Title

Gaining traction on cattle exploitation: zooarchaeological evidence from the western Balkan Neolithic (6000-4500 cal BC)

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Abstract

This study examines sub-pathological alterations to cattle foot bones from eleven central and western Balkan Neolithic sites (c.61/6000 to 4500 cal BC). Systematic comparisons of bone remodelling in those elements shown to be most directly affected by traction is used to determine the potential use of cattle as engines across this region throughout the period. This study provides the earliest direct evidence for the use of cattle for light traction, long before the hard usage pathological evidence previously observed.

Keywords

Traction
Domestic cattle
Neolithic
Europe
Balkans
Sub-pathology
Pathology

Introduction

Andrew Sherratt's seminal argument for a 'secondary products revolution', or the intensification in the use of domestic livestock for dairy, wool and traction during the Old World Chalcolithic, was initially advanced in the absence of a substantial body of zooarchaeological evidence (Sherratt 1981, 1983). Over the subsequent three decades, the acquisition of abundant and high quality zooarchaeological data has advanced significantly our understanding of the changing roles of domestic livestock in prehistory (see Greenfield 1988, 2010; 2014b for extensive summaries of the relevant literature). As suggested by early criticisms (e.g. Chapman 1982, Bogucki 1984), it is widely acknowledged today that the picture is more complicated than originally envisioned, with no single revolutionary point in time or space to be found. The extensive research into secondary products has led to a much improved understanding of the scale and diversity of the early use of dairying and – to a somewhat lesser extent – wool production in both Europe and Asia (e.g. Arbuckle 2014; Becker et al. 2016; Breniquet and Michel 2014; Evershed et al. 2008; Ethier 2017; Greenfield 2014a, b; Greenfield and Arnold 2014; Outram et al. 2012; Pipes et al. 2014; Salque et al. 2012; Spiteri et al. 2016).

In contrast, both the earliest use of traction and its eventual intensification remain debated. Most research into the use of cattle for traction has focused on later periods, often on the basis of non-osteological data (e.g. Bakker et al. 1999; Bartosiewicz et al. 1997; Bondár & Székely 2011; Pétrequin et al. 2006; Milisauskas & Kruk 1991; Mischka 2011; Piggott 1983; Rowley-Conwy 1987). Numerous studies have used both osteological and non-osteological data to argue for the use of cattle for traction from the early 4th millennium cal. BC onwards, parallel to the earliest evidence for carts and ploughing (e.g. Bălăşescu et al. 2006; Bogucki 1993; De Cupere et al. 2000; Galindo-Pellicena et al. 2015; Johanssen 2006; Lingereux et al. 2006; Milisauskas & Kruk 1991). The possible earlier use of cattle for traction has been suggested for Europe but never systematically investigated (e.g. Isaakidou 2006; Tarrús et al. 2006). Here, we fill this damaging documentary gap by providing systematic positive identifications of traction by domestic cattle from the earliest Neolithic in the central and western Balkans (c.6000 BC).

Traction – what do we mean and what are we looking for

Traction in prehistoric Europe is often conflated with ploughing or the use of carts (e.g. Bondár & Székely 2011; Pétrequin et al. 2006). However, at its most essential interpretation, traction is the use of animals as engines in order to pull loads. While ploughing and cartage are forms of traction, they form only portions of a much broader spectrum of exploitation practices. Such specific use is commonly assumed to indicate the training and long-term management of specialized animals, in particular castrated males (oxen) of which identification is inferred from age profiles, sex comparisons and pathological studies (e.g. Bogucki 1993; Galindo-Pellicena et al. 2015; Tarrús et al. 2006). Ethnographic examples indicate that oxen are privileged due to the increased strength and stamina provided by their larger size, but also that cows (even while pregnant) can be used for traction when deemed necessary, or when labour demands are less intensive (Bartosiewicz et al. 1997; Halstead 2014). This is seen in the interpretation of age profiles, sex comparisons and pathological studies (e.g. Bogucki 1993; Galindo-Pellicena et al. 2015; Isaakidou 2006; Milisauskas & Kruk 1991; Tarrús et al. 2006). The identification of castrates in archaeological contexts is often implicitly linked with their putative exploitation for labour, as though castrate=oxen=traction (Galindo-Pellicena et al. 2015; Milisauskas & Kruk 1991). Perhaps a better way of viewing traction would be as a continuum, rather than a binary positive or negative value. There is a wide middle ground in which animals may be used for more occasional pulling activities, or used for regular labour over a shorter number of years. It is identifying this more limited or 'light' use of animals for traction which will inform us both as to how the more specialised traction-animal developed and the economic context of their emergence and maintenance.

