CAPRINE SKELETONS CAN BE "HERD"

SHANNON PFEIFFER
UNIVERSITY OF CALIFORNIA, BERKELEY

The skeletal morphology of animals provides information on how they lived, including their style of locomotion. When studying locomotive patterns, the skeleton can show very descriptive, even diagnostic, morphologies that are indicators of which muscle groups and joints were most important. When looking at animals domesticated and herded by human pastoralists, differences in their skeletal morphologies can inform how and where people traveled with their animals. This initial study proposes a pilot methodology for analyzing topographical extremes in herded caprines using muscle scarring, insertion sites, and bone histology with an overall goal to determine and compare differences in pastoral practices.

Recent research on musculoskeletal stress markers (MSM) and their possible relationship with the lifeways and activity patterns of humans is still considered controversial and problematic. Many variables must be controlled, such as age, sex, size of the skeletal element and its robusticity, and population (Weiss 2003). Even when multiple factors are controlled, many scientists are still skeptical about the findings of these studies, questioning the reliability of the measurements and their correlation with other factors (Weiss 2003). However, it is still thought that some musculoskeletal stress markers could lead to determining the habitual actions of an individual and, ultimately, a population (Weiss 2003).

Although humans have very different and complex behavioral patterns between individuals and populations that may be influencing their skeletal structures, some of these practices may also influence their domesticated animals. Previous studies on the earliest domestication of caprines, mainly goats (*Capra hircus*), in the Zagros mountains of Iran have dated it to more than 10,000 B.P. (Zeder and Hesse 2000). These studies have employed the work of von den Driesch (1976) to measure the sizes of the skeletal elements of domestic and wild populations from this area, finding there to be little to no distinction between the two populations (Zeder 1999). Age was also found to be a minor factor, while region had more influence on animal body size (Zeder 1999).

Since region had previously been established to significantly influence the size of goats (Zeder 1999), this study proposes to combine the measurement techniques of previous studies on human musculoskeletal stress markers and of von den Driesch (1976), as well as the knowledge of previous research on the initial domestication of *Capra hircus*. The hypothesis is that similar stress markers, along with other factors of an animal's skeleton, allow for the determination of herding site topography, considering that past pastoral and agricultural human populations in California would have resided on flat land. The goal of further research and analysis is to determine activity and subsistence patterns of past human populations in relation to domesticated herding animals. This preliminary work means to outline the methods and goals of future research on caprines from California, knowing that a larger sample size, improved resources, and further reading of previous research is necessary to produce viable data.

MATERIALS AND METHODS

In order to understand the questions this initial study seeks to answer in the future, it was necessary to understand prior research. Understanding the backgrounds of caprine domestication and musculoskeletal stress markers was a prime objective in order to combine the findings into a study that further enhanced those that came before it. Since the work is being performed on ruminants rather than humans, it was also necessary to employ the work of von den Driesch (1976).

A set of digital calipers, the left and right humeri from three comparatives, and a copy of von den Driesch (1976) were used to take left and right humeral measurements for greatest breadth of the

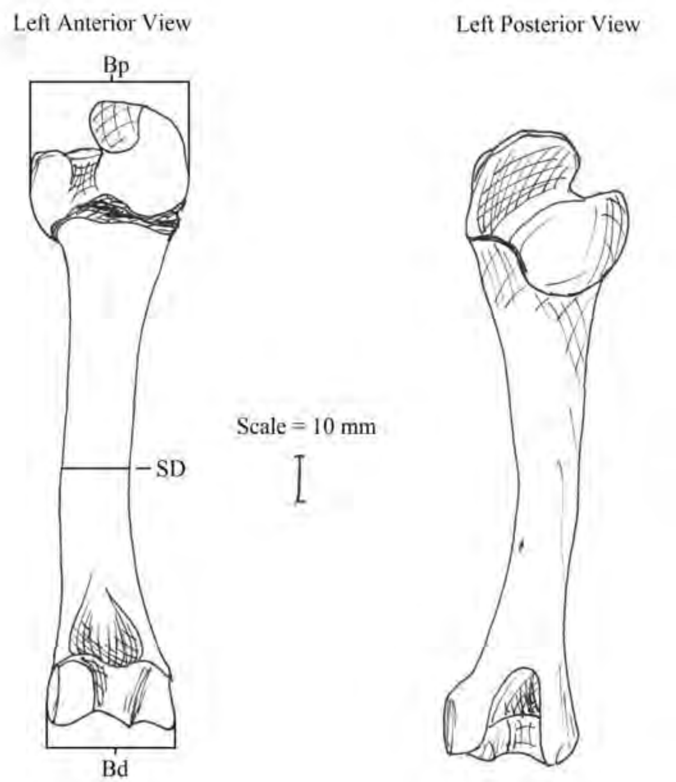

Figure 1. The left humerus of Specimen 1, showing the measurements taken using the methods of von den Driesch (1976). A comparative specimen from the Museum of Vertebrate Zoology, University of California, Berkeley.

