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Skeletal element distributions of the large herbivores from the Lingjing site, Henan Province, China

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More than ten thousands of bone fragments were recovered from the Lingjing site, Henan Province during 2005 and 2006. In this paper, through the quantification and statistical analyses of the skeletal elements of the two predominant species in this assemblage, aurochs (*Bos primigenius*) and horse (*Equus caballus*), the differential influences and weights of a variety of taphonomic agencies in the formation of the assemblage are assessed respectively. Compared to the natural agencies, hominid hunting and the subsequent disarticulation, slaughtering, and their transport of the bone elements of the prey species are the main factors accounting for the formation of the present assemblage. More importantly, this study initiatively identifies hominid's differential treatment of the bones of aurochs and horse in the Paleolithic record of East Asia and demonstrably suggests that hominids at the site have already practiced sophisticated hunting techniques and subsistence strategies and may be quite familiar with the ecological and anatomical characteristics and nutritional values of the large-sized prey animals and can accordingly take different processing and handling strategies at the hunting site.

Lingjing site, taphonomy, zooarchaeology, skeletal element distribution, human transport behaviors

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Archaeologists always intended to acquire information of human behaviors from the animal bones at archaeological sites. Via the observations of modern animals and their anatomical characteristics, archaeologists realized that different animal elements (or "units") have different food utilities; therefore they argued that ancient hominids should unavoidably be influenced by this factor [1–4]. However, as many scholars have pointed out, most faunal assemblages were actually the final combinations of a complicated process of hominid behaviors and natural agencies. On one side, some of the animals were involved in the formation of the archaeological site by diseases, accidents, fluvial actions, carnivore's hunting behaviors, etc., which will help to reconstruct the paleoecology or the living paleoenvironment of the occupants at the site. On the other side, some animals from the archaeological site, especially the large or middle-sized herbivores were mostly associated with early humans and thus were the most important media for us to know about the prehistoric hominid subsistence. Hominid action is only one part of many agencies of accumulation and modification of the animal bones, and thus for any archaeological fauna, before the study of the adaptive features of early hominid subsistence or strategies, we must first differentiate the natural elements from the hominid ones, and in great details discern their respective influences on the formation or development of the faunal assemblage. In this regard, Taphonomy, originated from Paleobiology will pro-

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vide us a unique perspective to solve the problems mentioned above and is thus the key to doing research on the zooarchaeological assemblages. In this paper, bones of two dominant species, aurochs (*Bos primigenius*) and horse (*Equus caballus*), unearthed from the newly excavated Lingjing site, Xuchang County in Henan Province, were studied systematically employing some taphonomic methods. In particular, we attentively observed, identified and quantified each bone element of the two animals and then we intended to discern the taphonomic processes and formational history of the fauna and to further distinguish hominid behaviors and their subsistence patterns from the complex.

1 Material and methods

The Lingjing site is located in the west part of Lingjing town, about 15 km to the northwest of the Xuchang City, Henan Province and stands at an elevation point of 117 m. Its geographical coordinates are 34°04′N, 113°41′E. Initially discovered in the middle of the 20th century, this site was re-excavated by researchers from the Henan Provincial Institute of Cultural Relics and Archaeology during 2005 to 2006. Within an area of about 300 m^2, the Lingjing site yielded nearly 20 fragments of human fossils, 10 thousands of stone artifacts and more than 10000 pieces of animal fossils [5]. So far, 18 species of mammal fossils have been identified from this fauna, including 2 species of Rodentia, 3 species of Carnivora, 1 species of Proboscidea, 4 species of Perissodactyla, and 8 species of Artiodactyla [6]. The taphonomic analysis shows that the aurochs (*Bos primigenius*) and horse (*Equus caballus*) are the predominant species of this fauna [7]. This newly discovered site is an important finding of Chinese Palaeoanthropology; it has presently yielded roughly 20 fragments of human skeletal materials, including parietals, occipitals, mastoids, etc. and provided a good opportunity to the study of modern human behaviors in East Asia. Based on the principles of biostratigraphy, Li Zhanyang and other scholars proposed that this fauna should be of about the same age with the Xujiayao fauna and its age should be around 100 ka BP [6]. The preliminary OSL dating results done by Zhou Liping indicated that human fossils from this site should be of the age of about 80–100 ka, and may even slightly older than 100 ka (detailed results will be published elsewhere). Within the Chinese Paleolithic cultural system, it is of the transitional status between the Early and Later Paleolithic Age [8, 9]. Animal fossils in this study are primarily from the stratum bearing the hominid fossils and stratigraphically belong to the "Lower Cultural Layer" [5].

