Archaeofauna 34(1) (2025): 275-285

A preliminary investigation of cattle (*Bos taurus*) size and shape changes between the Copper Age and the Bronze Age in Northern Italy

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(Received *24 October 2022*; Revised *12 April 2023*; Accepted *12 August 2023*)

ABSTRACT: The period spanning between the Late Neolithic and the Bronze Age in Northern Italy witnessed the introduction of a number of innovations, such as new settlement patterns and new husbandry strategies, which signalled a distinct break from previous Neolithic cultural and economic traditions. Previous zooarchaeological studies suggest that, until the late Copper Age, cattle were large, closer to their Neolithic counterparts in terms of size. In the Bronze Age, however, a significant reduction in body size was noted. Since that phenomenon has been mainly based on macroscopic observations, and the size reduction has never been confirmed in terms of biometry, this work aims to explore the presence (or absence) of size and shape variations in cattle throughout this period through the use of a variety of biometrical techniques. Our results appear to contradict what previous researchers had noted since postcranial measurements reveal no significant changes in body size and shape trends emerging between periods.

KEYWORDS: BIOMETRY, COPPER AGE, BRONZE AGE, CATTLE, NORTHERN ITALY

RIASSUNTO: Il periodo tra il tardo Neolitico e l'età del Bronzo in Italia settentrionale vide l'introduzione di una serie di innovazioni (nuovi modelli di insediamento e nuove strategie di allevamento) e una netta rottura con le tradizioni culturali ed economiche proprie del Neolitico. Precedenti studi archeozoologici suggeriscono che fino alla tarda età del Rame i bovini erano di grandi dimensioni, più vicini agli esemplari neolitici. Nell'età del Bronzo, tuttavia, si può notare una significativa riduzione di taglia degli individui. Poiché tale affermazione si basa principalmente su osservazioni macroscopiche e la riduzione di taglia non è mai stata pienamente dimostrata biometricamente, il presente lavoro si propone di identificare, con l'uso di diverse tecniche biometriche, la presenza (o l'assenza) di tali variazioni di taglia e forma nei bovini nel corso del tempo. I risultati del nostro studio sembrano contraddire quanto notato in studi precedenti: dalle analisi delle misure postcraniali dei bovini, infatti, non sono emerse significative variazioni di taglia e forma nelle popolazioni considerate.

PAROLE CHIAVE: BIOMETRIA, ETÀ DEL RAME, ETÀ DEL BRONZO, BOVINI, ITALIA SETTENTRIONALE

http://www.doi.org/10.15366/archaeofauna2025.34.1.026

RESUMEN: En la Italia septentrional, el período comprendido entre el Neolítico tardío y la Edad del Bronce evidencia la aparición de una serie de innovaciones en los patrones de asentamiento y estrategias pecuarias, que marcan una ruptura con las tradiciones culturales y económicas del Neolítico. Estudios zooarqueológicos previos sugieren que, hasta finales de la Edad del Cobre, el vacuno era grande, más cercano a sus homólogos del Neolítico, en términos de tamaño, en tanto que en el Bronce se comenta una reducción significativa del tamaño corporal en esta cabaña. Dado que este fenómeno se ha basado principalmente en observaciones macroscópicas, y la reducción de tamaño nunca ha sido confirmada en términos biométricos, nuestro estudio tiene por objeto explorar la presencia (o ausencia) de variaciones de tamaño y forma del vacuno durante estos períodos mediante el uso de distintas técnicas biométricas. Los resultados parecen contradecir lo que investigadores anteriores habían observado, puesto que nuestras mediciones de elementos poscraneales no revelan cambios significativos en el tamaño y forma del cuerpo referidas entre períodos.