Available data on early exploitation of domesticates for other secondary products, in particular dairy, do not indicate specialized secondary-product-maximising management. Rather, a more variable ad-hoc exploitation is indicated, often for prolonged periods prior to targeted management practices (Arbuckle 2014; Ethier et al. 2017; Greenfield 2014b; Spiteri et al. 2016). This has led to research focusing on both evidence for the early use of dairy products as well as a separate analysis of the increasing reliance on dairy products in animal management. A similar approach is advocated here for investigations of traction – by examining both early evidence and changes in the intensity of exploitation over time. The occasional use of a good-natured cow or young bull to haul timber would be traction exploitation, but one which would not necessarily alter either management profiles or significantly impact upon bone development across an entire faunal sample (De Cupere 2000; Lin et al. 2016). In this way, we may expect a certain period of limited traction exploitation, confined to a few individuals, possibly for only a portion of their lifetime, and which would thus not alter the larger age-at-death profiles for the herd as a whole. This paper aims at identifying this hypothesized early 'light' phase of exploitation of cattle.

Bone remodelling and stress

Bone surfaces remodel in response to stress and injury. Stress can relate to carrying the weight of the live animal as well as any additional load that is placed upon individual elements (Wolff 1892). Bone remodelling takes many forms, including enlargement of muscle and ligament attachments, and alterations to articular surfaces as a result of increased loading. Remodelling to bone surfaces can be classified into two groups (Bartosiewicz 2008; Bartosiewicz et al. 1997): those brought about by traumatic injury and/or old age (pathological) and those brought about as the result of increased strain (sub-pathological). The degree of remodelling in both cases relates to the intensity of strain (through time) or injury. The intensity of sub-pathological alterations developing from repeated additional strain on an element or set of elements relates to the type, duration and intensity of work involved. With regards to the effect of traction upon cattle skeletons, sub-pathological alterations are primarily directed through the medial articular surfaces of foot elements (metacarpus, metatarsus and phalanges: Bartosiewicz 2008).

Case-study: Neolithic cattle in the central and western Balkans

In order to test for the presence of such horizon of limited traction, we investigate cattle foot bones from twelve samples representing eleven sites covering the entire Neolithic period within the central and western Balkans (c.61/6000 – 4500 cal BC; see Table 1). Previous zooarchaeological work in this region has shown a relative initial diversity in animal exploitation strategies during the Early Neolithic, including sites focusing on the management of ovicaprines as well as others focusing cattle and pigs. During the Middle and Later Neolithic, we observe a shift to a pattern of domesticate exploitation generally focused on the exploitation of cattle and pigs, parallel to increased levels of hunting (Ethier et al. 2017; Greenfield 1986, 1991, 2008; Orton et al. 2016). Temporal changes are observable in relation to the age, sex and size distributions of cattle kept at sites, although there is no evidence for the retention of individuals into advanced age, castrated males, over-representation of male animals, or an increase in mean body size (Gaastra & Vander Linden in prep; Greenfield 1986, 1991; 2008).