proximal end (Bp), smallest breadth of the diaphysis (SD), and greatest breadth of the distal end (Bd), as seen in Figure 1. Due to the need for future studies, only the humeri were measured, in relation to previous MSM research (Niinimaki 2012). Since this study is to focus on muscle attachments, a forth measurement was taken (see Figure 2). The deltoid muscle attaches to the humerus at the deltoid tuberosity and creates the deltoid ridge on the anterolateral side of the element. The length of the ridge (LD) was measured under the assumption from MSM research that the marker provides an indication of the robusticity of the muscle (Niinimaki 2012). The preference would have been to measure the depth or ruggedness of the ridge, but the calipers were less than sufficient to do so properly. The length of the deltoid ridge was measured from the most distal tip to the most proximal cusp. With a small sample size of only three *Capra hircus* specimens, only minor data could be gained, though some inferences could be made based on prior studies.

Table 1 shows the results of the LD and three von den Driesch measurements taken on the available specimens. When the three specimens are compared based on sex, apparent age, and with the studies of Weiss (2003) and Zeder (1999), findings may be supported. Specimen 2 is a juvenile male, though older than Specimen 1, based on the epiphyseal fusion of the long bones and horn size. Measurements show a correlation between age and robusticity, while overall humeral length was similar, as confirmed in Weiss (2003). When comparing Specimen 3, an adult female, with Specimen 2, Bp, SD, and Bd support sex as a major factor in robusticity, since humeral length is significantly in favor of Specimen 3. LD presents a different trend, possibly due to age and overall body size, as seen in the differences in bone length. Since Specimen 1 shows no measureable deltoid ridge, it may be possible to rule out age due to the closeness in age of 1 and 2, though difficult to determine with the given sample size. If one assumes that age is not a major factor of the LD measurement differences, only body size and

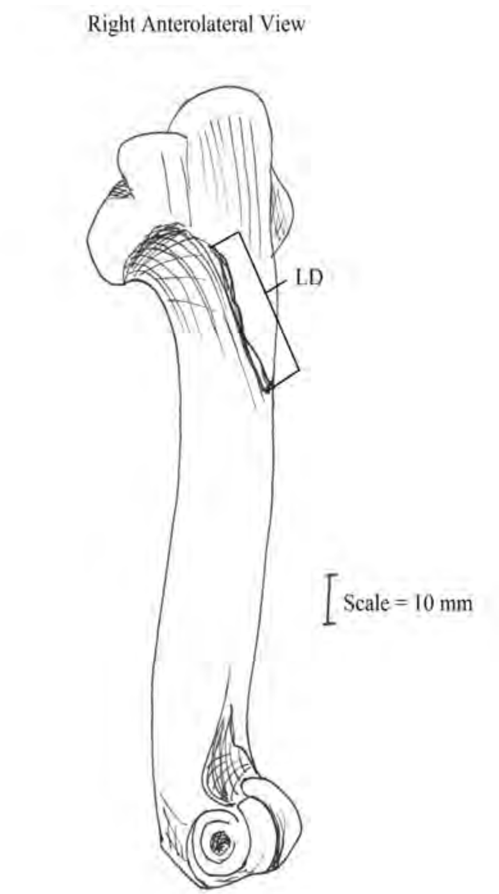

Figure 2—The right humerus of Specimen 3, showing the LD measurement. A comparative from Professor Jun Sunseri, UC Berkeley.

sex, in favor of the female, are left, unless one considers the possibility of topographical herding differences.

Although it is likely that the LD differences between Specimens 2 and 3 are due to the differences in age and body size, the contrast between Specimens 1 and 2 seems drastic enough to have a more external cause than age difference (Figure 3). If these two animals were within a few months to a year of each other in age, it is possible that the largest impact on the robusticity of the humeri was caused by differences in the topography where the animals were herded over extended periods of time, Specimen 2 having possibly been herded in a topography of higher incline and elevation. Again, this is difficult to determine with calipers and three specimens that have very little known background history beyond being from California.

Though the data are not sufficient to make valid interpretations at this point in the study, they are sufficient to recognize that herding topography may play a role in determining where and how domesticated caprine populations were herded, especially since Zeder's (1999) work on the Zagros populations previously determined that region was a significant factor in the skeletal element size of the animals. However, this study has proposed the need to control for body and element size as well as age, sex, breed, and robusticity in order to focus on whether or not terrain is a significant factor in MSM development in these animals.