PALABRAS CLAVE: BIOMETRÍA, EDAD DEL COBRE, EDAD DEL BRONCE, BOVINO, ITALIA SEPTENTRIONAL

INTRODUCTION

It is well known that the Bronze Age (*c*. 2200 B.C. – 900 B.C.) in Northern Italy brought significant changes in the way ancient communities interacted with their environment and represented, in several respects, a break from the Neolithic (*c*. 5500 B.C. – 3400 B.C.) and Copper Age (*c*. 3400 B.C. – 2200 B.C.) cultural traditions. During the Neolithic, cyclical and itinerant agriculture was practised: human communities inhabited short-lived villages until the fertility potential of the land was exhausted, forcing them to move on to another location (Rottoli & Pessina, 2007; Nisbet, 2013; Starnini *et al*., 2017). Conversely, in the Bronze Age, thanks to the technological innovations introduced during the Copper Age (such as metallurgy, the introduction of the plough and the wheel), sedentary and long-lasting settlements appeared to be systematically inhabited (Tecchiati *et al*., 2020). This change in settlement patterns went hand in hand with other important developments: human communities started to rely more heavily on husbandry and slowly abandoned hunting and gathering activities which, in previous periods, had great economic significance (Carra, 2012). Animal husbandry, as we know it, was established in the Bronze Age (although this process was very slow and was not equally widespread in all of Northern Italy), and zooarchaeological evidence (Salvagno & Tecchiati, 2011; Tecchiati *et al*., 2020) shows that it is in this period that the exploitation of the highlands for transhumance became systematic. Finally, we believe that it is only in the Bronze Age that the secondary products revolution took place [*i.e*., the systematic exploitation of domestic animals not only for meat, leather and bones, but also for milk, wool and traction power. See Sherratt (1981) and Putzolu (2021)].

Zooarchaeology has the potential to give us an insight into husbandry practices and shows us how these were influenced by, and adapted to, the changing economy and society that characterized the period between the Late Neolithic and the Bronze Age (Riedel, 1976a). While it is a well-known phenomenon that across Neolithic Europe cattle size tends to get smaller through time (Bökönyi, 1974; Meadow, 1989; Manning *et al*., 2015) in Norther Italy like in Switzerland (Bopp-Ito *et al*., 2018; Wright *et al*., 2021), we do not see such pattern. It is generally believed that cattle size changed later, between the Copper Age and the Bronze Age in this area: cattle seem to be large until the end of the Copper Age (possibly due to the persistence of a type of exploitation where breeds were not selected for different uses), in the Bronze Age, new exploitation techniques led to a decrease in size of this species (Riedel, 1976a). While a most recent study conducted by Trentacoste *et al*. (2018) has showed that in Northern Italy cattle size increases between the Bronze Age and the Iron Age (*c*. 1650-150 B.C.), comprehensive biometrical studies such as this have not been carried out for earlier periods. In fact, the belief that between the Copper Age and the Bronze Age cattle underwent a size decrease in Northern Italy is still mainly based on Alfredo Riedel's macroscopic observations (*i.e*., visual inspection of faunal remains). An early attempt to biometrically detect such phenomenon was made by Riedel

himself (1976b, c). However, a common practice in Riedel's work was to compare the average of measurements from one site with the same data from other contemporary (or not contemporary) sites. Riedel can rightly be considered a pioneer of Zooarchaeology, and his work holds still indisputable scientific value; nevertheless, with the adoption of new biometrical techniques, his approach might be regarded as obsolete, especially when seeking an in-depth insight into size and shape variations in archaeological populations. Considering these premises, the aim of this paper is to start a very preliminary biometrical analysis of Northern Italian cattle (*Bos taurus*) assemblages dated between the Late Neolithic and the Bronze Age in order to: A) identify, with the use of a variety of biometrical techniques, the presence (or absence) of size and shape variations in cattle through time; B) if present, try to identify the timing of such changes; and C) assess whether cattle size changes were influenced by/adapted to the adoption of different political and economic systems happening in the period considered.

