INVISIBLE HORSEWOMEN:
HORSE RIDING AND SOCIAL DYNAMICS ON THE STEPPE

By

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ABSTRACT

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This dissertation examines the relationship between horse riding and social dynamics in nomadic Mongolian societies through the analysis of muscle attachment sites on the skeleton called entheses. Nomadic societies have traditionally been portrayed as static, homogenous, and parasitic. While recent archaeological research has shown this view to be inaccurate, little work has been done on the internal dynamics of these societies. The Xiongnu and the Mongols, two of the largest nomadic polities known historically, originated in Mongolia. Histories and evidence from mortuary and landscape studies suggests that there was an increase in social complexity and sexual inequality from the Xiongnu to the Mongol periods. Given the importance of horse riding to these societies, these changes should be evident in the social organization of horse riding in each period. A sample of 86 individuals from both time periods is used to examine potential changes in who was riding horses in each of these societies. Additional samples of 92 Arikara and 103 British individuals are used to investigate if suites of entheses used to identify horse riders can be applied cross-culturally.

The results of the cross-cultural skeletal analysis suggest that there is no universal suite of identifying markers for horse riders. Using samples of known riders and non-riders for each culture, suites of entheses for identifying horse riders are developed for both British and Mongolian riding styles. Horse riding in British society during the Post-

Medieval period appears to be related to status and this is reflected in which British subsamples were identified primarily as riders.

Males and females were both found to ride horses regularly in each Mongolian society; however, the amount of riding done over the life span and between the sexes changed between the Xiongnu and the Mongol period. The meaning of horse riding, and thus who has access to this activity, may be transitioning during the Mongol period, resulting in individuals negotiating for access to this activity. Finally, this study provides a model to use activity performance as a symbol that can be used analytically like any other symbol, including as a proxy for social dynamics.

Dedicated to
my parents,
who always believed I would eventually graduate

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Chapter 1

Introduction

Daily life is composed of the performance of numerous tasks. There are tasks related to economic, social, ritual, and subsistence systems. These activities are performed using specific equipment and in particular places, both of which can leave traces in the archaeological record. Such tangible remains have resulted in any study of activity focusing on where and when activities were performed and what technology was involved. Though informative, these studies are limited in that they cannot effectively examine who performed any specific activity and how it was done. Activities are known to have symbolic importance within cultures so this inability to address these aspects prevents activity studies from reaching their full potential. This research uses the development of muscle attachment sites on bone to deal with these issues, allowing activity to act as a foil for examining the social dynamics of gender and power in two nomadic societies over time.

Introduction: Activities as Symbols

A symbol is anything that conveys meaning for a society. Originally thought to be static and necessary for the smooth functioning of social systems, is now known that meanings of symbols can be manipulated and contested and are more involved with the dynamics of social systems rather than their smooth static functioning (Hendon, 2000; Pfaffenberger, 2001; Thomas, 1991). Traditionally, only material culture was viewed as having symbolic value. Only artifacts, monuments, and artistic motifs were thought to be imbued with meaning (Conkey & Spector, 1984; Kopytoff, 1986; Levy, 1995; Miller, 1982; Thomas, 1991). Gradually, this definition has been expanded to include natural features on the landscape and parts of the body (Buikstra & Charles, 1999; Gilchrist, 1999;

Hendon, 2000; Kuijt, 2001; Wells, 1998). It has only been relatively recently that activities have been included in the aspects of a culture that may bear symbolic meanings (Kuijt, 2001). Activity is defined as the physical performance of a series of related tasks whose purpose is to achieve some desired result, be it an artifact, a monument, movement from one place to another, community cohesion, a particular ritual, etc. Behavior, in contrast, is not only about the physical performance of an activity but rather refers to the social or cultural aspects of it – not just how something was done but why it was done, who did it, and where they did it (Kent, 1984). There are three ways behavior can interact with systems of symbolic meaning: no relationship, a causal relationship, or a nested relationship.

Many studies of activities implicitly view them as being separate from other social systems. Such studies imply that activity has no meaning or function to a society other than what it produces. This view is inherent in many activity reconstruction studies done in physical anthropology, where the goal is simply to reconstruct how an activity was physically performed (Kent, 1984). These studies are rightly referred to as activity reconstructions and not behavioral reconstructions. Just as not all artifacts are imbued with symbolic meaning, not all activities may bear symbolic meaning in a society (Pfaffenberger, 2001; Thomas, 1991).

More recent studies of behavior, using new theoretical perspectives and new ethnographic information, suggest that performance of activities can cause an otherwise mundane component of material culture to develop, maintain, or alter symbolic meaning. Since symbols must be understood by the whole society if they are to be useful, the creation of social memory often uses activity to attach symbolic meaning to an artifact, landscape, etc. These community activities and rituals mark components of material culture and the landscape by providing a touchstone for shared memories, a physical reference for what such activities or rituals were meant to accomplish (Buikstra & Charles, 1999; Kopytoff, 1986; Hendon, 2000; Hastorf, 1991; Kuijt, 2000; Richards, 1999; Wright, 2006). In a similar way, the frequent performance of an activity by a particular subgroup can lead to the society associating that activity with a specific identity. This association allows for the manipulation of identity in community activities (Fisher & Loren, 2003). This effect is perhaps most visible in studies of status and gender roles, where one can manipulate what gender or status they are perceived as simply by performing specific activities in a given situation (Conkey & Spector, 1984; Hendon, 2000; Miller, 1982; Stine, 1992). The causal relationship between activities and symbols is, perhaps, the most common association seen in behavioral studies.

Out of studies of this causal relationship came the idea of a nested relationship – activity doesn't just result in material culture having symbolic meaning, it is a symbol unto itself. This idea developed from two different perspectives: the anthropology of technology and embodiment and inhabitation theories. From anthropological studies of technology comes the idea that the manufacture and use of material culture, the activities associated with them, are what really bear symbolic meaning in a society and any resulting meaning attached the material culture is a by-product of activities (Pfaffenberger, 2001; Wells, 1998). Embodiment theory refers to how people live in their bodies and posits that some activities are performed solely for their symbolic value, without regard to any possible resulting material products of that activity. In this view, the body and its experience is a dynamic place of discourse and not a static, passive object (Fisher & Loren, 2003; Meskell, 2000; Wengrow, 2006). Inhabitation theory is much like embodiment theory except that it refers to how people live in and attach meaning to the landscape and built environment (Bradley, 1998; Thomas, 1990; Wright, 2006). In all of these various perspectives, it is the activity itself that is symbolic to people. The material remains of these activities may serve as repositories of social memory of these activities but this is seen as more of a by-product than the goal, as is the case in the causal relationship. In this relationship, activity is considered a type of symbol.

All three of these relationships between activity and symbolic meaning likely exist in each society. Some activities may have no symbolic meaning at all. Some may result in the generation of meaning in some type of artifact. And some activities may be performed specifically because they are the symbol themselves. The social organization of habitual activities, who is performing them, that have no symbolic meaning are unlikely to change unless a change in the environment or a technological advance catalyzes it. However, if an activity is related to some symbolic meaning, either through a causal or nested relationship, the social organization of that activity may change with changes in that symbols social system. For example, if an activity such as horse riding is considered a mark of status, either because only those with high status had the resources for such an activity or because the activity itself was an admired skill, then who is riding should change as the status system changes. If it is a gender-based system, the higher status gender should be riding. If it is an elite-based system (a gender-neutral system), then only the elites, but all genders of elites, should ride. Such an idea could be most useful working on nomadic pastoralist societies, where highly mobile populations have left largely ephemeral material remains and made traditional attempts to analyze social dynamics more difficult.

Nomadic Pastoralists

Due to the sparseness of archaeological remains of these highly mobile peoples, much of the original work done on these societies relied heavily on the textual evidence left by their sedentary neighbors, with whom they may not have always had the most congenial relations. As a result, nomadic pastoralists societies were often viewed as static, parasitic, homogenous entities incapable of forming centralized polities on their own (Barfield, 1989; Di Cosmo, 2002; Honeychurch, 2004; Salzman, 2004). More recent archaeological work, combined with ethnographic studies, has found this view to be a largely inaccurate oversimplification.

Agricultural fields have been found among most of these groups, supporting the idea that there is no "pure" nomadic pastoralist societies and that many are, in fact, agro-pastoralists (Chang & Koster, 1986; Honeychurch & Amartuvshin, 2007; Wright, 2006). These fields also demonstrate that these societies did not need to parasitize their sedentary agrarian neighbors for produce, they could provide their own. Urban centers, in the sense of a gathering and administrative locale, have also been found among some nomadic pastoralist societies (Davydova, 1996; Honeychurch & Amartuvshin, 2007; Rogers, 2007). This new evidence suggests that these polities could and did centralize on their own and that they did so using their own traditions of legitimation and control (Honeychurch & Amartuvshin, 2007).

Most of the recent work on nomadic pastoralist societies, particularly on the steppe where these societies have flourished for centuries, has focused primarily on changing the traditional views of these mobile societies. As a result, little work has been done on their internal social dynamics, the interplay of social systems as societies change over time.

Some mortuary analyses suggest that these societies had complex and changing status systems over time and that multiple different ethnic identities may have been incorporated into these polities (Honeychurch & Amartuvshin, 2006; Linduff, 2008). Though such work does shed some light on how these societies organized themselves, little has been done on how different sexes and genders experienced life in these groups and how that may have changed over time. It has only been within the past several years that bioarchaeology has moved beyond just descriptions of differential mortuary treatment between the sexes in nomadic societies (Linduff, 2008). The lack of sex- and gender-based analyses on the steppe in particular has led to many facetious comments about there being no females or women at all in these societies and that sons simply spring up out of the saddles. Given the importance of horse riding on the steppe, an analysis of who was riding and when over the life course they did it could provide much needed information on the social dynamics of steppe polities.