Table 1: Humeral measurements

Element	Measurement	Specimen 1	Specimen 2	Specimen 3
Left Humerus	Bp	38.59 mm	48.53 mm	45.53 mm
	SD	14.78 mm	19.93 mm	18.91 mm
	Bd	30.12 mm	38.74 mm	34.14 mm
	LD	N/A	24.78 mm	37.71 mm
Right Humerus	Bp	38.02 mm	47.98 mm	45.75 mm
	SD	14.80 mm	20.04 mm	18.73 mm
	Bd	30.08 mm	39.43 mm	34.32 mm
	LD	N/A	24.46 mm	37.78 mm

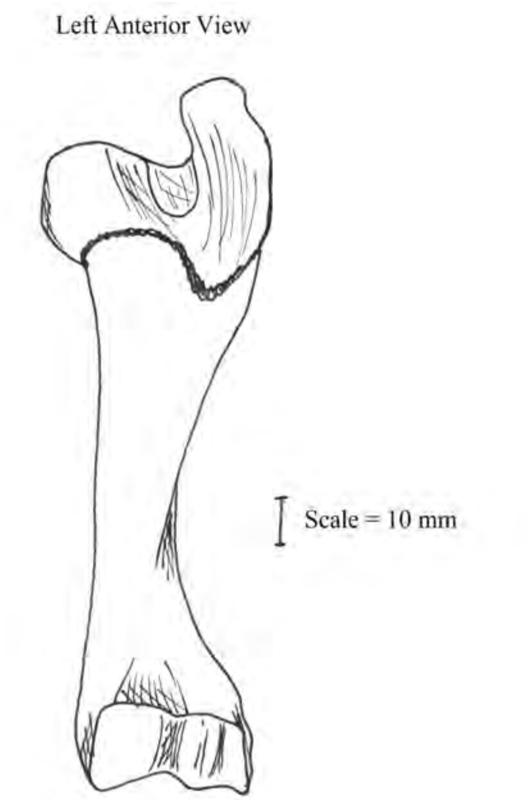

Figure 3—The left humerus of Specimen 2. A comparative from Professor Jun Sunseri, UC Berkeley.

DISCUSSION

Limited resources had an impact on the types of measurements that could have been performed. Digital calipers were helpful in preventing errors in measurement readings, although they were not large enough to measure the length of all skeletal elements, while the concurrent use of other instruments could have further limited error. It is also necessary to continue to seek out past research on similar studies to determine the best way to carry out future studies. As the hypothesis presented by this study is tested in the future, it will be important to maintain dynamic methods in order to ensure that valid data are collected as knowledge and information change.

As for measuring the LD, the calipers were difficult to manipulate in this manner. While this measurement still needs to be further tested for validity, a more precise measuring device for an area of bone such as the deltoid ridge would provide assistance. A device to measure MSM depth would also allow for more MSM data to be collected and compared. Further understanding of the anatomy of *Capra hircus* will also be analyzed to determine which muscles are most affected by topographical changes.

Cross-sectional analysis and histology could help to provide further information on bone density and growth and its reaction to external stressors and muscle formation. However, non-invasive techniques would be preferred so as not to destroy the specimens, though resources such as these are currently unavailable to the author.

Again, a sample size of three specimens is not ideal when attempting to produce a statistical analysis. In the future studies, a larger sample size will be key, preferably at least 30 specimens each, with known histories, of populations that were mostly maintained in flat grasslands and that were heavily herded over large topographical changes, such as in the mountains. Similar numbers of males and females will be necessary as well as comparable age groupings, preferably juvenile, middle-aged, and full-grown adult. This will allow for the ability to account for a variety of factors and make statistical analyses and comparisons based on topographical differences.

CONCLUSION

The preliminary findings of this study seem to support prior research in caprine domestication and musculoskeletal stress markers. Although MSM studies have not been widely observed in zooarchaeology, this study proposes that animal bones and muscles react in the same way that those of a human would when exposed to habitual external stressors and activity patterns. Future studies will require a larger number of specimens for comparison in order to control for the multiple factors that may also be affecting the morphology of the animals' skeletal elements. If future studies were to confirm the hypothesis proposed here, not only could this lead to determining where humans herded caprines in California or other regions, it could possibly lead to further understanding the activities and subsistence strategies of the related human populations.

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REFERENCES CITED

Niinimaki, S.

2012 The Relationship between Musculoskeletal Stress Markers and Biomechanical Properties of the Humeral Diaphysis. *American Journal of Physical Anthropology* 147:618-628.

von den Driesch, Angela

1976 *A Guide to the Measurement of Animal Bones from Archaeological Sites*. Harvard University Press, Cambridge, Massachusetts.

Weiss, Elizabeth

2003 Understanding Muscle Markers: Aggregation and Construct Validity. *American Journal of Physical Anthropology* 121:230-240.

Zeder, Melinda A.

1999 Animal Domestication in the Zagros: A Review of Past and Current Research. *Paléorient* 25:11-25.

Zeder, Melinda A., and Brian Hesse

2000 The Initial Domestication of Goats (*Capra hircus*) in the Zagros Mountains 10,000 Years Ago. *Science* 287:2254-2257.