MATERIALS AND METHODS

The cattle assemblages used in this study were selected from archaeological sites in Northern Italy from which extensive and chronologically reliable faunal collections originated. All assemblages are dated to between the Late Neolithic and the Late Bronze Age (Table 1 in Supplementary Material 1, Figure 1). Within each main chronological period several chronological sub-phases existed, however, these had a small number of measurements. As such, in order to improve sample sizes, the data were organised in three main groups: the Late Neolithic, the Copper Age and the Bronze Age. While this data organization increased sample sizes, it

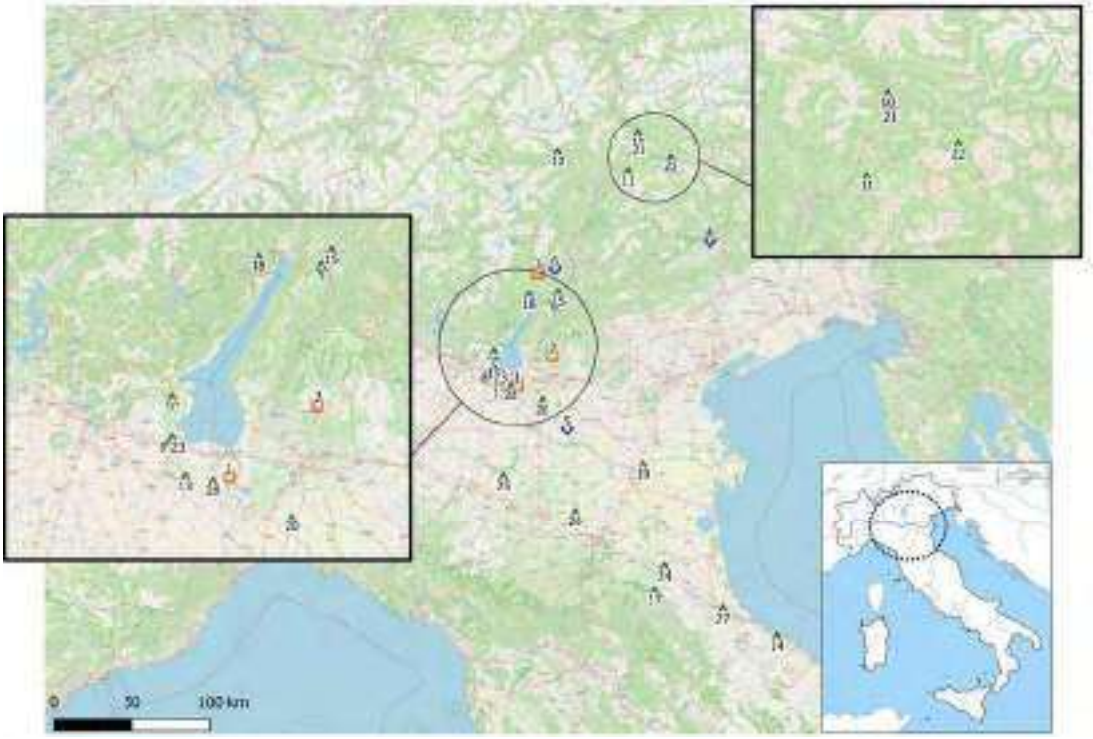

FIGURE 1

Map showing the location of the sites included in this study (GIS by Dr. Fiorenza Gulino). 1: Tosina di Monzambano; 2: Colombare di Negrar; 3: Fiavè 1; 4: Belluno, Col del Buson; 5: Gazzo Veronese, Il Cristo; 6: Lasino, Riparo del Santuario; 7: Lucone; 8: Lavagnone; 9: Colombo di Mori; 10: Nössing; 11: Siusi, Castelrotto; 12: Naturno; 13: Barche di Solferino; 14: Cattolica; 15: Grotte di Castel Corno, Isera; 16: Sergnano; 17: Grotta dei Banditi; 18: Ledro; 19: Canàr; 20: Camponi di Nogarole Rocca; 21: Albanbühel; 22: Sotciastel; 23: Lavagnone; 24: Solarolo, Via Ordiere; 25: Santa Rosa di Poviglio; 26: Montirone di Sant'Agata Bolognese; 27: Case Missiroli; 28: Castellaro Lagusello. Chronological periods are referred to as follows: orange square = Late Neolithic; blue rhombus = Copper Age, green triangle = Bronze Age.

also made it impossible to assign patterns to tighter chronological periods.