All zooarchaeological material used in this study was directly studied by JSG and HJG, using the same protocol and recording of bone alterations. Seven assemblages were entirely recorded, whilst five were partially exported for curation, meaning that only a sub-sample was available for the present study. An overview of the sites studied by each analyst is given in Table 1 and their locations are shown in Figure 1. Radiocarbon dates are available for nine site samples and are provided in in SI1.

[Figure 1]
[Table 1]

Methods

Foot elements (metacarpals, metatarsals and first and second phalanges) of both domestic cattle (*Bos taurus*) and aurochs (*Bos primigenius*) were examined for all sites. These elements were selected as they are the best direct reflection of traction in the osteological record, being both the most directly affected by the stress of pulling (versus age or increased body weight) as well as commonly found at low levels of fragmentation (Bartosiewicz 2008; Bartosiewicz et al. 1997). A summary of the phases represented from these sites and the number of elements studied is given in Table 1.

Foot elements were studied for both pathological and sub-pathological alterations. These were scored on the basis of their Pathology Index (PI hereafter) values following Bartosiewicz et al. (1997) and the distributions of PI values were compared between sites. Sub-pathological alterations consistent with traction were recorded and their frequencies per sample are given in Table 2.

Measurements were also taken for the distal metapodia following the traction index osteometric system developed by Lin et al. (2016). The diagnostic index “e/D1” was measured for all distal metapodia of both cattle and aurochs. This index describes the degree of remodelling and extension of the medial condyle, with a value of 0.75 or higher indicating a degree of remodelling consistent with traction usage in modern reference specimens (Lin et al. 2016).

The combination of both systems allows for the comparison of alterations across all foot elements (PI) as well as a direct index of metapodial remodelling independent of the more subjective PI approach. Where it was possible to estimate the sex of individuals (e.g. through metrical comparisons of distal metapodia) this was included as part of the recording of pathological and osteometric data. Elements were studied from aurochs as a control group for both PI and osteometric comparisons.

Results

All studied Neolithic sites demonstrate pathological and/or sub-pathological alterations to cattle bone. The overall level of pathological or sub-pathological alterations remains low, with the majority of alterations being graded as minor to moderate (Grades 1-3 on the Bartosiewicz et al. 1997 system). The number of pathological or sub-pathological specimens from each site is small (see Table 2), in keeping with the findings of researchers working on later periods (e.g. De Cupere et al. 2000). All sites studied demonstrate a combination of age/trauma (pathological) and usage-related (sub-pathological) remodelling to bone surfaces. Pathological remodelling was identified on remains of both domestic cattle and wild aurochs and include exostoses present at tendon and ligament attachments on the distal surfaces of phalanges and metapodia, to medial and/or lateral faces of distal metapodial shafts (Figures 2 and 6), to proximal shafts of metapodia, and the posterior surfaces of proximal phalanges.

[Table 2]
[Figure 2]

By contrast, sub-pathological remodelling of bones from traction was identified only on domestic cattle. These include extension of the margins of the medial condyle of metapodia (Figure 3) as well as extension of the medial facet of the proximal articular surface of both first (Figure 4) and second (Figure 5) phalanges. The restriction of such sub-pathological remodelling to domestic cattle only is significant. This form of remodelling (in particular on hind limbs) has been shown to relate most directly to the motion and strain of pulling rather than to other factors such as the age or weight (Bartosiewicz 2008; Bartosiewicz et al. 1997; Lin et al. 2016). These alterations show no chronological or geographical patterning in the frequency or intensity of remodelling (Table 2).

