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New osteological criteria for the identification of domestic horses, donkeys and their hybrids in archaeological contexts

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ABSTRACT

The identification of domestic equid remains is a recurrent issue and an intense subject of discussion in zooarchaeological studies. Indeed, despite historical sources describing the key role of equids in numerous past societies, their accurate identification on archaeological sites is still problematic, and only few methods have been developed in order to distinguish the bones of horses, donkeys and their hybrids. Moreover, some of the extant published visual macroscopic criteria are considered as possibly unreliable, partly because of the absence of preliminary test on a large sample of modern specimens. In this work, we try to solve these issues by testing a set of macroscopic visual criteria, collected in the literature or newly described, on a comparative sample of 107 modern skeletons of domestic equids. We quantified the reliability of these criteria and found evidence of 26 osteological characters allowing for the identification of between 90% and 100% of the horses and donkeys of our comparative sample. A method to identify the complete or sub-complete skeletons of hybrids is also proposed using combinations of characters observed on several bones. Finally, the defined osteological criteria are observed on a set of archaeological skeletons, coming from antique to modern sites, in order to demonstrate the applicability of our approach to archaeological remains. The use of our methodology on zooarchaeological samples could allow for a better assessment of the presence of donkeys and hybrids in archaeological sites, and thus, could help improve the knowledge of their respective importance and use by human past societies.

1. Introduction

The reliable identification of closely related taxa is a recurrent issue in zooarchaeology and this question is critical for taxa of specific socio-economical interest, such as equids (Clutton-Brock, 1992). The latter are represented by two domestic species which may have been simultaneously present in European archaeological sites since the Iron Age (Bökönyi, 1991): the horse (*Equus caballus* Linnaeus, 1758), and the donkey (*Equus asinus* Linnaeus, 1758). The identification of these taxa is made even more complex by the fact that they can crossbreed, which implies the potential occurrence of their hybrids in archaeological deposits: mules (*Equus asinus* x *Equus caballus*), and hinnies (*Equus caballus* x *Equus asinus*).

An accurate and systematic identification of archaeological equid remains is however mandatory for a good understanding of archaeological deposits, and for a correct description of animal exploitation strategies in past human societies. Indeed, domestic equids are known to have played a key role in the economy of many past civilizations worldwide, and many historical sources extensively describe their respective uses by humans (Clutton-Brock, 1992). For instance in the Roman empire, horses were largely used for riding, hunting and racing (White, 1970) because of their running ability, whereas donkeys were acknowledged for their endurance making them particularly suitable for traction, and as pack animal in farming activities (Hyland, 1990; Peters, 1998; Toynbee, 1973). Concerning mules, they were renowned for their vigor and were mostly employed for long distance transport of persons or goods (Armitage and Chapman, 1979). At the opposite, hinnies were rarely used, and are described as being of low working interest (Clutton-Brock, 1992; Loudon, 1825). This broad diversity of uses demonstrates that an accurate and reliable identification of equid archaeological remains is of high interest for a better understanding of socio-economic systems in past societies.

Several methodologies have been developed in order to distinguish equid species from bone morphology. Approaches based on the observation of visual macroscopic criteria were first proposed (Arloing, 1882; Rosselli Vilá, 1921) and, more recently, methods using geometric morphometrics (GMM) have been applied to this question in order to provide more reliable identifications (Cucchi et al., 2017; Hanot et al.,

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2017). Nevertheless, GMM approaches remain challenging to implement, and they currently suffer from a low practicability in routine zooarchaeological studies due to the relatively long sequence of analytical protocols they require. On the other hand, the reliability of the methods based on macroscopic criteria is often called into question partly because of the surprisingly small amount of remains attributed to donkeys and hybrids in archaeological sites which contrasts with their seeming economic importance documented by historical sources (Albarella et al., 1993; Bökönyi, 1974; Johnstone, 2006; Manconi, 1995; Peters, 1998). Most of the currently used identification criteria are based on the morphology of teeth enamel (Armitage and Chapman, 1979; Davis, 1980; Eisenmann, 1986; Payne, 1991; Uerpmann, 2002), and of the skull (Albizuri and Nadal, 1991; Azzaroli, 1978; Eisenmann, 1986, 1980; Groves and Mazák, 1967; Kunst, 2000) but only few criteria are available for postcranial elements (Arloing, 1882; Barone, 1986; Eisenmann and Beckouche, 1986; Peters, 1998; Rosselli Vilá, 1921). Unfortunately, most of these characters are considered as unreliable or difficult to observe (Albarella et al., 1993; Baxter, 1998; Johnstone, 2004; Zeder, 1986). The main issue of these works is often related to the number of specimens included in the comparative sample used to describe the criteria. Indeed, the used sample size is often small and unfitted to a correct consideration of the intraspecific variability within each taxon. Moreover, these works generally lack preliminary tests performed on a reference sample in contrary to what has been done on other taxa (Bochaton et al., 2016; Zeder and Lapham, 2010; Zeder and Pilaar, 2010); this prevents to quantify the reliability of the defined identification criteria. These difficulties frequently result in identifications of archaeological equid remains mainly based on the largely criticized criterion of simple bone size (Forest, 2008), considering that horses and mules are larger than donkeys. However, this size criterion was recently demonstrated as irrelevant by a study of bone shape data which allowed for the identification of small size horse bones in archaeological contexts (Hanot et al., 2017). The same study also revealed that bone size is not appropriate for the distinction of modern horses, donkeys and hybrids. Another major limitation is the near-absence of criteria allowing for the identification of hybrids. This is mainly explained by the fact that they probably concomitantly display morphological characteristics of both their parents (Forest, 1997). In addition, the small number of hybrid skeletons available in osteological collections has likely contributed to restrain the development of identification methodologies (Johnstone, 2006).