The skeletal element study was widely adopted by taphonomists in the 1980s or earlier periods. In the 1950s, White [10] proposed that the difference of the skeletal element profiles from the archaeological sites could be interpreted by the schlepp effect [1]. They believed that "the larger the animal and the farther away from the point of consumption it is killed, the fewer of its bones will get 'schlepped' back to the camp, village, or other area". After that, more attention was paid to the study of skeletal element profiles of animals from the archaeological sites, notable among them are the works conducted by Binford [2] in Nunamiut. However, when entering the 1990s, with the sweeping development of the actualistic studies (including the experimental and the ecological simulation studies) conducted by the American archaeologists, the observation and analysis of bone surface modifications began to play a more and more important role in the taphonomic study of the faunal remains; in contrast, probably due to the problems of equifinality [11], the importance of the skeletal element study declined drastically and many western scholars even neglected this method in their study of the faunal remains from the archaeological sites. Meanwhile, a group of scholars were still endeavored to improve this method and tried to make it alive again [12, 13].

In the research of the Lingjing fauna, we observed and quantified the skeletal elements of both *Bos primigenius* and *Equus caballus* by the traditional taphonomic method. Take *Bos primigenius* for example, first we recorded the MNE of each bone element according to its specific anatomical landmarks (these are the scan sites in Lyman's classic book, such as the epiphysis, nutrient foramen, etc.) [14]; second divided the MNE by the number of times that anatomical unit occurs in one complete skeleton; and third normalized the MNE by Binford's method and then got %MAU (Table 1) [2]. In the following analyses, the %MAU was taken as the normalized value of each element. Based on the %MAUs of the elements, the significances of fluvial actions, carnivores, hominids and the postdepositional processes, etc., which are the potential taphonomic factors contributed to the formation and aggregation of the fauna, were assessed respectively. This is also the most normalized statistical analysis procedure in vertebrate taphonomy.

2 Results and discussion

2.1 The effects and influences of the natural agencies on the skeletal element profiles

2.1.1 Fluvial action and carnivores

As to the formation of most faunal assemblages, fluvial action is an unavoidable taphonomical factor. Generally, the running water will transport the lighter bones further away, while leaving the heavier ones *in situ* or moving them only for a short distance [15]. The examination of the alignments of the bones and the investigation of the effect of hydrodynamic sorting on archaeofauna are the traditional ways to know whether fluvial actions once happened at the archaeological site. In environments adjacent to the rivers or lakes (these are commonly the places where archaeological sites are located), Fiorillo's experiments have demonstrably shown that tramplings from the large-sized ungulates who frequent the site could totally distort the images of the regular alignments of animal bones caused by fluvial actions [16]. Fortunately, with the development of taphonomic study, we may adequately assess the effects of fluvial actions on the archaeofauna.

In this paper, based on %MAU, we classified the skeletal elements of the *Bos primigenius* into different Voorhies groups [17] (Figure 1). The %MAU for the scapular of *Bos primigenius*, which belongs to the first or second group in Voorhie's system, is relatively high (36.47) among all the skeletal elements, which signifies the insignificant role played by water in the formation of the Lingjing fauna even if the fluvial sorting of the bones did occur at the site. Meanwhile, judging by the large disconformities between the particle size of the sediments here and the calculated diameters of quartz equivalents of the animal bones [18, 19], we can similarly discern the absence of fluvial actions in the formation of the fauna [7].