In order to carry out our biometrical analysis, measurements of cattle molars and postcranial bones were collected from the relevant literature (see Table 1 in SM 1). All measurements collected were taken using the guidelines published by Driesch (1976), however, only fusing and fully fused specimens were included in the analysis. Both tooth and postcranial measurements were considered. Tooth size tends to be more conservative and less affected by environmental factors, age and sex, thus allowing us to make considerations about genetic change in the livestock population (Payne & Bull, 1988). Contrarily, changes in postcranial measurements could be linked to changes in the environment, nutrition, or sex ratio of the herd (Grau-Sologestoa & Albarella, 2019). An initial metric assessment was carried out using scatterplots for both tooth and postcranial measurements. Change in the shape of postcranial bones was investigated using shape ratios of astragalus measurements (Bd/GLl vs Dl/GLl). These measurements were chosen due to their relatively large sample size. Maximum M_3 (third lower molar) width was plotted as a histogram to identify change in tooth size through time. Molar width was chosen for this assessment as it is not much affected by sexual dimorphism and shows less age-related changes than length.

To better evaluate size changes through time, the log ratio technique was used (Simpson, 1941; Meadow, 1999; Albarella, 2002); this allows us to combine different measurements on the same axis, (i.e., lengths, widths and depths) thus enabling us to work with larger sample sizes. Lengths, widths, and depths (when possible) were analysed separately, as combining different planes could blur changes affecting one particular dimension of the bones. Measurements from teeth and postcranial bones are usually considered separately in this technique to distinguish genetic from environmentally induced changes (Albarella & Payne, 2005); however, in our case, cattle tooth measurements were not enough and, as such, they were excluded. The log ratio technique is a size scaling method which is based on the comparison of the relative size (rather than absolute) of archaeological specimens to a standard (a population or a single individual) by calculating the logarithm of the ratio between the archaeological measurement and the standard (Payne & Bull, 1988). In this study the standard used is a 13-year-old modern Hinterwälder female (Z-2431) (Breuer *et al.*, 1999; Bopp-Ito *et al.*, 2017; Wright, 2021). Only a selection of all possible measurements was considered for this analysis; these were chosen because: A) they are commonly present in archaeological assemblages; B) they are standardised and commonly taken, thus allowing comparability across different researchers; C) they are not highly affected by sexual dimorphism and D) they are not highly age dependant (Popkin *et al.*, 2012). The list of anatomical elements and measurements used for this analysis is provided in Table 2 in SM1. SM1 also shows measurements sample size for each axis per chronological period (Table 3 in Supplementary Material).

The statistical significance of observed differences in size between periods was tested using a non-parametric test such as the Kruskal-Wallis test (1952). This test was chosen because sample sizes for the different chronological periods were unequal and not normally distributed.

RESULTS

A first attempt to detect changes in size and shape of cattle was made by using scatterplots comparing linear measurements for as many anatomical elements as possible. Due to the small number of measurements at our disposal (dominated by breadth), we could only use the following elements and combination of measurements: scapula (BG/GLP), radius (BP/BFp), ulna (DPA/BPC) and astragalus (Bd/Dl and Bd/GLl). Scatterplots for all the above-mentioned elements (excluding the astragalus) are provided in SM2 (Figure 1). Figure 2 shows the results we obtained with the astragalus, the only element for which we had a relatively large sample.

If we look at Figure 1 in SM2 and Figure 2, some considerations can be made. First, it should be noted that there is a significant difference in terms of sample size: the Bronze Age sample is much larger than the Late Neolithic sample and even more so for the Copper Age sample. Secondly, if we look at the distribution of the data, the Bronze Age sample presents a very similar variability to the Late Neolithic sample: both groups, in fact, occupy the same area of the graph (evident in both the astragalus and the scapula). If a difference in size was present, we would expect both samples to be aligned to the regression line but both plotting in a different area of