Activity Reconstruction

Identifying who was riding horses in any society can be a difficult task. Studies of material culture, particularly from mortuary contexts, can be problematic as these are not always indicative of the activities an individual engaged in during life (Conkey & Spector, 1984; Shelach, 2008). The most direct way to identify who was riding horses is to examine their skeletal remains. However, “most” direct is a relative description and there are still several problems to consider in this type of study.

Habitual performance of any activity can impact the skeleton in a number of ways. The two most commonly studied are cross-sectional geometry and enthesial robusticity. Cross-sectional geometry is better suited to the study of general loading patterns while enthesial robusticity is better suited to the identification of specific activities, such as horse riding (Benjamin, et al., 2006; Li, et al., 1991; Hawkey & Merbs, 1995; Woo, et al., 1981). Entheses are muscle attachment sites on the cortex of bones. Theoretically, when muscles stress these attachment points, bone is laid down around the connecting fibers to prevent the muscle from being torn off the bone (Hawkey & Merbs, 1995). This additional bone increases the appearance of the enthesis' robusticity. As the habitual performance of different activities requires the repeated contractions of different muscles, entheses are better positioned for studying specific activities.

There are some difficulties inherent to the study and interpretation of entheses. One such difficulty is the lack of information on thresholds that must be reached before enthesial robusticity begins to develop (Frost, 1990, 2001; Hsieh, et al., 2001; Lanyon, et al., 1979; Li, et al., 1991; Ruff, et al., 2006; Zumwalt, 2006). Different entheses appear to respond to force differently (Frost, 2001; Hsieh, et al., 2001; Zumwalt, 2006). Additionally, it is not known how changes in muscle use over the life course affect enthesial robusticity. One school of thought suggests that once robusticity develops, it remains on the bone for the rest of an individual's life. Another school of thought suggests that bone remodels enthesial robusticity to adjust for changes in loading, just as it does the rest of bone, so that once robusticity can increase and then decrease over the life course (Zumwalt, 2006). There is also some debate as to whether or not males and females develop robusticity the same way or if the modulating effects of estrogen on bone remodeling adversely impact the development of enthesial robusticity in females (Agarwal & Grynpas, 1996; Hawkey & Merbs, 1995; Ruff & Hayes, 1983; Weiss, 2007). An extensive examination of entheses may provide new information on these interpretative difficulties.

Research Goals

Bioarchaeology is uniquely suited to dealing with behavioral reconstruction in past societies as it can use information from both physical anthropology, including that from skeletal remains, and archaeology, such as mortuary data, landscape analyses, etc., to better understand life experiences in past societies. The goal of this study is to better understand the meaning of horse riding in a nomadic pastoralist culture over time and how changes in that system impacted the internal social dynamics of this culture. The research questions are designed to address how an activity, in this case horse riding, interacts with social systems at different levels of resolution from the individual to the society to the culture as a whole. The three research goals are:

1. To understand how horse riding impacts enthesial robusticity in the skeleton. If and how habitual activity affects the skeleton is not well understood. This study provides evidence that horse riders can be identified from skeletal remains using culturally-specific suites of entheses, that enthesial robusticity is not significantly affected by sex differences, and that it is dynamic and can change over an individuals life span.
2. To test if symbolic meanings impact the social organization of an activity. In order to use activity as a way to study social dynamics, it must first be demonstrated that the social organization of an activity mirrors its associated social system. This study uses the known association of horse riding to status in Post-Medieval British society to show that the social organization of horse riding does match the organization of the status system in this society. This provides some evidence for the use of behavioral reconstructions to study social dynamics.

3. To better understand what horse riding meant in Mongolian societies. Little work has been done on the internal dynamics of these nomadic pastoralist societies, particularly with regards to sex- and gender-based systems. Horse riding is highly symbolic activity in these societies. Using skeletal remains, this study provides evidence on the meaning of horse riding within these societies and on the shift from a more sex-, and potentially, gender-equal power system to one of greater inequality over time.

Organization of Dissertation

The main goal of this study is to explore the social dynamics of horse riding in Mongolian societies. This goal requires an understanding of how the body is impacted by horse riding, what was the place of horse riding in mobile societies, and how this mobility impacts society. Chapter Two discusses the varied impacts of mobility on societies in general. Nomadic pastoralist societies are some of the most mobile complex societies. The current state of research on these groups is also detailed in Chapter Two. This discussion leads to the explication of the research hypotheses and expectations for this study. Since activities effects on the skeleton are used as the foil for this research, Chapter Three discusses the current state of activity studies in bioarchaeology, including the background on the biology of how habitual performance of activity is translated into changes in the skeleton.

Chapter Four provides information on the materials and methods used for all stages of this study. This information includes data on all the samples used for the analysis of effects of horse riding on the skeleton, as well as what data was collected from these remains. Chapter Five details how data was processed, what analyses were performed, and what results were obtained. The results of these analyses and how they inform the research questions of this study are discussion in Chapter Six. Finally, Chapter Seven summarizes the conclusions of the study and suggests several avenues for future research.

Chapter 2

Anthropological Background

Mobility has become increasingly recognized for its profound effects on society. It is now understood to be a complex system, complete with multiple components that impact and are impacted by all other social systems within and between societies. Though many aspects of these systems can be studied archaeologically, determining *who* was mobile has always been difficult with material culture. This is a critical gap in the knowledge and understanding of mobility. Who is mobile can speak to the power system in a society, the gender system, how people identify themselves, how societies interact with each other. It is these people who are the key agents in mobility systems, providing much of the motivations behind mobility. Yet, identifying *who* is mobile in a society and how and why that may change over time, the social dynamics of mobility, are perhaps the least understood aspects of mobility systems.

The goal of the research presented here is to illuminate changes in the social dynamics of mobility over time in one highly mobile culture. In Mongolia, nomadic societies have existed for over a millennium. This nomadic culture has given rise to two expansive nomadic societies: the Xiongnu and the Mongols. Both are well known around the world for their horsemanship and mobility based on writings from the sedentary societies they encountered. Though these sources have provided much, albeit not always accurate, information on this culture, they have failed to shed light on its internal social dynamics. Given the highly mobile nature of these nomadic societies, the study of mobility and who was mobile can provide a new perspective into how social dynamics within these Mongolian societies changed over time.

Mobility

Definitions of mobility are usually behavioral: how, where, and when did people move. However, such definitions tend to mask the differing social implications for various types of mobility. Mobility is usually described as either residential mobility or logistic mobility (Wendrich & Barnard, 2008; Binford, 1980). Residential mobility refers to movement of the home (Binford, 1980). Societies are often placed on a continuum of sedentism to nomadism based on how often people move their houses or shelters. By comparison, logistic mobility refers to movement of only part of a group for subsistence activities (Binford, 1980). People may be mobile for foraging, hunting, pasturing, or trading for example. A third description of mobility is tethered mobility, where people are mobile within a specific limited range or time (Binford, 1980). These types of mobility are not mutually exclusive. Which type(s) of mobility a society employs can have profound effects on its internal social dynamics.

Binford's (1980) ethnoarchaeological study of the Inuit was one of the first to observe how being mobile affected the way people interacted with their environment. His goal was to provide a means for understanding site formation and variability among mobile hunter-gatherers. The results of his work showed that what type of mobility people used was not directly related to food resource availability but rather to broader environmental factors and a form of risk-reward assessment. In addition, the results demonstrate how mobility can impact what activities are performed at different locations. He was also one of the first to note how types of mobility can change over time. Mobility was less a static feature of hunter-gatherer societies and more of an adaptive strategy to a specific set of environmental factors used by all societies.

Susan Kent and Claudia Chang, among many others, continued with this type of work, observing how mobility impacts people's lives and translating that into what would be seen in the archaeological record. Kent's (1991) cross-cultural study of several groups inhabiting similar environments showed how anticipated mobility altered site structures. Site size, presence of storage areas, house size, and construction investment were all most strongly correlated with anticipated mobility, rather than actual mobility or environmental factors. In Kent's (1991) study, why a certain degree of mobility was anticipated was not always explicitly given but it was implied to be related to environmental and economic reasons. In contrast, Chang's (2006) work on pastoralists demonstrated that there were also social reasons for mobility and these also impacted site structure, perhaps more so than anticipated mobility. Having mobility as part of an economic strategy allows it to also be directed toward political or social ends (Chang, 2006).

While much of Kent's work focused on how mobility altered the archaeological record, she also studied how the change from being highly mobile to mostly sedentary altered social dynamics in one forager community (Kent, 1989). These changes included the development of political centralization, changing gender roles, and an increase in violence. Others have also noted changes in construction investment and storage technology as mobile groups become more sedentary (Ibrahim, 2004; Stenning, 1994; Tomka, 1993). All these changes were attributed specifically to the change in mobility. If this strategy is removed, the internal dynamics of a society must shift to compensate. Social anthropological studies of mobility have shown its importance in nearly all societies.