Carnivore damage is also a main agency of the modification of skeletal elements at the archaeological sites, which is closely related to the bone density of each element [14]. Thus, the high percentage of some light bones from the Lingjing site, such as scapulars mentioned above, could also in some degree testify the weak influence of the carnivores. This conclusion corresponds well to the low percentage of

Table 1 The skeletal element distributions of the aurochs (*Bos primigenius*)

Scan site	Skeletal element	Number of times that element occurs in a complete skeleton	Bone density	MNE	MAU	%MAU
AC1	Pelvis	2	0.53	2	1	8.97
AS1	Astragalus	2	0.72	7	3.5	31.39
ATl	Atlas	1	0.52	2	2	17.94
AX1	Axis	1	0.65	2	2	17.94
DN4	Mandible	2	0.53	7	3.5	31.39
FE1	Proximal femur	2	0.31	9	4.5	40.36
FE6	Distal femur	2	0.26	5.5	2.75	24.66
HU1	Proximal humerus	2	0.24	1	0.5	4.48
HU5	Distal humerus	2	0.38	11	5.5	49.33
MC1	Proximal metacarpal	4	0.59	10.3	2.575	23.09
MC5	Distal metacarpal	4	0.46	26.1	6.525	58.52
MR1	Proximal metatarsal	4	0.52	10.3	2.575	23.09
MR5	Distal metatarsal	4	0.4	26.1	6.525	58.52
NCl	Naviculo-cuboid	2	0.48	6	3	26.91
P12	First phalange	8	0.46	12	1.5	13.45
P23	Second phalange	8	0.46	7	0.875	7.85
RA1	Proximal radius	2	0.48	22.3	11.15	100
RA5	Distal radius	2	0.35	7.3	3.65	32.74
SP1	Scapula	2	0.5	12.4	6.2	55.61
TI1	Proximal tibia	2	0.41	0	0	0
TI5	Distal tibia	2	0.41	9	4.5	40.36
UL1	Proximal ulna 1	2	0.34	2	1	8.97
UL2	Proximal ulna 2	2	0.69	2	1	8.97

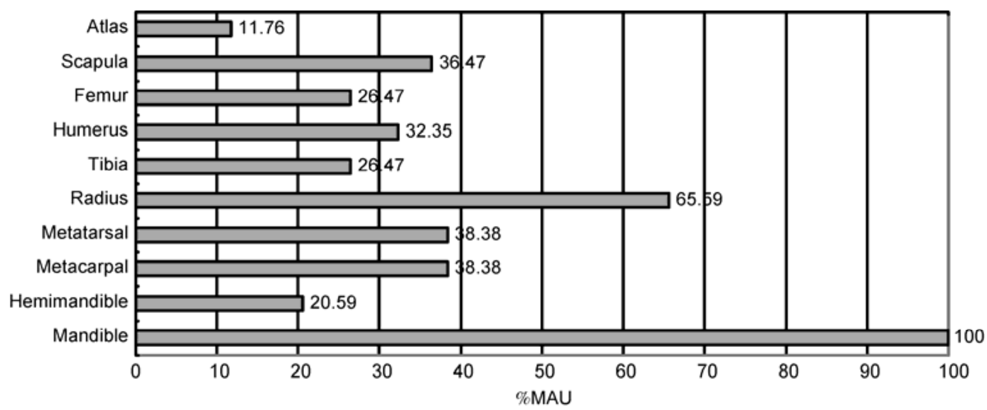

Figure 1 The skeletal element profiles of *Bos primigenius*.

the tooth-marked specimens in the assemblage (5.4%) [7].

2.1.2 The post-depositional processes

Animal bones will experience a variety of post-depositional processes after their deposition. These processes include biological actions, hominid or ungulate tramplings, diagenesis or weathering, etc., [14]. Commonly, most bones will become more fragmentary after these processes, which will decrease the bone's identifiability, and therefore in some degree influence the quantification and interpretation of the skeletal element profiles and bone surface modifications. Thus, the assessment of post-depositional processes is of prerequisite and necessity to the interpretation of the archaeofauna. Taphonomists have conducted many experiments in this regard, of which the widely accepted one is Marean's Completeness Index [20]. Although the number of the carpals or tarsals from the Lingjing assemblage is very small, based on the 15 specimens of this kind, we find that the Completeness Index for this assemblage is almost 100% (Table 2), which implies that the post-depositional processes have had little influence on the formation of this fauna.

2.2 The effects and influences of hominid behaviors on skeletal element profiles

Hominid transport of the animal bones is also a major agency of the accumulation of the archaeofauna, and the study of skeletal element profiles is thus an essential method to reconstruct hominid behaviors, their social activities or the functions of archaeological sites [14, 15] .

