

Webb S (1995) Paleopathology of aboriginal Australians: health and disease across a hunter-gatherer continent. Cambridge University Press, Cambridge

Wilkinson RG (1997) Violence against women: raiding and abduction in prehistoric Michigan. In: Martin DL, Frayer DW (eds) Troubled times: violence and warfare in the past. Gordon and Breach, Amsterdam, pp 21–43

Wu ZJ (2005) A research on the western area cemetery at Jinggouzi and relative problems. Master dissertation, Jinlin University

Yang JH (2004) The formation of Chinese northern Frontier Belt during the spring-autumn and Warring States Period. Cultural Relics Publishing House, Beijing

Zhang DD, Jim CY, Lin GCS, He YQ, Wang JJ, Lee HF (2006) Wars and dynastic cycles in China over the last millennium. Clim Chang 76: 459–477
Zhang DD, Brecke P, Lee HF, He YQ, Zhang J (2007) Global climate change, war, and population decline in recent human history. Proc Natl Acad Sci 104:19214–19219
Zhang DD, Lee HF, Wang C, Li B, Pei Q, Zhang J, An Y (2011) The causality analysis of climate change and large-scale human crisis. Proc Natl Acad Sci 108:17296–17301
Zhang QC (2010) A research on the skeletons of Xindianzi graveyard, Helingge'er county, Inner Mongolia Autonomous Region. Science Press, Beijing
Zhang QC, Zhu H (2010) Migration and amalgamation: geographical distributive characteristics of population in the south-middle area of Inner Mongolia in the Pre-Qin Period. J Minzu Univ China (Philos Soc Sci Ed) 37(3):87–91
Zhao WL (1985) Population migrations as a response to population stress, based on a discussion on Chinese migrations in historical times. Popul Econ 1:38–43 (in Chinese)
Zheng JL (2004) The determinant standard on nomadic relics and related issues. Research of China's frontier archaeology. Science Press, Beijing, pp 425–457
Zhu H (2015) The racial types of ancient population in the Inner Mongolia-Great Wall region. In: Zhu H (ed) The physical anthropological research on the ancient Chinese. Science Press, Beijing, pp 19–31
Zhu H, Zhang QC (2007) A research on the ancient human bones unearthed from the Jinggouzi cemetery in Linxi county, Inner Mongolia. Acta Anthropol Sin 26(2):97–106
Zuev SM, Kingsmore SF, Gessler DDG (2006) Sepsis progression and outcome: a dynamical model. Theor Biol Med Model 20063:8. https://doi.org/10.1186/1742-4682-3-8