[Figure 3]
[Figure 4]
[Figure 5]
[Figure 6]

Previous research has been shown that only a sub-set of the cattle population provides evidence of traction and that the distribution of PI values is of far more importance than the sample's mean PI value in identifications of traction (De Cupere et al. 2000). Therefore, PI value distributions are plotted here as histograms (Figure 2). The majority of elements for both taxa across all sites scored between 0-1 and 1-2, both of which categories can be considered as indicating normal bone development. In domestic cattle, a small proportion of each assemblage exhibited sub-pathological alterations consistent with bone remodelled due to the strain of traction (2.5-3 and 3-3.5 in PI score, see Figure 2 and Table 2). These alterations included broadening of medial condyles for both metacarpal and metatarsal as well as extension of the medial proximal articular facet to both first and second phalanges (see Figures 3, 4, and 5). These were present on a subset of cattle elements from all three Neolithic periods. The distribution of PI values provides some indication of more extensive remodelling to bones in cattle of Late Neolithic sites (Figure 2), although this variation is too minor to draw any conclusions.

Osteometric analysis of distal metapodia following the criteria of Lin et al. (2016) also points to the usage of cattle for traction from at least the beginning of the Neolithic in the western Balkans. The index "e/D1" indicated traction-positive cattle metacarpals and metatarsals from sites in all three Neolithic periods. All traction-positive metapodia came from domestic cattle only and all had distal PI values of three or higher (Bartosiewicz et al. 1997). These indices can be seen in Figures 5 and 6, where the "e/D1" index has been plotted alongside distal breadth/Bd (Lin et al. 2016) to indicate the sex of animals measured. From these data, we can see not only the presence of traction-positive cattle from both distal metacarpals and metatarsals but also a bias towards evidence from the hind limb. This is consistent with the findings of Lin et al. (2016) and further confirms that these sub-pathological alterations are the result of the strain of traction, which is more strongly expressed in the hind limb (Bartosiewicz 2008; Lin et al 2016) These data also indicate the usage of both females and males for traction during the Neolithic, although given the small sample sizes available it cannot be determined at present whether or not male animals were more commonly used for traction in the Late Neolithic (Figures 7 and 8).

[Figure 7]
[Figure 8]

Conclusion

This study has demonstrated the existence of 'lighter' use of cattle for traction long before the hard-usage pathological evidence seen from previous studies (e.g. De Cupere 2000; Galindo-Pellicena et al. 2015). As indicated by the two techniques used here, it appears that some cattle, both males and females were already being used for traction from the time of their introduction onwards across the central and western Balkans. Small numbers of animals that were used for traction are identifiable in earliest Neolithic settlements, a pattern observable throughout the entire 1500 years duration of the local Neolithic, and thus presumably afterwards.

Comparative analysis of sub-pathological and osteometric comparisons for cattle thus provides firm indications for the exploitation of cattle labour dating back much earlier than generally considered. This exploitation is not only systematic across multiple sites over a long period of time, but also only points to non-intensive use of cattle for traction. It is also noteworthy that this widespread, non-specific use of cattle for traction recalls similar patterns observed for contemporaneous dairy production. Traction is not an all-or-nothing affair; we need instead to think about it as a more complicated process with multiple ways in which animals can be used as engines. This repeated identification of draught exploitation of cattle calls into question the current scope of analysis and interpretation of such exploitation in prehistoric Europe.

These data indicate a need for investigators to systematically employ analytical techniques to further document this crucial phase of initial cattle traction utilization detectable through sub-pathological alteration of foot bone elements. From our study, it is clear that cattle are being exploited for traction from the onset of the Neolithic. Such studies need to be replicated in other regions of Europe in order to determine the extent and duration of this form of traction utilization. It is still unknown whether this form of traction is seen in only a selection of Neolithic groups or was a common component across Europe. A firm understanding of the nature of early traction evidence in prehistoric Europe has significant implications of such practices for our understanding of both management practices and the nature of labour and movement in prehistoric societies. What is needed now is a wider comparative assessment of sub-pathological evidence for cattle traction in Neolithic (and post-Neolithic) Europe to determine both how widely distributed was this pattern of early traction, and at what point we begin to see evidence of specialized heavy-traction animals.

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References

Arbuckle, B.S. 2014. Inequality and the origins of wool production in Central Anatolia. In B.S. Arbuckle and S.A. McCarty (Eds.), *Animals and Inequality in the Ancient World*. Colorado: University Press of Colorado: 209-230.