2.2.1 Correlation analysis

Since the 1960–1970s, taphonomists have put forward quite a few utility indexes to weigh the influence of hominid transport behaviors on the formation of the archaeofauna. In studying remains of *Bos primigenius* from the Lingjing site, we employ Emerson's BMTP (Bison Modified Total Products) index [21]. It measures the difference among each element of the skeleton of the large-sized *Bos*, and therefore can reflect hominid's nutritional considerations upon transport of the animal bones. Here the %MAUs of elements of *Bos primigenius* and Emerson's %BMTP are scatter-plotted on a chart to see if any pattern is visible (Figure 2). It becomes immediately apparent that there is no significant correlation between the skeletal element profile of *Bos primigenius* and Emerson's BMTP ($r_s = 0.115$, $N = 24$, $P = 0.593$).

Table 2 The Completeness Index of the carpal or tarsal bones from the Lingjing site

Carpals or tarsals	Completeness Index (%)
Astragalus (8 pieces from Artiodactyls, 2 pieces from Carnivores)	100[(9+0.5)/10]=95
Naviculo-cuboid (5 pieces from Artiodactyls)	100[(5)/5]=100

This result does not fall much out of our expectation. Utility index of the skeletal elements of a specific animal is definitely not the only evidence that could signify the hominid transport behaviors. Actually season or time when hominid acquired games, size of the animals, number of hunters participating the campaign, weather and the competition between the carnivores, etc. will all potentially affect the selective transport behaviors of hominids and therefore influence the extent of correlations between the utility index and the skeletal element profiles [22]. However, employing other means of zooarchaeological and taphonomical analysis, we could still identify whether the hominid behavior is the major conditioner of the faunal assemblages.

2.2.2 The analysis of long bone surface modification

Through ecological observations and experimental studies in the field, Domínguez-Rodrigo constructed some modes to identify hominid behaviors based on cut mark studies [23, 24], which were widely adapted in the study of archaeofaunas [25] and considered as an important way to resolve the problems of equifinality [22]. Observing the distributional patterns of cut marks on the long bones of animals from the site, we found that most cut marks were on the midshaft portions of the bone (185 pieces, 98.45%), whereas only two pieces of distal epiphysis and one piece of proximal epiphysis (1.06% and 0.53%) were cut-marked. And of all the cut-marked long bones, 34% and 41% specimens belong to the upper and middle limbs of herbivores respectively, whereas only 25% belong to the lower limbs. The data are similar to those of Domínguez's experiments and Lupo's ethnic observations, which imply that hominids at the Lingjing site first accessed the animal resources prior to the carnivores and cut off the meat on the long bones. It firmly demonstrates hominids' decisive effect on the formation of the Lingjing fauna (Figure 3).

2.2.3 The mortality patterns

To the study of archaeofauna, the mortality patterns of prey animals from the site are significant to the reconstruction of taphonomic history of the archaeological site and to the Interpretation of hominid behaviors [13, 22]. Based on the

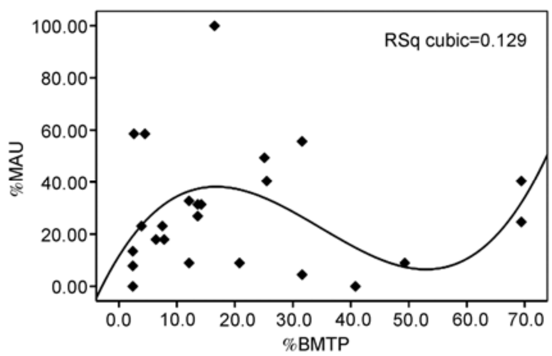

Figure 2 The correlation between %MAU and %BMTP of *Bos primigenius*.

Figure 3 Cut marks on the rib of a large-sized herbivore.

dental materials, mortality patterns are constructed respectively for the two dominant species of the Lingjing site and it becomes apparent that both animals analyzed here have the mortality profiles of prime-adults dominated and accompanied by a small proportion of juvenile individuals [26], which is a unique pattern indicating hominid's selective hunting behaviors. The prime-dominant patterns of *Bos primigenius* and *Equus caballus* at the Lingjing site are identical to those of the European and the Near East sites of the similar age. It implies that hominids there already had relatively mature and systematical living strategies and social organizations in this period.