These analyses led to a more holistic view of mobility starting with the description of activity systems. Rapoport (1990) described activity systems as having four components: where an activity was performed, when it happened, why it was done, and who did it. In Rapoport's systems, the physical tasks needed to perform the activity are only the beginning of understanding the activity's place in a society. Next come the components of the activity system, which help to understand how activities are related to each other. Finally, all these components are related through the meaning of the activity to the society (Rapoport, 1990). It is this last level, the level of meaning, which may explain why mobility has such a variety of impacts on society. If activity has meaning, it can be considered a symbol. As a result, like any other symbol, it can be manipulated. Whereas other symbols can be manipulated by possessing a symbolic object or decorating with a symbolic motif, symbolic activities would be manipulated through performance. So, examining how who performs an activity changes over time can inform on the social dynamics within a society.

Rapoport's (1990) general description of an activity system was defined more explicitly in terms of mobility in Wendrich and Barnard's (2008) introduction to The Archaeology of Mobility. Though they did not call it a system, all the components of Rapoport's activity systems were described with factors specifically applicable to the study of mobility. In this more detailed listing of factors, Wendrich and Barnard noted that not all a population may be mobile, that different groups may vary in their mobility, and that which segment(s) of the population that were mobile may be defined by different criteria. They also note, in their "Motivation" category, how mobility may be viewed within a society is not necessarily the way it is viewed by other societies. In other words, activities related to mobility can have one symbolic meaning among members of a society and another among outsiders of that society. Additionally, these meanings are culturally specific and can differ from one society to another according to both their internal histories and their relations with their neighboring cultures. To further complicate matters, the perspective from which these societies are studied can make disentangling the meaning of mobility from its various systems more difficult. The history of nomadic studies provides a case study in how investigators' perspectives can alter the view of mobility's meaning within and between societies.

Nomadic Societies

The word "nomad" originally referred to flocks and herds (Wendrich & Barnard, 2008). It was associated with pastoralism from the beginning. However, as mobility studies developed, the need to disaggregate these terms became apparent. Not all nomads are pastoralists and not all pastoralists are nomadic (Salzman, 2004). In order to appreciate this difference, these two terms need to be defined.

Nomadism refers to residential mobility, the movement of base camp, not to the movement required for economic activities (Binford, 1980; Kelly, 1992). This movement can be once a week, once a lifetime, or any point in between. As a result of this variation, nomadism is considered to be a continuum of highly nomadic to highly sedentary. This definition is broader and more applicable to all mobile groups regardless of economic systems. It encompasses pastoralists as well as foragers, hunter-gatherers, and transhumant agriculturalists. By using this term, the focus is on a group's mobility without reference to any one economic form.

Pastoralism, by comparison, refers specifically to an animal based economy that requires managing herds, flocks, and their associated pastureland (Chang & Koster, 1986; Salzman, 2004). Though this subsistence strategy is often associated with nomadism, mobility isn't required. For example, some steppe pastoralists move every month or two while transhumant pastoralists only move twice a year with the seasons and ranchers in the American West rarely move their home base yet maintain a predominantly, if not exclusively pastoral subsistence.

Reaggregating these terms, the term "nomadic pastoralists" refers to people who practice a primarily herd-based subsistence and move their home bases with their herds. Such a definition is still fairly broad. It does not specify what types of animals make up the economy, what animal products they produce, nor how often they move their home base. This flexibility in definition is essential to the study of nomadic pastoralists as the single common trait shared by all such societies is their fluidity (Salzman, 2004). Despite its ubiquitous nature, this fluidity was not part of the original studies on nomadic pastoralists.

Past Views on Nomadic Societies

The original studies on nomadic pastoralists portray these societies as static and highly specialized (Barfield, 1989; Di Cosmo, 1994; Khazanov, 1984; Rogers, 2007; Salzman, 2004). This high degree of economic specialization was thought to make these societies unviable on their own, requiring them to parasitize their sedentary agriculturalist neighbors (Barfield, 1989; Di Cosmo, 1994; Khazanov, 1984; Rogers, 2007). Either by trade, tribute, or raiding, nomadic societies were thought to require the products of sedentary societies to survive and function.

This view extended to the political systems of nomadic pastoralists societies as well. It was thought that the most complexity these societies could achieve was a loose confederation of tribes (Barfield, 1989; Honeychurch & Amartuvshin, 2006). Centralized government was considered out of the reach of such highly mobile societies. It was the mobile nature of these peoples that lead to this view. The general consensus was that as long as people could move, they would simply leave if they were unhappy with any authority's decision. This quality would prevent any one group from gathering and centralizing power and stymie the development of a truly complex society (Barfield, 1989).

This economic specialization and relatively simple sociopolitical system were originally thought to be static. Strongly tied to these societies' high mobility, these traits were considered unchangeable without sedentarization or the influence of sedentary societies (Barfield, 1989; Khazanov, 1984). Sedentarization was thought to be the only way to bring people under a central authority and to develop the surplus needed to support a ruling class. There was a view at this time that portrayed nomadic pastoralists as incapable of sedentarizing on their own and would only do so under the influence of neighboring sedentary societies (Barfield, 1989; Di Cosmo, 1994; Khazanov, 1984). This view held that knowledge of agriculture could only come from these societies and centralization would only develop as a way to interact with agriculturalists.

One of the reasons for the prominence of this view in early studies of nomadic pastoralists was the sources used for this research. As noted previously, archaeological sites from these peoples were difficult to find prior to ethnoarchaeological studies of mobility. People were looking at the wrong scale for the wrong type of sites. As a result, studies of nomadic pastoralists in the past relied primarily on the written records of the neighboring sedentary agriculturalists (Di Cosmo, 1994; Honeychurch & Amartuvshin, 2006; Rogers, 2007). As might be suspected in such circumstances, these records later proved to be biased and incomplete (Honeychurch & Amartuvshin, 2006; Linduff, 2008; Rogers, et al. 2005). Some early researchers were aware of this bias and tried to adjust their interpretations (Di Cosmo, 1994). However, it was not until ethnoarchaeological studies described what types of sites to look for that archaeologists were able to provide new evidence for the study of nomadic pastoralists.

This improved understanding of mobility was not the only source of new information on nomadic pastoralists. The 1980's saw the fall of the Iron Curtain and the influx of information about nomadic pastoralists on the steppe. This influx was furthered by the collapse of the Soviet Union that allowed for an increase in international collaborations in this region (Hanks, 2010). The result of these two events has greatly increased understanding of the complexity and fluidity of nomadic societies from a region where nomadic societies have existed for thousands of years.

New Views of Nomadic Societies

Three types of research have dominated the study of nomadic societies: ethnography and ethnoarchaeology, mortuary analyses, and landscape archaeology. Ethnographic and ethnoarchaeological research includes studies of site formation as well as studies on human-animal interactions and logistic, political, and risk aversion strategies. The results of these studies have shown that though herding abilities are highly valued in these societies, the ability to form and use networks is perhaps more valuable. Research on other groups living in marginal environments has shown networking to be one of the most common and possibly most valuable risk aversion strategies (Rautman, 1993; Salzman, 2004; Sneath, 1999). Among nomadic pastoralists, these networks can be used to find new pasturelands and water sources as well as new allies for raiding, defense, and political mobility (Honeychurch & Amartuvshin, 2006).

One of the primary ways these networks are formed is through marriages. Both men and women bring their families' networks to the marriage. Given the value of these networks in survival, it is common for them to be a source of power for both genders (Erdenebaatar, 1996; Humphrey, 1979; Salzman, 2004; Sneath, 1999; Tavakolian, 1984). In some societies, this may have been part of a power system that either had separate but equal spheres of power for each gender or gender equality. The idea of separate but equal spheres of power refers to the development of parallel power systems, each with its own sublevels, rules, and traditions (Gilchrist, 1999; Kent, 1999; Levy, 1999). In these systems, each gender has equal access to power but use different avenues to attain it. Power systems with gender equality gave each gender equal access to power through the same avenues (Kent, 1999). Both types of power systems are thought to exist among nomadic pastoralists in part because of the value of networks each gender brings to the family.

There is a third option for the articulation of gender and power systems among nomadic pastoralists seen in ethnoarchaeological studies: gender inequality. In this type of power system each gender does not have equal access to power, regardless of the avenue(s) available for attaining it. Among nomadic pastoralists, this inequality can be as minor as baring women from only the highest rung of power or as major as baring women from holding power at all (Morgan, 2007; Tavakolian, 1984). There is no known nomadic pastoralist society where the inequality is in women's favor. In the extreme case, where women are bared from holding power at all, they may still exercise power through their networks and their production (Tavakolian, 1984).

The gendered division of labor within nomadic pastoralist societies often provides women with at least some economic power. Women are often in charge of the home and processing of animal products. They may literally own the tent as well as maintain it, clean the house, prepare the food, care for the children, and tend any herds or gardens near the house. Women are responsible for converting milk into cheese or yogurt, curing meat, and working wool and hides into usable textiles. Men are usually in charge of the herds: moving multiple types of herd animals between pastures, making sure they all have access to water, protecting the animals from predators and thieves, and maintaining connections with neighbors (Barfield, 1989; Chang, 2006; Erdenebaatar, 1996; Shombodon, 1996; Tavakolian, 1984). It should be noted that among many nomadic pastoralists, these are not rigid divisions. With many families separated by the need to care for herds each gender must often perform the duties ideally ascribed to the other (Little, 1985; Shombodon, 1996). The variability and fluidity of these social dynamics may have gone unrecognized if not for the many ethnographical and ethnoarchaeological studies on nomadic pastoralists.