Bakker, J.A., Kruk, J., Lanting, A. E., & Milisauskas, S. 1999. The earliest evidence of wheeled vehicles in Europe and the Near East. *Antiquity* 73 (282): 778-790.

Bălăşescu, Adrian, Dragoş Moise, and Valentin Radu 2005 Use of bovine traction in the Eneolithic of Romania: a preliminary approach. In Cucuteni: 120 ans de recherches: le temps du bilan. G. Dumitroaia, J. Chapman, O. Weller, C. Preoteasa, R. Munteanu, D. Nicola, and D. Monah, eds. Pp. 277-284. Piatra-Neamțea: Editura Constantin Matasă.

Bartosiewicz, L. 2006. Mettre le chariot avant les boeufs: anomalies osteoligiques liees a l'utilisation des boeufs pour la traction. In P. Pétrequin, R.M. Arbogast, A.M. Pétrequin, S. van

Willigen and M. Bailly (Eds.), *Premiers Chariots, Premiers Araires: La Diffusion de la Traction Animale en Europe Pendant les IVe et IIIe Millénaires avant Notre Ère*. Paris: CNRS Editions: 259-267.

Bartosiewicz, L. 2008. Bone structure and function in draft cattle. In G. Grupe, G. McGlynn and J. Peters (Eds.), *Limping Together Through the Ages: Joint Afflictions and Bone Infections*. Rahden: Verlag Marie Leidorf GmbH: 153-164.

Bartosiewiez L., Van Neer W. & Lentacker A., 1997. *Draught Cattle: Their Osteological Identification and History*. Tervuren: Annalen Koninklijk Museum voor Midden-Afrika, Zoölogische Wetenschappen.

Becker, C., Benecke, N., Grabundžija, A., Küchelmann, H.-C., Pollock, S., Schier, W., Schoch, C., Schrakamp, I., Schütt, B. and Schumacher, M. 2015. The textile revolution. Research into the origin and spread of wool production between the Near East and Central Europe. *Journal for Ancient Studies* 6: 102-151.

Bogucki, P. 1984. Ceramic sieves of the Linear Pottery Culture and their economic implications. *Oxford Journal of Archaeology* 3: 15-30.

Bogucki, P. 1993. Animal traction and household economies in Neolithic Europe. *Antiquity* 67: 492-503.

Bondár, M and Székely, G.V. 2011. A new Early Bronze Age wagon model from the Carpathian Basin. *World Archaeology* 43:4: 538-553.

Breniquet, C, and C. Michel, eds. 2014. Wool Economy in the Ancient Near East and the Aegean: From the Beginnings of Sheep Husbandry to International Textile Industry. Oxford: Oxbow Books.

Chapman, J. 1982. 'The secondary products revolution' and the limitations of the Neolithic. *Bulletin of the Institute of Archaeology* 19 : 107-122.

De Cupere, B. Lentacker, A., Van Neer, W. Waelkens, M. and Verslype, L. 2000. Osteological evidence for the draught exploitation of cattle: first applications of a new methodology. *International Journal of Osteoarchaeology* 10: 254-267.

Ethier, J., Banffy, E., Vuković, J., Leshtakov, K., Bacvarov, K., Roffet-Salque, M., Evershed, R.P. and Ivanova, M. 2017. Earliest expansion of animal husbandry beyond the Mediterranean zone in the sixth millennium BC. *Nature Scientific Reports* 7: 7146. DOI:10.1038/s41598-017-07427

Galindo-Pellicena, A., Martín-Francés, L., Gracia, A., de Gaspar, I., Arsuaga, J.L and Carretero, J.M. 2015. Evidences of the use of cattle as draught animals in Chalcolithic El Portalón (Sierra de Atapuerca, Borgos). *Quaternary International* 438 Part B: 1-10.