2.2.4 The distributions of the long bone circumferences and bone lengths

The distributions of the long bone circumferences and bone lengths could partially reflect the differential modifications of the hominids and carnivores on archaeofauna [3, 27]. On one aspect, for the long bones of herbivore, the circumference of most specimens of the Lingjing assemblage is less than 25%, which is identical to that of hominid sites, but much different from that of the carnivore lairs (Figure 4(a)). On the other aspect, as for the lengths of the 1300 pieces of long bones that have been systematically measured, most of them are distributed in the area of 3–6 or 6–9 cm (Figure 4(b)). This result is very similar to those of the Castanet, Combe Saunière, Cuzoul de Vers and Jonzac site, which are the middle Paleolithic sites in France and the lengths of the animal bones from these sites mainly fall into the area of 3–5 or 5–7 cm [27]. In conclusion, the distributions of the long bone circumferences and bone lengths clearly display hominids' influences on the archaeofauna at the Lingjing site.

3 The difference of skeletal element profiles between *Bos primigenius* and *Equus caballus* and its archaeological significance

The difference on skeletal element profiles among different species is an important clue for detecting how hominids acquired, processed, transported and even consumed the animal resources [28]. In the study of Lingjing fauna, we focus on the study of the skeletal element profiles of *Bos primigenius* and *Equus caballus*.

From Figure 5, it is easy to see that the %MAU of the mandibles of the two species are nearly the same, whereas for the other elements, the %MAUs of *Bos primigenius* is obviously higher than those of *Equus caballus*. It seems that there is a big difference between the skeletal element profiles of the two animals. Even though samples analyzed here are small, Chi-square test shows that there are significant differences between the skeletal element profiles of *Bos primigenius* and *Equus caballus* (χ^2=17.576, df=8, P<0.05).

From above, it is clear that there are significant differ-

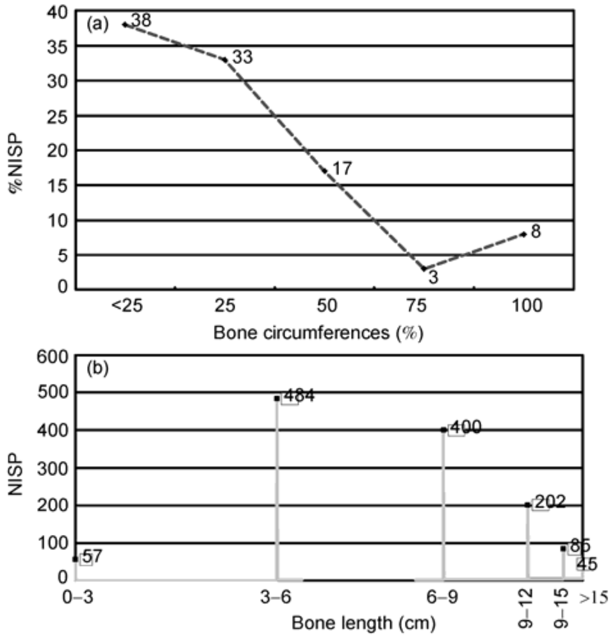

Figure 4 The measurement of long bones of the Lingjing assemblage. (a) The distribution of circumference; (b) the distribution of bone lengths.

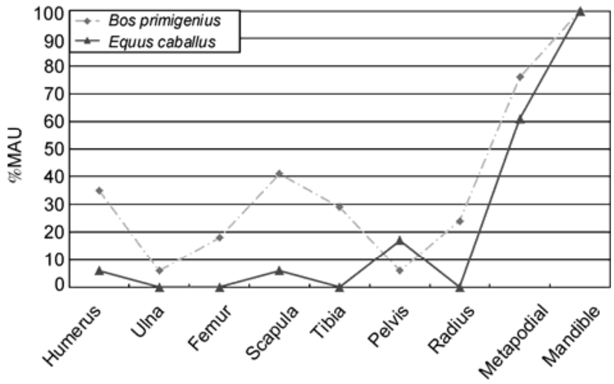

Figure 5 The comparison of the skeletal element profiles of *Bos primigenius* and *Equus caballus*.