Mortuary analyses are a second source of information on nomadic pastoralist societies. For many years, this was the single greatest source of data on prehistoric nomadic pastoralists (Hanks, 2008; Honeychurch & Amartuvshin, 2006; Wright, 2007). Burials are some of the least ephemeral archaeological sites left by nomads. This visibility often means that many of these burials were robbed in antiquity. Despite these disturbed contexts, much has been learned from burials.

Burials among nomadic pastoralists are not the uniform displays one would expect of a homogenous society. Rather, they differ in size, architecture, and burial inclusions (Tseveendorj, et al., 2003). These differences suggest multi-component status, power, and/or gender systems (Honeychurch & Amartuvshin, 2006). Such differentiation within burials mirrors the internal differentiation of these societies as a whole. This internal differentiation provides further evidence for the complexity of nomadic pastoralist societies.

The mortuary context is a symbol-laden arena for the negotiation of identities, power relations, and community building (Brown, 2003; Buikstra, 1995; Charles & Buikstra, 2002; Conkey & Spector, 1984; Kuijt, 2001; Shanks & Tilley, 1982). As such, the items found in these contexts are thought to have symbolic value and importance within these societies. The items commonly found in burials in nomadic pastoralist societies include those of practical import, such as weapons and drinking vessels, all or part of some of the herd animals forming the basis of their economy, and ornamentation that often depicts animal motifs (Anthony & Brown, 2003; Crubézy, et al., 2006; Garofalo, 2004; Honeychurch, 2004; Linduff, 2008; Miniaev & Sakharovskaia, 2008). These last two types of burial goods point to the importance of animals in the pastoral life. Horses in particular are common motifs and funerary offerings among horse riding nomadic pastoralists (Anthony & Brown, 2003; Linduff, 2008; Miniaev & Sakharovskaia, 2008). The prominence of the horse in the symbolically heavy mortuary sphere signifies the importance of the horse, both practically and symbolically, in these societies. Mortuary analyses of nomadic pastoralists provide evidence of the internal segmentation, fluidity, and complexity of these societies as well as offering a window on what was truly valued by these peoples.

A third source of new information on nomadic pastoralists is landscape archaeology. This research offers new insight into a complex multi-resource economy, suggests a new political form for controlling a mobile population, and provides evidence for the development of community among these mobile peoples. Studies of satellite imagery, surveys coupled with excavation and the occasional isotopic study suggest that nomadic pastoralists utilize every aspect of their often marginal environments (Chang & Koster, 1986; Honeychurch & Amartuvshin, 2007; Makarewicz & Tuross, 2006). This extensive resource use includes hunting and gathering, fishing, and agriculture (Wright, et al., 2009). The discovery of agricultural fields, in particular, offered new evidence for the self-sufficiency of these societies (Wright, et al., 2009). This evidence suggests that nomadic pastoralist societies where not the parasitic neighbors of sedentary agriculturalists as the original view of these societies portrayed.

The discovery of large walled "urban centers" suggested a new political strategy for dealing with mobile populations. The original views of nomadic peoples held that the only way to control them was to tether people to specific areas and restrict their movement (Barfield, 1989; Khazanov, 1984; Krader, 1978). The finding of these "urban centers" suggests instead that elites and their courts were mobile (Honeychurch & Amartuvshin, 2007). These "urban centers" were not cities in the sense of cities among sedentary agriculturalists (Honeychurch & Amartuvshin, 2007; Rogers, et al., 2005). Most had little or no permanent housing. What few buildings there were appear to be primarily administrative and/or trade related. Space was set aside within the walls of these centers for nomadic pastoralists to pitch their tents, presumably (Rogers, et al., 2005).

One city has been found among the perennially nomadic pastoralists of the steppe. Ivolga appears to be an intensive agricultural center, complete with several types of buildings, permanent housing, and a bounded cemetery (Davydova, 1996). How this city was viewed within the larger Xiongnu society to which it belongs is unknown. Nomadic peoples do not tend to hold the settled life in high regard (Bovin, 1990; Little, 1985;

Ibrahim, 2004). However, these cities and "urban centers" do point to a unique management system for this complex, multi-resource society.

These more recent studies using new approaches, techniques, and technology have shown nomadic societies to be as complex as agrarian societies. Nomadic cultures exhibit multi-resource economies, fluid and mobile elite control, and complex and heterogeneous social structures. Though this research has gone a long way towards dispelling the idea that nomadic societies are static and undifferentiated groups, it has not yet delved much into their social dynamics. This problem was likely due to both the need to change views of nomadic groups and to the relative dearth of recovered material, as compared to more sedentary agrarian cultures. The creative and persistent methods of researchers studying these nomadic societies have noticeably altered views of them and have begun to amass the necessary amount of material needed to attempt a more in-depth examination of the internal dynamics of these peoples.

Internal Dynamics of Nomadic Societies

Recent work has brought a more social anthropological approach to studies of nomadic peoples. However, little work has focused on the internal dynamics of these groups. The lack of work on the internal dynamics of nomadic societies has led to an assumption of static homogeneity within nomadic societies. However, ethnographic studies of modern nomadic groups have shown that the internal structures of these groups are as dynamic as more sedentary agrarian societies.

When looking at nomadic pastoralist societies, one of two mobility models is usually identified: an elite-mobility model or a male-mobility model. In an elite-mobility model, high status individuals are the most mobile segment of society while lower status individuals are far less mobile. In a male-mobility model, men are the most mobile group while women are less mobile. Each model affects the larger cultural system differently.

Elite-mobility models affect life at the household level, power structures, and identity. The more sedentary lower classes may invest more in their habitation sites with a permanent or semi-permanent home base that can lead to changes in storage technology and landscape use (Ibrahim, 2004; Stenning, 1994; Tomka, 1993). Mobile elites are able to create and maintain large networks which may aid them in getting or keeping power and wealth (Bovin, 1990; Little, 1985; Salzman, 2004). This difference in degrees of mobility between elites and commoners can lead to changes in identity, ideology, and ultimately, to ethnogenesis as seen in the cases of the Il Chamus (Little, 1985), FulBe of Africa (Bovin, 1990), and the Jatts of India (Ibrahim, 2004). Ethnogenesis is possible in elite-mobility models because the entire family unit has a similar degree of mobility and feels the same mobility-related cultural effects. This is not the case in male-mobility models where different members of the family unit have different degrees of mobility and thus feel different mobility-related cultural effects.

Male-mobility models affect the division of labor and power structures. Generally speaking, more mobile men tend herds away from the encampment while less mobile women process animals products, provide childcare, perform housework, and tend herds near the encampment (Barfield, 1989; Shombodon, 1996; Sneath, 1999; Tavakolian, 1984). Though these are “traditional” gender roles, there can be overlap in tasks and tasks performed by both genders, such as shearing sheep (Shombodon, 1996; Sneath, 1999). There may be other genders present in nomadic societies; however, their roles are not mentioned in ethnographies. These differences in the gendered division of labor may lead to differences in technology used by and iconography associated with each gender (Joyce, et al., 1993; Merbs, 1983; Spector, 1983). This separation in the space associated with each gender, as well as differences in activities, leads to both genders having significant power within the society, power resulting from each gender having control of and making decisions for their own spheres (Keith, 2005; Levy, 1999; Morgan, 2007; Spector, 1983). Separate spheres of control lead to separate avenues of power, heterarchical power systems, and conflicts of power (Gilchrist, 1999; Joyce, et al., 1993; Levy, 1999).

This list is by no means exhaustive and provides only a sampling of the direct and indirect effects of mobility on a culture.

Mongolian Societies

Some of the most highly-mobile societies are those of the eastern steppe. The two most well-known of which are the Xiongnu, who are thought to be the reason the Great Wall of China was begun, and the Mongols, whose empire reached all the way to Medieval Europe. However, these were only two of aseries of centralized nomadic pastoralist polities in the region, demonstrating a long tradition of legitimation and control unique to these peoples (Honeychurch, 2004; Rogers, 2007). In addition to this political continuity, there is also evidence of continuity in the agro-pastoral economy, though its emphasis on either the agricultural or the pastoral components may have shifted back and forth over time, combined with hunting and fishing (Honeychurch & Amartuvshin, 2007; Morgan, 1986; Rogers, 2005; Wright, et al., 2009). Material culture, such as the use of gers and high-cantled saddles also appear to be continuous throughout these societies. This continuity suggests that while the politics may shift over time, the symbolic meanings in this culture have remained largely unchanged. Thus, these symbols, including symbolic activities such as horse riding, can provide a useful foil for investigating changes in social structures over time.

Xiongnu

The Xiongnu society existed from the 4th century BC to the 4th century AD (Honeychurch & Amartuvshin, 2007; Wright, 2006). These peoples first appeared in the Chinese historical record in 318 BC, when they attacked the growing state of Qin (Barfield, 1989; Linduff, 2008). Their empire expanded into China when the Qin empire crumbled in 209 BC (Linduff, 2008). This is the first centralized polity to develop on the steppe. It had three administrative levels: the Shan-yu and his marquises, 24 imperial leaders who often relatives of the Shan-yu or members of the aristocracy, and indigenous tribal leaders (Barfield, 1989). In addition to this administrative hierarchy, there was a military hierarchy of decimal ranks (e.g. leaders of 1000, leaders of 10,000). There is some debate as to how much control these hierarchies had among the Xiongnu people. There is evidence for a variety of ethnic groups and tribes within this polity that appear to have maintained much of their own identity and control over pasturage, suggesting that these hierarchies did not have much power over individuals (Barfield, 1989; Linduff, 2008). However, there is also evidence for some consistent rituals and material culture over the whole of the Xiongnu empire, suggesting that this may have been a centralized state (Honeychurch, 2004; Honeychurch & Amartuvshin, 2007). This discrepancy may be a sign of the flexible nature of the Xiongnu political system which allowed it to retain at least some control over the eastern steppe for the longest of all the steppe polities (Barfield, 1989). In the 2nd century AD, a series of natural disasters weakened the southern Xiongnu, resulting in their surrender to the Han. The Xiongnu polity officially ended in the 4th century AD due to the effects of two civil wars, natural disasters, and succession disputes (Barfield, 1989).