Gaastra, J.S. and Vander Linden, M. in prep. Beyond taxonomic proportions: regional and cultural patterning in herding practices of the western Balkan Neolithic.

Greenfield, H.J. 1986. *Palaeoeconomy of the central Balkans (Serbia). Zooarchaeological Perspective on the Late Neolithic and Bronze Age (4500–1000 BC). British Archaeological Reports International Series 304*. Oxford: Archaeopress.

Greenfield, H.J. 1988. The origins of milk and wool production in the Old World: a zooarchaeological perspective from the central Balkans. *Current Anthropology* 29 (4): 573-593.

Greenfield, H.J. 1989. Zooarchaeology and aspects of the secondary products revolution a central Balkan perspective. Archaeozoologia 3(1-2): 191-200.

Greenfield, H.J. 1991 Fauna from the Late Neolithic of the central Balkans: issues in subsistence and land use. *Journal of Field Archaeology* 18: 161-186.

Greenfield, H.J. 2005. A reconsideration of the secondary products revolution: 20 years of research in the central Balkans. In J. Mulville and A. Outram (Eds.), *The Zooarchaeology of Milk and Fats (Proceedings of the 9th ICAZ Conference, Durham 2002)*. Oxford: Oxbow Press: 14-31.

Greenfield, H.J. 2008 Subsistence systems during the Early Neolithic of the central Balkans: a faunal taphonomic perspective. In C. Bonsall, V. Boroneanț, and I. Radovanović (Eds.), *The Iron Gates in Prehistory. British Archaeological Reports, International Series* vol. 1893. Oxford: Archaeopress: 103-114.

Greenfield, H.J. 2010. The Secondary Products Revolution: the past, the present and the future. *World Archaeology* 42(1): 29-54.

Greenfield, H.J. 2014a. H.J. Greenfield (Ed.), *Animal Secondary Products: Domestic Animal Exploitation in Prehistoric Europe, the Near East and the Far East*. Oxford: Oxbow Books.

Greenfield, H.J. 2014b. Some reflections on the origins and intensification of dairying in the archaeological record. In H.J. Greenfield (Ed.), *Animal Secondary Products: Domestic Animal Exploitation in Prehistoric Europe, the Near East and the Far East*. Oxford: Oxbow Books: 20-39.

Halstead, P. 2014. *Two Oxen Ahead: Pre-Mechanized Farming in the Mediterranean*. Oxford: Wiley Backwell.

Heron, C., Craig, O. E., Luquin, A., Steele, V. J., Thompson, A., & Piličiauskas, G. (2015). Cooking fish and drinking milk? Patterns in pottery use in the southeastern Baltic, 3300–2400 cal BC. *Journal of Archaeological* Science 63: 33-43.

Issakidou, V. 2006. Ploughing with cows: Knossos and the secondary products revolution. In D. Serjeantson and D. Field (Eds), *Animals in the Neolithic of Britain and Europe. Neolithic Studies Group Seminar Papers 7*. Oxford: Oxbow Books: 95-112.

Jakucs, J., Bánffy, E., Oross, K., Voicsek, V., Ramsey, C.B., Dunbar, E., Kromer, B., Bayliss, A., Hofmann, D., Marshall, P. and Whittle, A. 2016. Between the Vinča and Linearbandkeramik worlds: the diversity of practices and identities in the 54th–53rd centuries cal BC in southwest Hungary and beyond. *Journal of World Prehistory* 29: 267-336.

Johannsen, N.N. 2006. Draught cattle and the South Scandinavian economies of the 4th millennium BC. *Environmental Archaeology* 11 (1): 35-48

Lin, M., Miracle. P. and Barker, G. 2016. Towards the identification of the exploitation of cattle labour from distal metapodials. *Journal of Archaeological Science* 66: 44-56.