The aim of this study is to try to solve these different issues concerning the identification of archaeological equid remains by proposing an easily applicable identification method for isolated bones of horses and donkeys using reliable macroscopic osteological criteria. We also investigate the morphology of hybrids in order to evaluate their morphological variability and to propose an identification method.

To do so we use a large comparative sample of 107 modern skeletons of horses, donkeys, and hybrids in order to assess the reliability of a set of morphological criteria defined on nine different bones. Eleven of these characters have been collected in the literature (Barone, 1986; Eisenmann, 1986; Kunst, 2000; Peters, 1998), but we also describe a set of 15 new criteria. Finally, in order to demonstrate the relevance of our approach, we performed an application of our identification methodology on a sample of five equid skeletons discovered on French archaeological sites.

2. Material and method

2.1. Research of osteological criteria for the distinction between horses and donkeys

Our modern comparative sample includes 82 complete or subcomplete skeletons of horses (39 specimens) and donkeys (43 specimens) from several European museum institutions (see online Supplementary material S1). Horses specimens are represented by the two extant caballine species (both belonging to the subgenus *Equus*; Groves and Grubb, 2011): 23 domestic horses (*Equus caballus* Linnaeus, 1758) of various breeds, and 15 Przewalski's horses (*Equus przewalskii* Poliakov, 1881). Both males and females are included, in relatively equal proportions (see online Supplementary material S1). All specimens are adult with fully fused long bones epiphyses in order to discard the impact of growth on bone morphology.

Our study focused on nine bone elements from cranial (skull and mandible) and postcranial (scapula, humerus, radius/ulna, third metacarpal bone, femur, tibia, and proximal phalanx) skeleton. Between one and five criteria were found as reliable on each bone, 15 of these criteria were newly described by the authors and 11 originated from the literature. These criteria are described in our study following the anatomical nomenclature of Barone (1976). For each criterion, two character states were defined corresponding to horse ("A") and donkey ("B"). When the character state was not clearly recordable on comparative specimens, it was registered as such ("A/B"). A criterion which was impossible to observe (e.g. broken bone, bones kept in anatomical connection, etc.) was registered as unobservable ("-"). All the observations were carried out by a single observer (PH).

To synthesize the observations, several quantification tools were defined. The Number of Observations (NObs) refers to the total number of times a criterion was observed should it be a clear character state ("A", "B") or not ("A/B"). The Number of Attributions (NA) corresponds to the number of times a criterion was unambiguously attributed to a character state ("A" or "B"). The Number of Correct attributions (NC) corresponds to the number of correctly-classified specimens for each criterion (sum of the number of horses correctly identified by the "A" state and of the number of donkeys correctly identified by the "B" state). This allows us to compute the Percentage of Assessment (PA = NA/NObs*100) and a Correct Identification Rate (CIR = NC/NA*100). The PA is supposed to reflect the variability of the criterion and the difficulty to clearly define the character state. As for the CIR, it is also supposed to reflect the reliability of the criterion. Only the criteria with CIR above or equal to 90% and PA above or equal to 80% were retained and are described in this study.

2.2. Research of osteological criteria for the identification of hybrids

Our modern comparative sample includes 25 skeletons of hybrids between horse and donkey: 8 hinnies (*Equus caballus* x *Equus asinus*) and 17 mules (*Equus asinus* x *Equus caballus*). The characters found as reliable for the identification of horses and donkeys were tested on hybrid specimens; among them four have been previously described by Peters (1998) as allowing to identify mules.

2.3. Archaeological application

The applicability of the defined identification criteria to archaeological material was assessed using 5 archaeological equid skeletons (Table 1). All of these specimens are complete, or almost complete, and come from French sites dating from the 3rd to the 19th century. They were all recorded as articulated skeletons in the field and were considered as corresponding to single individuals. The only exception is the set of bones from Elbeuf - "Rue Guynemer" whose attribution to a single specimen is mainly related to the fact that they were discovered in the same archaeological feature (Barme and Clavel, 2015). All the skeletons have previously been identified (Table 1) on the basis of both visual macroscopic (Barme and Clavel, 2015; Derbois, 2006; Lepetz, 1996; Yvinec, 1998), and GMM criteria (Hanot et al., 2017). However, it should be mentioned that the identification of the specimen from Elbeuf has proven to be problematic. Indeed, it was primarily supposed to be a donkey on the basis of visual criteria observed on teeth coupled with the small size of its bones (Barme and Clavel, 2015); but a subsequent study using GMM data has suggested it was a mix between horse and donkey bones (Hanot et al., 2017).