As most of the historical sources on the Xiongnu come from China, who were concerned primarily with the political structure of this polity, little is known about the mundane lives of the common Xiongnu people. Differences in mortuary practices suggest that there was internal differentiation among commoners in regards to gender, status, and ethnic identity (Honeychurch, 2004; Linduff, 2008; Wright, 2006). The control structure detailed in Chinese histories suggests that families were organized along lineage lines with political decisions for most commoners coming from tribal leaders, regardless of whether that individual was following the orders of the Shan-yu or not (Barfield, 1989).

Additionally, there is some evidence for an increase in agriculture at this time. A survey of one northern valley demonstrates an increase in the number of agricultural fields during the Xiongnu period (Honeychurch & Amartuvshin, 2007) while the settlement at Ivolga offers evidence of at least some intensive agriculture at this time (Davydova, 1996). Agriculture tends to occur with a decrease in mobility, at least long-distance mobility (Bridges, et al., 2000; Ruff & Larsen, 1990). Ethnographic work on other nomadic populations has shown that agriculture is disdained and considered a low status occupation by these groups, possibly due to its departure from a mobile lifestyle (Bovin, 1990; Ibrahim, 2004; Little, 1985). So, it is likely that if agriculture increased during the Xiongnu period, it was the commoners who took it up and decreased their mobility as a result.

Mongol

By comparison the shorter-lived Mongol empire existed from the 13^{th} to the 14^{th} century AD however, there is mortuary evidence suggesting the Mongol society may have existed since the 10^{th} or 11^{th} century AD and after the 14^{th} century AD (Honeychurch, 2004; Morgan, 1986; Wright, 2006, pers. comm.). This empire was founded by Genghis Khan, called Chinggis Khan in Mongolia, in 1206 AD (Barfield, 1989; Honeychurch, 2004; Morgan, 1986; Onon, 2001). The original core of this polity was roughly the same size as the initial Xiongnu polity but expanded at a rapid rate. Within two generations, the descendents of Genghis Khan had furthered the expansion stretching the Mongol empire from China to Eastern Europe (Honeychurch, 2004; Morgan, 1986). Genghis Khan exhibited a great deal of distrust towards his family and they only began to play a role in the leadership of the empire after his death. Due to this distrust, this polity was perhaps the first steppe polity to try to prevent family ties from having such an impact on political mobility (Barfield, 1989). By 1260, succession disputes had resulted in the splitting of the Mongol empire into regional successor states, such as the Yuan dynasty of China and the Il-Khanate of the Middle East (Honeychurch, 2004; Morgan, 1986). These were each eventually dissolved or defeated and by the 14^{th} century AD, what little remained of the Mongol empire had dispersed into other cultural traditions of the steppe and its adjacent regions (Morgan, 1986).

Much of the research from this period has focused on elite Mongols. These individuals had the most impressive burials and were the most likely to gain mention in historical sources, be they external or internal to the polity. As a result, far less is known about the life experience of common people during this time. What work has been done suggests that the Mongol empire bore many similarities to the Xiongnu empire, only more complex. The economic system was primarily agro-pastoral supplemented by hunting and fishing, though there is some evidence for increasing economic specialization (Honeychurch, 2004; Morgan, 1986). There seems to be less of a focus on larger tribal or corporate groups in this period and more focus on smaller family units (Honeychurch, 2004). Histories from this period also suggest that there was greater gender inequality in the Mongol period (Morgan, 1986). This increase in segmentation supports Kent's (1984) hypothesis that increasing complexity results in increasing segmentation within all social systems in a society. Such segmentation likely also extended to the social organization of horse riding.

Research Questions and Hypotheses

Activities are an integral part of cultural systems. They can be used to both produce symbolic meaning in material culture and to act as symbols themselves. Though these properties mean that the study of activities can provide new perspectives on social dynamics within any society, it cannot attempt to reach this potential unless the performers of specific activities can be identified in prehistory. Analyses of material culture can provide some insight into this problem but the most direct way to identify activity performers is to look at their skeletal remains, which may bear the evidence of habitual activity performed by an individual. The goal of this study is to investigate the meaning of horse riding in Mongolian societies. So, it must first be determined if horse riders can be identified from their skeletal remains. Activity has not been used in this way to examine social dynamics, so it should be tested on a society where the outcome is predictable. Post-

Medieval British samples were used as it is known that horse riding was a symbol of status in that society. This analysis acts as a type of assay control to determine if activity can be used as a foil for the study of social dynamics in past societies. Finally, after determining if horse riders can be identified in past societies and that activity can inform on social systems, the meaning of horse riding can be studied in Mongolian societies through the changes in its social organization over time. The research questions addressed in this dissertation are:

1. How does horse riding impact enthesial robusticity in the skeleton?

2. Do symbolic meanings impact the social organization of an activity?

3. What did horse riding represent in Mongolian societies?

Hypothesis 1a:

Enthesial robusticity can be used to separate horse riding and non-horse riding groups.

Entheses are muscle attachment sites. Habitual use of the attached muscle(s) is thought to increase the robusticity of these markers, as bone is laid down to prevent muscles from avulsing off the bone (Hawkey & Merbs, 1995). Entheses have been used in many studies to attempt to document which individuals were performing specific activities. However, these markers exist at the intersection of two complex and interdependent biological systems, the skeletal and the muscular system. Both of these systems are comprised of multiple layers of organization, from cell to tissue to organ to system, which are each subject to various forces impacting a body. So, if these attachment sites are to be used to identify the performers of a specific activity, some considerations must be kept in mind.

Biological thresholds are highly variable. At the base of each of these biological systems are cells, which must respond to their environment. This property does not necessitate that cells respond to the same stimulus in the same way. There is some evidence that cells in different mechanical environments respond to mechanical stimuli in different ways and at different thresholds (Frost, 1990, 2001; Galtés, et al., 2006, Hsieh, et al., 2001). What this means for activity studies using enthesial robusticity is that not all muscles will develop enthesial robusticity at the same loading threshold, or develop robusticity at all. Furthermore, changes in cells' abilities to respond to stimuli may change over the life span. So, a body's ability to develop enthesial robusticity may change as it ages.

Life consists of many different activities that use many different muscles. As a result of this obvious observation, it is necessary for an activity to be unique enough in its motion that its performers can be separated from nonperformers. In the case of this study, horse riding must use motions that unique enough to horse riding that they result in the novel use of muscles, compared to everyday life, and thus, the development of a unique suite of robust entheses.

If enthesial robusticity is to be used to identify horse riders, a difference in enthesial robusticity for a particularly suite of markers should be observable between riders and non-riders. There is often an implication that horse riding markers are universal – how an individual rides is unimportant. So, any combination of known riders should exhibit consistently different robust entheses compared to any combination of non-riders. Significant differences in robusticity should be observed between riding and non-riding groups in partial correlation analyses. Logistic regression equations should be able to accurately classify riders and non-riders using enthesial robusticity scores. Allowing for the possibility that technology has some effect which muscles are used for riding horses, saddle riders were tested separately versus non-riders. As with the aggregated rider samples, significant differences in robusticity should be observed between saddle riding and non-riding groups in partial correlation analyses and logistic regression equations should be able to accurately classify saddle riders and non-riders using enthesial robusticity scores. Both partial correlations and logistic regressions are used as partial correlations allow for the testing of each enthesis individually while logistic regression allows for combinations of entheses to be tested together.

Hypothesis 1b:

Habitual horse riding in different riding styles results in increased robusticity of different entheses.

There is the possibility that different riding styles use different muscles and thus, habitual riders in different styles would develop different suites of robust entheses. The aggregated rider samples can be broken up into three different riding styles: bareback, English, and Mongolian. If these different styles result in style-specific suites of robust entheses, then 1) they should be significantly different than their associated non-rider samples in partial correlation analyses and accurately classifiable in logistic regression analyses and 2) the suites of entheses used in the logistic regression analyses to do the classification should be different for each style.

Hypothesis 2:

The social organization of horse riding in 17th- to 19th-century Britain mirrors the status system at the time.

Horse riding has not been used in this way to study social dynamics. Since there is no study to use as precedent, a sort of assay control is needed. The purpose of an assay control is to determine if the method being used in a study will work as expected. The method is used with samples whose results are known. If the results come out as expected, then the method is working. If not, then there is a problem with the method. To test the idea that the social organization of an activity relates to its symbolic meaning in a society, samples from Post-Medieval Britain were used. Horse riding is a symbol of status in this society so its social organization should mirror the society's status system.

During the 17th- to 19th-century in Britain, the beginning of the industrial revolution resulted in increased urbanization while still maintaining an agrarian economic base. Wealthy landowners maintained their country estates, where they rode horses both for leisure and utilitarian purposes. Wealth was necessary to keep horses, as they require a large amount of land and resources to stay healthy. In contrast, poorer individuals were moving into the city at this time looking for work. Most of the individuals lacked the necessary wealth or land to keep horses and horses were not essential for much of their work, so it is unlikely that these low-status individuals rode horses.