Lingereux, Y., Vaquer, J. and Collonge, J. 2006. Traction animale et lesions osseuses. Quelques cas dans le néolithique final languedocien (France). In P. Pétrequin, R.M. Arbogast, A.M. Pétrequin, S. van Willigen and M. Bailly (Eds.), *Premiers Chariots, Premiers Araires: La Diffusion de la Traction Animale en Europe Pendant les IVe et IIIe Millénaires avant Notre Ère*. Paris: CNRS Editions: 31-38.

Marciniak, A. 2011. The Secondary Products Revolution: empirical evidence and its current zooarchaeological critique. *Journal of World Prehistory* 24: 117-130.

Milisauskas, S. and Kruk, J. 1991. Utilization of cattle for traction during the later Neolithic in southeastern Poland. *Antiquity* 65: 562-566.

Orton, D., Gaastra, J. and Vander Linden, M. 2016. Between the Danube and the deep blue sea: zooarchaeological meta-analysis reveals variability in the spread and development of Neolithic farming across the Western Balkans. *Open Quaternary* 2 (6): 1-26.

Outram, A. K., Kasparov, A., Stear, N. A., Varfolomeev, V., Usmanova, E., & Evershed, R. P. 2012. Patterns of pastoralism in later Bronze Age Kazakhstan: new evidence from faunal and lipid residue analyses. *Journal of Archaeological Science* 39 (7): 2424-2435.

Pétrequin, P., Arbogast, R.M., Pétrequin, A.M., van Willigen, S. and Bailly, M. 2006. *Premiers Chariots, Premiers Araires: La Diffusion de la Traction Animale en Europe Pendant les IVe et IIIe Millénaires avant Notre Ère*. Paris: CNRS Editions.

Piggott, S. 1983. *The Earliest Wheeled Transport: From the Atlantic Coast to the Caspian Sea*. London: Thames & Hudson.

Pipes, M.-L., Kruk, J. and Milisauskas, S. 2014. Assessing the archaeological data for wool-bearing sheep during the middle to late Neolithic at Bronocice, Poland. In H.J. Greenfield (Ed.), *Animal Secondary Products: Domestic Animal Exploitation in Prehistoric Europe, the Near East and the Far East*. Oxford: Oxbow Books: 80-102.

Rowley-Conwy, P. 1987. The interpretation of ard marks. *Antiquity* 61 (232): 264-266.

Sherratt, A. 1983. The secondary exploitation of animals in the Old World. *World Archaeology* 15 (1): 90-104.

Salque, M., Radi, G., Tagliacozzo, A., Pino Uria, B., Wolfram, S., Hohle, I., Stäuble, H., Whittle, A., Hofmann, D., Pechtl, J., Schade-Lindig, S., Eisenhauer, U. and Evershed, R.P. 2012. New insights into the Early Neolithic economy and management of animals in Southern and Central Europe revealed using lipid residue analysis of pottery vessels. *Anthropozoologica* 47(2): 45-61.

Spiteri, C.D., Gillis, R.E., Roffet-Salque, M., Navarro, L.C., Guilaine, J., Manen, C., Muntoni, I.M., Segui, M.S., Urem-Kotsou, D., Whelton, H.L. and Craig, O.E. 2016. Regional asynchronicity in dairy production and processing in early farming communities of the northern Mediterranean. *Proceedings of the National Academy of Sciences* 113 (48): 13594-13599.

Tarrús, J., Saña, M., Chinchilla, J. and Bosch, A. 2006. La Drada (Banyoles, Catalogne): traction animal à la fin du VI[e] millénaire? In P. Pétrequin, R.M. Arbogast, A.M. Pétrequin, S. van Willigen and M. Bailly (Eds.), *Premiers Chariots, Premiers Araires: La Diffusion de la Traction Animale en Europe Pendant les IVe et IIIe Millénaires avant Notre Ère*. Paris: CNRS Editions: 25-30.

Wolff, J. 1892. *Das Gesetz der Transformation der Knochen*. Berlin: A. Hirschwald.