ences between the skeletal element profiles of *Bos primigenius* and *Equus caballus* and it is common to find this kind of records from the Paleolithic archaeofaunas around the world. Actually at many Eurasian Palaeolithic sites including Hoxne in England [29], Combe Grenal in France [30], Torralba and Ambrona, etc. in Spain [31, 32], the skeletal element profiles for horses differ noticeably from those for large bovid and cervid species. At Reignac, Boyle found that the skeletal element representation of reindeer and red deer reflects a "gourmet" strategy, with a predominance of the highest utility elements, whereas that of the horse is consistent with a "bulk" strategy, represented by a wider range of high and medium-utility body parts [33]. At many Spanish sites, horse remains are dominated by maxilla and mandibles; deer are represented by a greater proportion of postcranial elements [31, 32].

Obviously, the significant differences on the skeletal element profiles between horse and artiodactyls species is not an accident. Some key taphonomic or archaeological information probably hide behind this phenomenon. We may suspect that the differential representation of the skeletal elements of the two animals from the Lingjing fauna probably arises from the differences of the bone density of the two animals and their differential resistance to carnivore damages, post-depositional diagenesis or other kinds of taphonimic agencies. However, Lam et al. [28] have argued that the differences on the skeletal element profiles between the large-sized mammals such as *Bos primigenius* and *Equus caballus* should be related to the selective transport behaviors of hominids; bone density has little relation to this phenomenon. We would also suppose that this record may closely associated with the different intensities of the carnivore damages to the bones of the two animals. Compared to the anatomical characteristics of the artiodactyls, the postcranial bones of horses are probably more attractive to the carnivores and thus could result in the differential skeletal element representations at the Lingjing site. But the ecological observations and taphonomic studies instantly exclude this possibility for us. Among bone assemblages from modern carnivore lairs or from the paleontological sites, the bones of horses and artiodactyls were unearthed together but no differential representation of the skeletal elements from the two animals was reported [34–36]. Actually, bones of the horse even behave better than those of the other large or middle-sized ungulates as for its resistance to weathering [35, 36]. This is probably because bones of the horse, especially its long bones, are thicker than those of the artiodactyls [37, 38]. Zedda et al. [39] found that osteons within the bones of the horse were more numerous and composed of a higher number of well-defined lamellae when compared with those of the cow. Diameter, perimeter, and area of osteons and Haversian canals were always higher in horses than in cows.

As the natural factors presently known cannot reasonably explain this phenomenon, we certainly need the perspective of human beings to answer the question and ethnological data may provide us a way to solve this problem. Among the Hadza in modern Africa, zebra skeletons are usually moved completely back to the base-camps or the skulls are simply discarded in the field [40, 41]. This pattern is different from the treatment of similar-sized artiodactyls, for example alcelaphines, the bones of which are often broken and discarded by the Hadza in the procurement site after their feeding of the bone marrows. Compared to the similar-sized artiodactyls, marrow content within the long bones of zebra is lower [37], but Hadza members are always focused more on zebra's marrow [40]; they seem to prefer zebra's muscles as well [42]. Levine also recorded that in many groups of modern hunter-gatherers, equid muscles and milk products will be given special preference [43]. Levine reasoned that it is due to the relatively higher essential fatty acids (EFA) content in the bones of equids, which is very important for the neurological development of human infants [43]. Because of the differences in the digestive systems, these polyunsaturated fats are hydrogenated by the micro-organisms in artiodactyls and therefore rarely exist in their bones but can be retained in the bones of horses in the longer term.

Skeletal elements of the two animals from the Lingjing fauna indicate some kind of differential distributions. As to the horses, there are relatively more fragments of skulls and mandibles; long bones of this fossil species are almost absent from the site. This observation is in good conformity to the pattern seen among modern hunter-gatherers. That is, just as modern humans did, the ancient hominids at the Lingjing site always preferred to transport all the skeletal parts of the horses back to their base-camps whereas they dropped most of the bones of the aurochs in the killing sites. The taphonomic study of the Lingjing fauna indicates that the differential treatment of these two fossil species was already in its place at the transitional period from the Early to the Late Paleolithic Age in East Asia. However, we do not think this human behavior may be simply out of ancient human's cognitive abilities or their special nutritional preferences for equids; this phenomenon may instead have originated from the anatomical differences and the quantitative nutritional gaps between equids and artiodactyls after the field-processing of the bone elements.