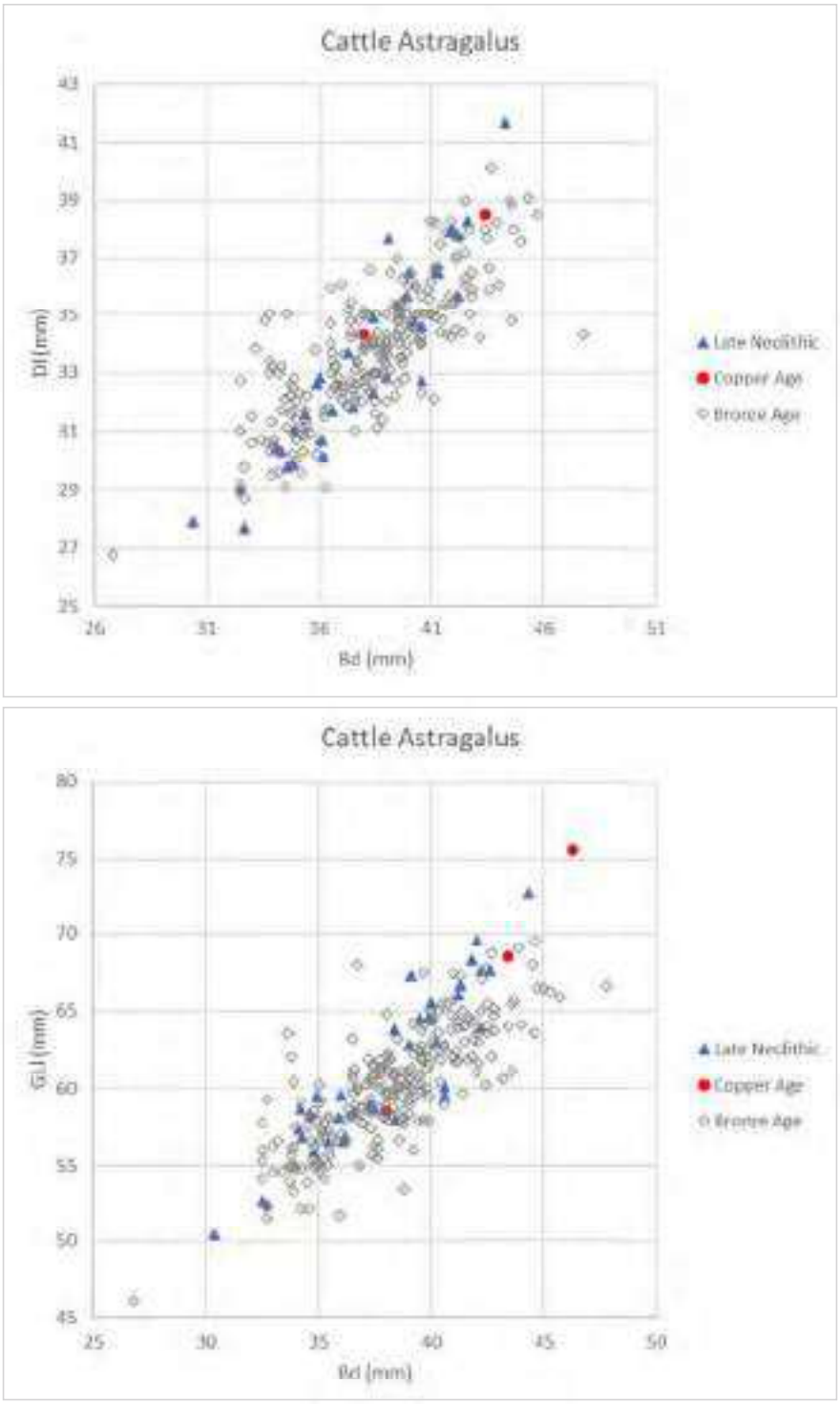

FIGURE 2

Scatter plots comparing cattle astragalus measurements (Bd= greatest breadth of distal end; Dl= greatest depth of the lateral half; GLl= greatest length of the lateral half).

the graph. This is not what our graphs show. While this pattern could perhaps not be genuine due to the relative paucity of data for the Late Neolithic and the Copper Age, we cannot ignore the fact that, even when the sample size increases (see astragalus in Figure 2), no clear pattern can be seen.