If horse riding is a symbol of status, and if both sexes have access to high status, then horse riding should be sex-neutral in this society. That means both high-status males and females should be horse riders while both low-status males and females should be non-riders. There should be a significant difference in the number of riders between the status categories but not within them. Logistic regressions using only English-style riding markers should be able to accurately classify individuals into their respective status categories but be inaccurate in classifying males and females within each status category.

Hypothesis 3a:

Females and males were both habitual horse riders in Mongolian societies.

Horse riding is often considered a defining characteristic of a steppe nomad in Chinese histories. As sedentary agriculturalists, the constancy with which the Xiongnu and later the Mongols were seen on their horses was sufficient to mark these peoples as "other" to the Chinese. The result is that horse riding is assumed to be a marker of identity for steppe nomads throughout antiquity and until the present day. However, this assumption does not consider that an activity can bear multiple meanings. To the Chinese populations, horse riding may be a symbol of nomadic identity but that does not require it to mean the same thing to the nomadic peoples. Within these societies, horse riding may be a symbol of gender, status, or power in addition to, or instead of, its meaning of nomadic identity. Due to the connection between symbols and social dynamics, the social organization of horse riding over time can be used to study its symbolic meaning.

Nomadic identity does not appear to change over time. If horse riding is a symbol of identity, both sexes should be riding horses in both the Xiongnu and the Mongol periods. However, if horse riding means something else in addition to or instead of identity in these societies, there should be differences seen between the sexes over time. What these differences should be is dependent on the differences between these societies in gender, status, and power systems.

Both the Xiongnu and the Mongol society appear to have a binary gender system. No evidence has been found of a third gender in these societies. Gender roles appear to be highly fluid in these societies but neither mortuary data nor iconographical evidence suggests that any additional genders existed (Linduff, 2008). This lack of evidence may be due to western biases, sampling biases in the samples, the lack of third gender markers being used in these arenas, or simply to a lack of a third gender in these societies. However, since there is no sign of a third gender in either the Xiongnu or Mongol societies, biological sex is being used as a proxy for gender. Since gender is a socially-constructed category, not a biological one, and gender roles in these societies are fluid, this is not an ideal solution. However, it provides a starting point for studying the meaning of horse riding in these societies. It is men who are documented from Chinese histories to be horse riders in Mongolian societies. So, males are assumed to be the horse riders in the Mongolian samples. If horse riding relates to gender, then there should be differences seen in the percentage of males and females riding horses within each time period but no differences over time within the each sex.

Both the Xiongnu and Mongol societies have documented, complex status hierarchies. Among the Xiongnu, elite status lies with the Shan-yu and his family lineages (Honeychurch, 2004). In the Mongol period, this blood-relation requirement becomes much more relaxed and "adopted" individuals can gain access to high status (Barfield, 1989). None of the samples used here are thought to contain high-status or elite individuals. All the samples used in this analysis are thought to be commoners. If horse riding is related to status in the Xiongnu and Mongol societies, then none of the individuals in the sample should be habitual horse riders. There should be no differences seen in the percentage of females or males riding horses within or between time period samples.

Status and power are not always related. Individuals can have high status but little power while some may have a low status but more power. The power systems of the Xiongnu and Mongol societies are not entirely known however, they can be inferred from various types of evidence. Mortuary evidence suggests that in the Xiongnu society, both males and females had equal access to elaborate burials and burial inclusions, though what specifically was included appears to vary by gender, among other factors (Honeychurch, 2004; Linduff, 2008). This is not to say that there was total sexual equality but rather it suggests that males and females may have had equal access to power, though not necessarily through the same channels. It appears that only the highest rungs of power were off-limits to females. In contrast, mortuary data suggests that there was far greater sexual inequality in the Mongol period. The largest and most elaborate burials were reserved solely for males and often it was only males that were buried nearest to these elite burials (Crubézy, et al, 2006). Female burials are often smaller, less elaborate, and less rich than male burials are. Historical texts also suggest that women had very little power in the Mongol period (Morgan, 1986; Onon, 2001). If horse riding is related to power in these societies, then there should be no differences between the percentage of horse riders between Xiongnu males and females or between males from each time period. Differences in the percentage of horse riders should be observed between Mongol males and females and between females from each time period. All of these possibilities are summarized in Table 1.

Hypothesis 3b:

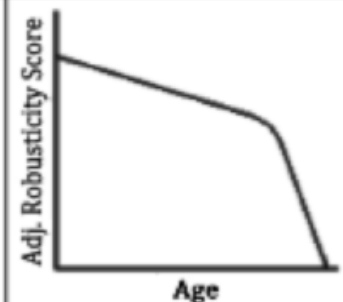
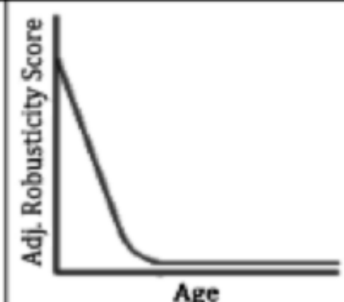
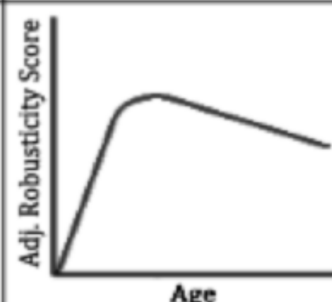
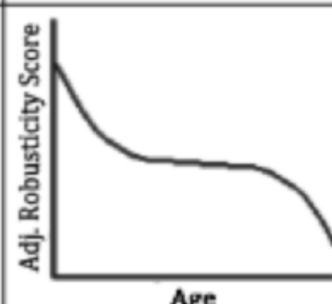
The social organization of horse riding over the life course did not differ between the Xiongnu and the Mongol period for each sex.

Evidence from both ethnographical studies and mortuary data suggest that the activities individuals engage in can change over the life course. These changes relate to notions of social age and rites of passage that mark an individual's movement through society. As an individual transitions from one stage to another, different roles and their associated activities become available. As a result, an individual may alter how often he or she performs a specific activity and this can, in turn, alter how that activity impacts the skeleton. If an activity has symbolic meaning, its availability and frequency of performance can change over the life course as individuals transition through life stages. By going in reverse, how the performance of an activity changes over the life course can provide information on the social systems associated with the symbolic meaning of that activity.

Table 1. Summary of predicted differences between Mongolian subsamples for each potential symbolic meaning of horse riding. A red "X" represents predicted significant differences while a green "O" represents a lack of significant differences between subsamples. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation.

Potential Symbolic Meaning	Predicted Results			
	Xiongnu vs. Mongol Males	Xiongnu vs. Mongol Females	Xiongnu Males vs. Females	Mongol Males vs. Females
Identity	O Riders	O Riders	O Riders	O Riders
Gender	O	O	X	X
Status	O Non-riders	O Non-riders	O Non-riders	O Non-riders
Power	O	X	O	X

Table 2. Potential scenarios for horse riding over the life course and their predicted robusticity curves for a horse riding enthesis.

	Potential Scenario	Predicted Robusticity Curve
Lifetime	• Began horse riding as a childhood and rode constantly throughout life. • Maximum robusticity is reached as a subadult and maintained until death.	
Not Old Age	• Began horse riding in childhood and rode constantly through middle age but stopped riding in old age. • Maximum robusticity is reached as a subadult and maintained until old age when the enthesis is resorbed.	
Only Childhood	• Began horse riding as a child then stopped as an adult. • Maximum robusticity is reached as a subadult but the enthesis is resorbed in adulthood.	
Only Adulthood	• Began horse riding as an adult and rode constantly throughout life. • Maximum robusticity reached in early adulthood and maintained until death.	
Composite	• Began horse riding in childhood, rode much less in early adulthood, increased riding in middle age, stopped in adulthood. • Maximum robusticity reached as a subadult, robusticity decreases to middle age, levels out in middle age, and decreases again in old age.	

Differences observed between males and females in the Xiongnu and Mongol societies over the life span should match those seen in Hypothesis 3a. For example, if horse riding is a symbol of identity, both sexes should be riding horses as often as possible over their entire life spans in both the Xiongnu and the Mongol periods. So, male and female curves for each society should overlap.

While the robusticity curves for males and females in each society should match the expectations for each scenario given in Hypothesis 3a, this has no bearing on what shape those curves would make over the life span. For instance, riding horses beginning in childhood and continuing to do so as often as possible would present a very distinct robusticity curve. This pattern would be represented by a robusticity curve that begins high and decreases linearly with the slope of the age correction factor. Since enthesial robusticity increases with age simply as a product of living in a particular society, this increase must be adjusted for when examining only the effects of horse riding over the life span. By comparison, if horse riding does not begin until adulthood but continues for the rest of the life span, the curve would begin low, peak rapidly, and then gradually decrease. Theoretical robusticity curves for several life course scenarios are given in Table 2.

Chapter Summary

Mobility can have varied and far-reaching impacts on a society, particularly in highly-mobile societies. It can affect gender and status systems and alter power dynamics within and between groups. Nomadic pastoralist societies are some of the most mobile societies in history. Studying how mobility changed over time can provide new information on social dynamics and complexity on these societies. Two of the most well-known nomadic pastoralist societies are the Xiongnu and the Mongols of the eastern steppe.

Though there is a great deal of evidence for cultural continuity between these two societies, their differing complexity likely impact the mobility system and its impact on people's lives. The research questions and hypotheses of this dissertation are presented.