In fact, experimental studies and anatomical evidence have indicated that, compared to the artiodactyls, skeletal elements of the equids have relatively stronger muscle attachment points [44, 45]; even after a more detailed field processing (such as defleshings, etc.) there will still be a large amount of nutritional components attached to the bone surfaces. Therefore, if the ancient peoples dropped the bones in the field, it will inevitably have resulted in the loss of much nutrients; furthermore, the marrow cavities within the long bones of equids are significantly smaller and its marrow content is mainly inside the spongy parts of the bones, which is quite different from the artiodactyls, of which marrows are contained mostly in the long bone cavities. Therefore, without auxiliary heating tools, marrow contents of the equids, just as their muscles near the attachment points, cannot be efficiently utilized by ancient humans. The taphonomic study of the Lingjing site shows that this fauna is not a consequence of a large-scale hunting activity which would have led to the death of an extraordinarily large number of prey animals; instead it is just a final synthesis of several episodes of small-scale hunting events [7]. Therefore, it is reasonable to argue that when ancient humans caught the preys every time, they had just limited resources and should not easily waste any grab of possible nutritional components. For them, perhaps the most sensible choice is to move those skeletal elements which still have much nutritional contents adhered, back to the base-camp. There they not only have enough time, but also have technology and capacity to extract nutrition thoroughly from those bones. This point, even in today's hunter-gatherer practices, still must be carefully considered [45].

4 Conclusions

From the late 1990s, with the vigorous development of experimental and ecological studies in African grassland, bone surface modifications have attracted much attention in the field of taphonomy. By contrast, skeletal element studies were largely ignored because of their inability in settling on a solution to the problem of equalfinality. The taphonomic study of the Lingjing site shows that the studies of the skeletal element representations at archaeological sites are still far from extremity; the key to the rehabilitation of this study lies on the sound analytical means and comparisons.

Fluvial actions, carnivorous animals, hominid activities are the widely recognized taphonomic agencies in the accumulation of animal bone at archaeological site. Based on the statistical analysis of the skeletal elements of the two dominant species of the present fauna, we have roughly figured out the differential influences and weights of a variety of taphonomic agencies, such as fluvial actions, carnivores, hominids and post-depositional diagenesis in the formation of this assemblage. Nonhuman taphonomic agencies play only marginal roles in this process. This is in good accordance with other taphonomic evidence, such as the well preserved bone surfaces and the extremely uniform and weak weathering extents of the faunal remains. Compared to the natural agencies, hominids are the main factor responsible for the accumulation and modification of bones of the middle and large-sized herbivores of the fauna. We have not found the significant correlations between the skeletal element abundances of the aurochs and the food utility indexes of its corresponding bones; but the bone surface modifications, the mortality profiles, the distributions of the long bone circumferences and bone lengths and the differential representation of the skeletal elements of the two animals strongly suggest the leading role played by the hominids in the formation of the assemblage. The comparative absence of the natural agencies in this process also stands for a substantial effect of hominid activities. In conclusion, the study of the skeletal element profiles of the large-sized herbivores of the Lingjing fauna shows that hominid hunting and the subsequent disarticulation, slaughtering and transportation are the main factors accounting for the formation of the assemblage.

More importantly, unlike the previous analyses of archaeological fauna, this study not only focuses on the traditional quantifications of the cheek teeth of aurochs and horses, but also initially identifies the significant differences between the skeletal element profiles of the two species, which is a significant phenomenon not previously validated in the study of Paleolithic sites in East Asia. The Lingjing assemblage records the first case of this feature and further conveys important information concerning behaviors of early humans, who should have maintained amiable relationships with their surrounding environments. Particularly, with regarding to the large herbivores, humans have already learned powerful hunting techniques and may be quite familiar with these "neighbors" and their ecological and anatomical characteristics or nutritional values and can accordingly take different processing and handling strategies at the hunting site.

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