Maximum breadth and length of cattle upper and lower third molars (M^3 and M_3) were also used to assess whether patterns of size change could be identified. Figure 2 in SM2 shows that, when tooth measurements are considered, sample sizes increase for all periods (except for the Copper Age sample which is still underrepresented). For both M^3 and M_3, the Bronze Age population shows much more variability than the Late Neolithic (especially for the width measurements, see Figure 2 in SM2): the Bronze Age specimens are more scattered on the graph than the Late Neolithic specimens, which appear to be concentrated more tightly. Furthermore, in both teeth (but especially in M_3) a pattern can be identified: the Late Neolithic animals have, in general, a very similar width to the Bronze Age animals. However, many Bronze Age individuals tend to have smaller length values compared to the Late Neolithic populations. This pattern seems to suggest the existence of morphological differences between some of the Late Neolithic and the Bronze age animals (as changes involve prominently one of the two dimensions - the length of the tooth).

Change in postcranial bones shape was investigated using the shape ratio technique on the astragalus (chosen for its relatively large sample size). The combination of measurements used were Bd/GLl *vs* Dl/GLl (Figure 3). The plot shows that, once again, there is much more variability among the Bronze Age sample than the Late Neolithic. There is a lot of overlap between the Late Neolithic and the Bronze Age groups; however, even though no clear separation between periods is present, some of the Bronze Age individuals seem to occupy an area of the graph where not many Late Neolithic (and Copper Age) specimens lie (i.e. the top right corner). This distribution seems to suggest that some shape differences exist between the Late Neolithic group and the Bronze Age individuals (having generally higher values on both axes). This pattern is, however, not very clear.

The log ratio technique was then applied to detect size changes over time. By grouping different measurements on the same axis (in our case lengths

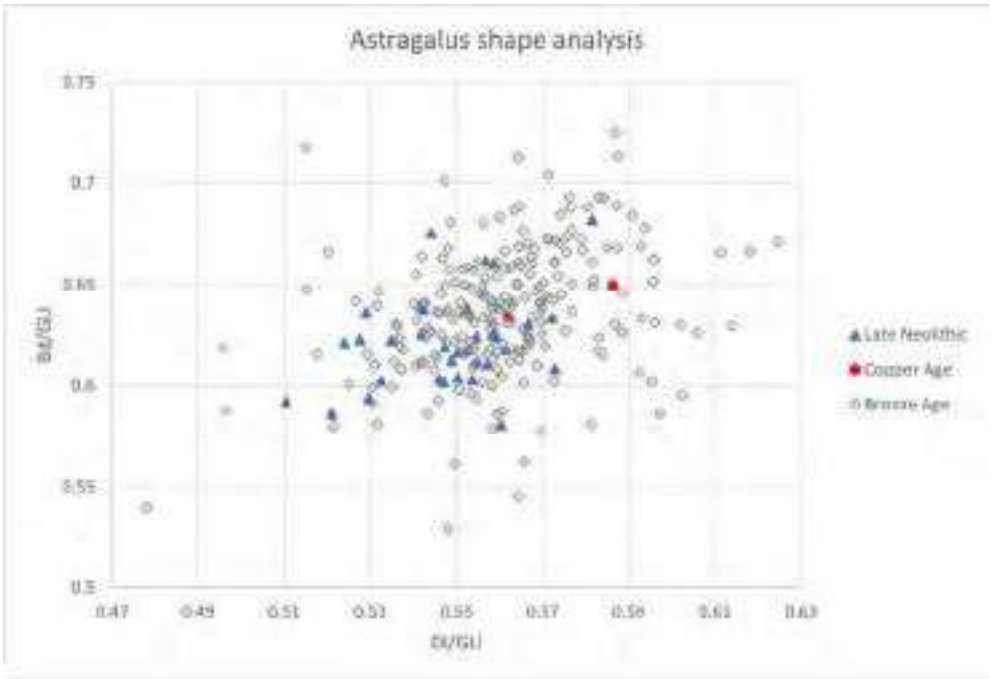

FIGURE 3

Scatter plot comparing the ratios of astragalus measurements for cattle (Bd= greatest breadth of distal end; Dl= greatest depth of the lateral half; GLl= greatest length of the lateral half).