Chapter 3

The Biological Basis of Skeletal Markers of Activity

The goal of this study is to use activity as a proxy for social dynamics. A necessary first step is to identify who was performing the activity under study; however, such information is difficult to obtain from material remains. For example, like many aspects of social dynamics, activity can leave evidence in individuals' skeletons because of the direct relationship between activity and biology. Activities require the performance of physical tasks. The body must move, which directly implicates the musculoskeletal system in the performance of any activity, symbolic or otherwise. Horse riding is no exception.

This direct relationship does not mean that analysis and interpretation of activity from skeletal remains is simple or straightforward. Though the concept of the musculoskeletal system is simple, a lever system of rods and pulleys, the actual biology of the continuum from cells to system is much more complex. This complexity affects both how performers of an activity are identified from the skeletal remains and the types of conclusions that can be drawn.

Terminology

There are three basic shapes of bones in the skeleton: the tubular long bones of the limbs; the flat bones of the hips, shoulders, and cranial vault; and the irregular bones of the ankles, wrists, and spine. Since activity studies are generally focused on movement of the limbs, the emphasis here will be on the long bones. However, the basic biology is similar for all shapes of bone.

Each long bone is divided into three regions. The diaphysis, or shaft, of the bone develops from the primary ossification center. The epiphyses, at the ends, frequently develop from secondary ossification centers. The flared region called the *metaphysis* connects the diaphysis to the epiphyses is.

There are two types of bone tissue in long bones: cortical and trabecular bone. These two types differ primarily in their porosity; cellular components are the same. *Cortical bone* is less porous than *trabecular bone*. The diaphysis in the adult is made up primarily of cortical bone. Epiphyses have an outer envelope of cortical bone but are predominantly trabecular bone. Metaphyses are transitional, going from primarily cortical bone closer to the diaphysis to mostly trabecular bone on the epiphyseal end.

Cortical bone is encased in two membranes. On the outside of bone is a tough, two-layer membrane called the *periosteum* with an outer layer of fibrous connective tissue and an inner layer that is vascularized. Some fibers from this membrane penetrate into bone and blood vessels from that layer nourish it while others intertwine with tendons to attach muscles to bone. The internal surface of bone has a similar membrane called the *endosteum*; however, the endosteum does not have the tough outer layer.

The microstructure of cortical bone consists of overlapping Haversian systems. *Haversian systems* consist of a central *Haversian canal* containing blood, lymph, and nerve fibers and concentric rings of bone called *lamellae*. Haversian canals follow the long axis of long bones while *Volkmann's canals* run obliquely, allowing vessels to connect between Haversian canals and creating a network of vessels to supply cells within the bone with blood and lymph.

Within the lamellae are small pockets in the matrix called *lacunae*, each containing an *osteocyte*, living bone cells derived from bone-forming cells called *osteoblasts*. As osteoblasts secrete bone matrix, they become trapped and transform into bone-maintenance cells or osteocytes. Each osteocyte is connected to other osteocytes in adjacent lacunae via small canals called *canaliculi*, which allow osteocytes to communicate with each other and with the cells of the periosteum and endosteum. This communication leads to one of two responses: either stimulating osteoblasts to secrete matrix and build more bone or stimulating bone-resorbing cells, called *osteoclasts*, to remove bone. A third type of cell found in bone is a bone lining cell. These cells cover surfaces that are not remodeling, can act as precursors for osteogenic cells and may extend cell processes into the canaliculi system, providing a means for transmitting mechanical signals from the osteocytes trapped in the cortex to the periosteum and endosteum. This communication system is critical to how bone can respond to mechanical loading.

When discussing mechanical loading in bone, some terms need to be defined. *Load* is the force exerted on a bone, usually the mass placed on the bone without regard to direction; it is a vector-less quantity. *Force* is the push or pull upon bone from a specific direction; it is a vector quantity. Different terms are used to describe the application of force from different directions. *Tension* is the magnitude of pulling force exerted on bone, it can result in stretching. *Compression* is the opposite of tension: the magnitude of pushing force exerted on bone, it can result in squashing or a decrease in volume. *Shear* force results from layers or planes of bone being shifted in relation to each other. *Torsion* is a measure of rotational force resulting from twisting a bone. *Stress* is a measure of pressure on bone. It is sometimes also called a measure of strength. *Strain* is a measure of the change in shape of an object under stress. The ratio between stress and strain can be used to study bone's strength.

There are many measures of biomechanics strength (e.g. compressive strength, tensile strength, fatigue strength). The term *strength* simply refers to the ability of a material to withstand an applied stress without failure. Since bone is a composite material, that is it is made up of more than one distinct constituents, mainly collagen fibers and calcium phosphate crystals though there are other minerals present. The particular combination of these components impacts the mechanical properties of any bone. A greater percentage of collage increases tensile strength while more mineralization increases compressive strength. The orientation of collagen and crystals within the cortex give bone its anisotropic properties. Bone is considered an anisotropic material meaning its mechanical properties vary with the direction of load. This means that any measure of strength of bone depends on the direction of load. For example, a human femur has a higher elastic modulus in the superior-inferior axis than it does in either the mediolateral or anteroposterior axis. The *elastic modulus* (or Young's modulus) is the ratio of stress to strain in a material or, put differently, a measure of how much a material will elongate or compress under stress.

Bone Biology

There are three processes by which osteoblasts and osteoclasts can alter bone: osteogenesis, modeling, and re-modeling. Which process occurs depends on the bone surface these cells act on and whether the cells functions are coupled or independent of each other. Osteogenesis is the process by which bone is created on a substrate of soft tissue, and usually only occurs during growth and healing, therefore it will not be discussed further. Modeling and remodeling take place on existing bone. When osteoblasts or osteoclasts work independently of each other, the process is called bone modeling. When these two cell types work together, the process is referred to as bone remodeling (Currey,2002; Martin, et al.,1998).

Bone modeling takes place on either the periosteal or endosteal surface of the cortex of bones. It is the process by which bones grow and change shape. Bone lining cells, responding to mechanical or metabolic stimuli, activate local precursor cells. These precursor cells may be either pre-osteoclasts in nearby blood vessels or pre-osteoblasts lining the bone. Regardless of which type of cell is stimulated, it acts independently. In bone modeling, osteoclasts and osteoblasts do not work together on a single surface. The results of this process are macroscopic changes rather than the microscopic changes seen in bone remodeling.

Bone remodeling occurs throughout the lifespan; modeling primarily occurs during growth. Bone remodeling is a mechanism for bone to repair microdamage, and happens through the activation of basic multicellular units (BMU). These units consist of several multi-nucleated osteoclasts forming a resorption front. As these cells resorb bone, they are followed by osteoblasts laying down new bone matrix along the walls of the resorption cavity, forming lamellae. Blood and lymph vessels will eventually reside in this newly formed Haversian canal.

Several factors affect the rate of modeling and remodeling. Genetics plays a role, but there are also several epigenetic factors that modulate the genes involved. These factors include nutrient availability and mechanical loading. Nutrient availability is affected by diet, food availability, and health. Bone can also function as a mineral reservoir. Therefore, as nutrients such as calcium are needed for physiological processes, remodeling rates may increase to liberate these nutrients from bone (Currey, 2002; Martin, et al.,1998).

Mechanical loading also affects modeling and remodeling. On important function of bone in the body is as structural support. As bone is loaded, the force of whatever load it is bearing is may not be on its strongest axis. To maintain structural integrity bone remodeling allows bone to adapt to better support the mechanical load it is bearing (Ruff & Hayes, 1983). This mechanical loading can result from a variety of forces including body weight, muscle contraction, and ground reaction force.

Bone-Muscle Interface

In addition to serving as a mineral reservoir and providing structural support for the body's soft tissues, bones also act as a series of levers and pulley allowing muscle contractions to cause movement. In order for it to move skeletal elements, muscle must attach to bone and this attachment must be able to withstand normal physiological loading, the normal pull of muscles, without tearing off the bone. Tendons and bone have different material properties, with different amounts of elasticity and different failure thresholds (Currey, 2002; Martin, et al., 1998), which adds an element of complexity to the system. Tendons are more elastic than bone to allow for some stretch to occur when a muscle contracts. This means tendons are less likely to fail under tension. By comparison, bone is more capable of withstanding compression, such as when standing (Currey, 2002; Martin, et al., 1998). As a result, bone fails first under tension (Berryman & Symes, 1998; Currey, 2002).

As fibers must transition between these two tissues, muscle has two ways of attaching to bone. These attachments points on bone are called entheses. In fibrous entheses, the tendon attaches directly to the bone or the periosteum (Benjamin, et al., 2002). In fibrocartilaginous entheses, tendons are separated from bone by two fibrocartilaginous zones (Benjamin, et al., 1986; Villote, et al., 2010). These two types differ both in their ossification and their location, which can affect how they are expressed on bone. These types also exhibit different transition zones, which are thought to help dissipate muscle force over the varying sizes of attachment observed for each type of enthesis (Benjamin, et al., 2002).

Fibrous entheses develop through intramembranous ossification and are found primarily on the diaphysis and metaphyses (Benjamin, et al., 2002). Tendons and ligaments in fibrous entheses can attach to the periosteum, sometimes called an indirect attachment, or directly into bone if the periosteum is absent, a direct attachment. Some muscles lack tendons and insert directly into bone via Sharpey's fibers. Muscles that attach via Sharpey's fibers also do so through fibrous entheses (Benjamin, et al., 2002).