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Figure 7: Osteometric comparisons of medial remodelling of distal metacarpals from domestic cattle (*Bos taurus*) and wild aurochs (*Bos primigenius*) using the index developed by Lin et al. (2016).

Figure 8: Osteometric comparisons of medial remodelling of distal metatarsals from domestic cattle (*Bos taurus*) and wild aurochs (*Bos primigenius*) using the index developed by Lin et al. (2016).

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Table 1: Summary of site samples used in the present study. Site names are given along with cultural affiliation, calibrated radiocarbon dates (where available) and the number available for each element studied. The number of elements identified as aurochs (*Bos primigenius*) is given in brackets. The Early Neolithic cultural complex Starčevo-Körös-Criş is abbreviated here to 'SKC'.

Table 2: Distribution of elements with positive (PI >2.5) indications of sub-pathological alterations relating to traction. As in Table 1, the number of aurochs (*Bos primigenius*) elements are given in brackets.

Site No.	*Site*	*Cultural Group*	*Date (cal BC)*	*Analyst*	*Metacarpal*	*Metatarsal*	*Phalanx 1*	*Phalanx 2*
	Early Neolithic: c.61/6000 to 55/5400 cal BC							
1	Blagotin	SKC	6000-5900	HJG	6 [1]	4[1]	3	5
2	Foeni-Salaş	SKC	6057-5971	HJG	4 [1]	3	4	3
3	At Vršac	SKC	5665-5471	JSG	2	1	1	1
4	Belišće	SKC	-	JSG	12 [3]	10 [2]	18 [1]	17 [1]
5	Kneževi Vinograd	SKC/Ražište	6001-5873	JSG	17 [3]	14 [2]	11 [4]	6 [3]
	Middle Neolithic: c.55/5400 to 5000 cal BC							
6	Potporanj	Vinča B	5180-5062	JSG	14 [3]	23 [2]	16 [5]	12 [4]
7	Stragari	Vinča Tordoš	-	HJG	2	3 [1]	7	8 [1]
8	Sânandrei	Banat	-	HJG	2	1	3	2
	Late Neolithic: 5000-4500 cal BC							
	At Vršac	Vinča D	4620-4358	JSG	4 [1]	6	4	3 [1]
9	Petnica	Vinča D	4729-4553	HJG	2	2	1	3
10	Hermanov Vinograd	Sopot	4730-4579	JSG	33 [2]	19 [1]	72 [8]	77 [5]
11	Kosjerovo	Sopot	4728-4549	JSG	3 [2]	4	12 [1]	4

Table 1*:* Summary of site samples used in the present study. Site names are given along with cultural affiliation, calibrated radiocarbon dates (where available) and the number available for each element studied. The number of elements identified as aurochs (*Bos primigenius*) is given in brackets. The Early Neolithic cultural complex Starčevo-Körös-Criș is abbreviated here to 'SKC'.

Site	*Metacarpal*	*Metatarsal*	*Phalanx 1*	*Phalanx 2*
Early Neolithic				
Blagotin	[0]		1	2
Foeni-Salaş	[0]		1	1
At Vršac			1	
Belišće	1 [0]	2 [0]	3 [0]	2 [0]
Kneževi Vinograd	1 [0]	2 [0]	2 [0]	3 [0]
Middle Neolithic				
Potporanj	1 [0]	2 [0]	3 [0]	2 [0]
Stragari		1 [0]	2	1 [0]
Sânandrei			1	
Late Neolithic				
At Vršac	[0]	1	1	1 [0]
Petnica		1	1	
Hermanov Vinograd	5 [0]	4 [0]	7 [0]	3 [0]
Kosjerovo		1	2	1

Table 2: Distribution of elements with positive (PI >2.5) indications of sub-pathological alterations relating to traction. As in Table 1, the number of aurochs (*Bos primigenius*) elements are given in brackets.