and widths as we did not have enough measurements to evaluate depth), we could work on larger sample sizes. Figure 3 in SM2 shows log ratio histograms for cattle postcranial length measurements for each chronological period. Unsurprisingly, the Late Neolithic and the Bronze Age samples are significantly larger (respectively 42 and 349 length measurements) than the Copper Age sample; this latter has a very small sample size making it impossible to draw any meaningful observation. If we consider the mean log value for the Late Neolithic sample (–0.03) and the Bronze Age sample (–0.04), we can see that they are both smaller than the standard but very close to each other. A similar result is also given when cattle postcranial bone widths measurements are considered (Figure 4 in SM2): the Late Neolithic and the Bronze Age log mean values (respectively –0.01 and –0.02) are very similar. This evidence suggests that the Bronze Age animals were similar in size to the Late Neolithic animals as far as postcranials measurements are concerned. The mean log values for both postcranial length and width measurements for the Late Neolithic and the Bronze Age samples were tested with a Kruskal-Wallis test and no statistically significant differences emerged (Table 1 in SM2).

Since it was not possible to apply the log ratio technique on tooth measurements due to their small sample size, we decided to use the maximum width of the M_3 (larger sample size than the M^3) to see whether we could see hints of size change in teeth. Figure 5 in SM2 shows that the width of the M_3 does not reveal a significant size change between periods (Late Neolithic Mean=13.32; Copper Age Mean= 13.03; Bronze Age Mean=14.00). These values were also statistically tested, and the results were not significant (Table 2 in SM2). It must be noted that the data for the Bronze Age have a wider distribution compared to the sample from the Neolithic period. Moreover, several Bronze Age animals have tooth width above 15mm showing, therefore, to have relatively more robust M_3. This might be an indication of some morphological differences, however the sample size for the two periods is very unequal.

DISCUSSION AND CONCLUSIONS

In this article we have only begun to uncover important research questions concerning changes in husbandry practices occurring in Northern Italy between the Late Neolithic and the Bronze Age. The Copper Age has, on many levels, always been considered a continuation of Neolithic economic and cultural traditions. On the contrary, the Bronze Age (especially during its earlier phases) represents a break from previous patterns of behaviour and brings elements of innovation which must have had an impact on the economic system adopted by human communities and, as such, on the husbandry strategies practised.

Previous studies suggest that, until the late Copper Age, larger animals, closer in size to their Neolithic counterparts were present (for example, in our sample see cattle size at the site of Gazzo Veronese, Il Cristo. Riedel & Rizzi-Zorzi, 2005). In the Bronze Age however, a significant reduction in body size can be noted. The results from our study seem to contradict the above statement. When cattle postcranial measurements were analysed using different techniques, no significant changes in body size emerged between periods. Even the results obtained from the biometrical analysis of the astragalus, the only element for which we had a good sample size, show no clear size pattern; however, we cannot help but wonder whether size differences in Figure 2 would be clearer if a group of very small individuals dated to the Late Neolithic (from the sites of Tosina di Monzambano and Fiavè 1) were excluded from the analysis. This exclusion would, in fact, determine a more defined size separation (with half of the Bronze Age astragali plotting on the left bottom corner while the Late Neolithic sample would mainly occupy the upper right area). Interestingly, the presence of very small cattle in Tosina and Fiavè 1 could be explained by the introduction of smaller animals from Switzerland and the Alpine area where their presence is well documented in the zooarchaeological records in the Late Neolithic (Boessneck *et al*., 1963; Förster, 1974; Wright, 2021). Naturally, such an introduction would first take place in the area around the Lake Garda (where the above-mentioned sites are located) as it is geographically closer to the Alpine regions and, most likely, heavily influenced by the Northern Alpine cultural facies.

Shape was also analysed using shape ratios (only on the astragalus) but very little indication of changes emerged (Figure 3). As far as cattle postcranial bone measurements are concerned, our results seem to describe a relatively static scenario.

A slightly different situation emerges from the analysis of cattle tooth measurements. In fact,

some differences seem to be present between the Late Neolithic and the Bronze Age populations affecting the length of the M_3 (Figure 2 in SM2). It would be very tempting to interpret this evidence as a possible indication of genetic change in the cattle population; however, these results must be taken with caution. Firstly, because we are comparing samples with very uneven sizes and, secondly, because we are using measurements that have been collected by different researchers and measurer variability is higher in tooth measurements than in postcranial measurements. In conclusion, our study has not brought to light clear evidence of size or shape changes affecting cattle between the Late Neolithic and the Bronze Age. However, some hints are present and only further studies will be able to clarify the situation. In addition, from our analysis, the presence of particularly small individuals dated to the Late Neolithic emerged. The introduction in Northern Italy of a smaller type of cattle in the Late Neolithic was contemporaneous with the presence of a larger type of animal, well attested in the archaeological record in the Early and Middle Neolithic (Cazzella *et al.*, 1976; Rowley-Conwy, 1997; Agrostelli *et al.*, 2015). Only in the Middle and Late Bronze Age did these larger animals disappear, and the smaller type become predominant. In a context in which animal husbandry starts to be dominated by new forms of animal management, such as pastoralism and transhumance, and characterised by the progressive transition from a nomadic way of life to the creation of permanent settlements, the "selection" of smaller animals seems understandable: smaller individuals would be much easier to control and to periodically move.

Our study also gave us the opportunity to identify areas of research which need further exploration and research aspects which should be prioritised:

a) Sample size is notoriously a problem when working with very old assemblages. We recommend that future studies on this topic collect as much metric data as possible and widen the geographic range considered. In addition, we recommend integrating the zooarchaeological data with paleoenvironmental and paleoecological data.

b) This, in turn, will allow consideration of to what extent ancient economies were subject to/changed by their local environment. In this regard, it would be interesting to see whether, with a bigger sample, differences in cattle size and morphology could be found between populations living in different geographical areas. This, in fact, would allow the evaluation of potential regional variability at play.

c) Early in this study the need for better defined chronologies emerged. While this is unfeasible for assemblages excavated in the 70s and 80s, it is highly desirable for more recently excavated assemblages. A more precisely defined chronology would, in fact, allow us to identify patterns with much greater temporal precision.

d) In our study we focused on anatomical elements which are less influenced by age and sex. However, considering the paucity of measurements available, we suggest including in the analysis other anatomical elements often abundantly present in Late Neolithic-Copper-Bronze Age assemblages. However, this will then require a more in-depth consideration of the extent to which factors such as age and sexual dimorphism affect size and shape in the sample. It is important to bear in mind that we are dealing with two chronological periods dominated by different economic choices: in the Late Neolithic with the main economic focus being on meat, we would expect both sexes to be killed equally. Contrarily, in the Bronze Age, with the interest shifting from meat to secondary products (especially milk), we would expect most of the herd to have been dominated by females. Biometrically, these economic choices would and should result in the Late Neolithic sample having larger measurements than the Bronze Age sample. To what extent it is possible to clarify whether size changes are genuine rather than the result of different male/female propositions in the sample is something we hope future researchers will be able to clarify.

We are aware of the preliminary nature of our study and that since our article was drafted and submitted for publication more cattle biometric data for our regions of interest were made publicly available (Trentacoste *et al.*, 2022). As such, we hope that our research will represent a jumping off point for further and wider research on this topic to be undertaken.

ACKNOWLEDGEMENTS

The idea of this paper was conceived and developed by F.F., L.S. and U.T. A first draft of the paper was written by F.F., L.S. and U.T. Data analysis was carried out by F.F. and L.S. in close consultation with U.T. The original metric data on which our analysis is based were either obtained from published literature or, in small part, were collected and owned by F.B. and A.A. The contribution of both is here acknowledged. We would also like to take this opportunity to sincerely thank Dr. Alex Fontana, for sharing with us essential biometric data and for engaging scientific discussions. We would also like to thank Dr. Fiorenza Gulino for her help with GIS.

SUPPLEMENTARY MATERIAL

See supplementary material at https://revistas.uam.es/archaeofauna/article/view/archaeofauna34.1_026

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