Nearly all tendons inserting into fibrous entheses are short and spread muscle force over a broad area, diminishing the stress caused by these muscles pulling on bone. Since muscle contraction causes the muscle belly to decrease in length, tendons must be able to stretch so as to make up the difference in distance from muscle belly to bone. As a result, tendons have a much greater elastic modulus than bone (Currey, 2002). This disparity in material properties requires a transition zone to prevent avulsion of these entheses. Matyas, et al. (1990) examined the medial collateral ligament attachment in growing rabbits. Though the authors are describing the attachment of a fibrous ligament, fibrous tendinous entheses are thought to be similar. They found that there were five layers during growth: three layers of connective tissue on the ligament side of the insertion and two on the cortical side, labeled I-V from superficial to deep. Layer IV provides the mineralization front that is likely observed at fibrous attachments in dry adult bone. This sequence differs markedly from the simple two fibrocartilaginous zones of a fibrocartilaginous enthesis. This discrepancy may result in a different sequence of development at fibrous entheses.

By comparison, fibrocartilaginous entheses are found primarily on the epiphyses and have four transition zones between muscle and bone. From the muscle side of the enthesis, these zones are: tendon or ligament, uncalcified fibrocartilage, calcified fibrocartilage, and bone (Benjamin, et al., 1986, Villotte, et al., 2010). Both fibrocartilage zones are avascular (Villotte, et al., 2010). Between the uncalcified and the calcified fibrocartilage is the tidemark, the junction between hard and soft tissues (Benjamin, et al., 1986). The tidemark is where soft tissues are removed from entheses during maceration (Villotte, et al., 2010). However, it is the junction between the calcified fibrocartilage and bone that is observed as an enthesis in dry adult bone. Though there are differences at the cellular level between fibrous and fibrocartilaginous entheses, both can potentially developed increased robusticity in response to muscle use.

Adapted Changes to Bone Create Activity Markers

Physical tasks require muscles to move bones. As bones are moved during the performance of an activity, they are loaded, which can stress and strain bone cells. This loading can lead to both modeling and remodeling in bones that can be measured, allowing bones to inform on activities individuals performed. Two types of markers are commonly used for reconstructing activity in past populations: cross-sectional geometry and enthesial robusticity.

Cross-sectional Geometry

Based on mechanical principles, cross-sectional geometry was one of the first markers used for activity reconstruction. However, the mechanical biology of the skeletal system was found to be more complex than the simple mechanical model cross-sectional geometry was based on. Culturally-specific performances of activities further complicate cross-cultural studies. Additionally, recent research into the etiology of changes in cross-sectional geometry suggests these markers are a better measure of cumulative loading over the lifespan rather than a marker of a specific activity. Since the goal of this project is to study social dynamics through horse riding, a specific activity, a different type of marker was needed.

Cross-sectional geometry refers to the amount and distribution of cortical bone, usually measured in the midshaft of a long bone, such as the femur or humerus (Ruff & Hayes, 1983). This concept is also called bone functional adaptation. Loading a bone is thought to cause stresses within bone shafts (Chamay & Tschantz, 1972; Ruff, et al., 2006). This stress results in stress on osteocytes within the cortex (Bonewald & Johnson, 2008; Nicolella & Lankford, 2002). The osteocytes transmit signals to bone lining cells in the periosteal and endosteal envelope through the canaliculi network, which instigate BMUs to remodel the cortex (Currey, 2002; Loitz & Zernicke, 1992; Ruff, et al., 2006). This new bone can change the shape of the shaft of the bone and presumably reduces stress on the lacunae.

Cross-sectional geometry is often used to study changes in locomotive and subsistence behavior (Bridges, 1991; Bridges, et al., 2000; Larsen, 1987; Larsen, 2002; Ruff, 1987; Ruff & Larsen, 1990). These studies focus primarily on changes to femoral midshafts using the idea that changes in these behaviors will change the amount of loading on the femur over a lifespan (Lanyon, et al., 1979). Though these studies often look at the same locomotive or subsistence behavioral transition, their findings often contradict each other.

Many of the contradictory results seen in earlier studies have been attributed to differences in the culturally-specific performance of activities. For example, both Ruff (1987) and Bridges, et al. (2000) have studied the transition from hunting and gathering to agriculture and found different results. Ruff (1987) examined sexual dimorphism and cross-sectional geometry of the femur in samples from Pecos Pueblo both before and after the transition to a primarily agricultural lifestyle. Males were found to have decreased ratios of anterioposterior/mediolateral diameters with the shift to agriculture. This is interpreted as a loss of mobility with the shift to a sedentary agrarian society. Interestingly, differences between males and females are explained by females wider hips causing greater mediolateral bending forces in their femora. The females did not exhibit changes in the ratio of their femoral diameters; however, this is attributed to no change in their pelvic width rather than to no change in their mobility. In contrast,

Bridges, et al. (2000) found most difference in cross-sectional geometry between females from the Middle Woodland through the Mississippian periods in west-central Illinois. The decline seen in right arm strength in males is attributed to replacement of the atlatl with the bow. However, changes in female arms are related to possible changes in the processing of, technology for, and relative inclusion of maize in the diet. Granted, much of this interpretation is based on a decline in the size of females' arms into the Mississippian period, though the data does not bare this out. Femoral strength is shown to increase over time, however this is attributed to behavior in this study and not to changes in pelvic width.

While Ruff (1987) found a decrease in robusticity among males with the adoption of agriculture in Pecos Pueblo, Bridges, et al. (2000) found an increase in robusticity among females in west-central Illinois with the same transition. The hypothesis offered to explain the discrepancy in interpretation between these two studies was that hunting and gathering on the coast differs from hunting and gathering inland, as does agriculture, so the transition on the coast and inland should result in different skeletal changes. Such an example highlights the need to know what activities were performed by a society and how that performance loads the bone under study for a full comparison of activities to be done.

Another consideration to come out of cross-sectional studies is the timing of these changes over the lifespan. New research is suggesting that the different bone surfaces around bone shafts are responsive to loading at different times in the lifespan. The periosteum appears to be active primarily during growth and development. Its susceptibility to loading seems to cease once epiphyses have finished fusing to the diaphysis (Li, et al., 1991). By comparison, the endosteum appears to be most responsive to loading only once a bone has finished fusing and throughout adulthood (Woo, et al., 1981). If true, then cross-sectional geometry then becomes a record of the cumulative loading on a bone over the lifespan. Though such data can provide some useful information for studying general activity patterns in a society, it is severely limited in studying specific activities, especially those activities that may not be performed over the entire lifespan.

Enthesial Robusticity

Enthesial robusticity refers to some measure of the development or breakdown of bone at muscle attachment areas. The concept behind this type of activity marker is that as muscles contract, their attachment points are strained by tension and the bone tissue is remodeled to maintain the muscle's connection to bone (Galtés, et al., 2006; Hawkey & Merbs, 1995; Hsieh, et al., 2001). There appear to be two bony responses at entheses: bone resorption, and bone deposition. There is some debate about whether bone resorption is pathological response to extreme overloading or if it is a normal response to muscle disuse (Drapeau, 2006; Nicolella & Lankford, 2002; Stadelmann, et al., 2008; Tan, et al., 2007; You, et al., 2008). Bone deposition is generally thought to result from repeated muscle use within healthy physiological limits over the lifespan (Benjamin & Ralph, 1998; Galtés, et al., 2006). An exception to this generality is osteophyte formation. Osteophytes are highly localized large depositions of bone and are thought to be a pathological response to muscle tears (Drapeau, 2006; Villotte, et al. 2010). As one of the goals of this research is to examine the routine (and thus assumed non-pathological) activity of a population, and since both bone resorption and osteophytes are thought to relate to pathological responses, this project will focus only on bone deposition at entheses.

Several studies have used the relative amounts of bone deposition at entheses to study both general activity patterns and specific activities within and between societies (e.g. Bridges, et al. 2000; Hawkey & Merbs, 1995; Hollimon, 2000; Peterson, 2000; Ruff, 1987;Stirland, 1998). Entheses can be used to study specific activities, while cross-sectional geometry cannot, because enthesial robusticity changes as a result of specific muscles pulling at specific attachment points, not simply due to general skeletal loading. Every activity requires a specific series of physical tasks that use specific muscles, therefore each activity should produce a unique pattern of enthesial robusticity. Consequently, in theory, enthesial robusticity has greater potential to identify performers of a specific activity than does cross-sectional geometry. However, the complex biology of the musculoskeletal system requires exploring the effects of some key variables in order to more accurately interpret the data from entheses: biological thresholds, age, and body size.

The first variable is related to biological thresholds required to stimulate changes in enthesial robusticity. Cells do not always react the same way to the same amount of stimulus (Frost, 1990, 2007; Hsieh, et al., 2001; Zumwalt, 2006). Osteocytes and chondrocytes appear to have different thresholds for change, even with the same genetic makeup and available resources (vitamins, minerals, etc.). It is hypothetically possible for osteocytes to have different biological thresholds in various entheses. All muscles within the body pull with different amounts of power. For instance, lower limb muscles pull with more force than upper limb muscles (Drapeau, 2006). Leg muscles must move the much larger leg or body while arm muscles only move the arm. Therefore, cells located at the attachment points for the large muscles of the thigh must withstand greater tensile strain than those at arm muscle attachments. For the same reason, leg muscles may hypothetically have stronger attachments to begin with and a higher threshold needed to remodel the entheses. As discussed earlier, there are two different types of entheses, fibrous or fibrocartilaginous. These may have different thresholds and different mechanisms for changing their enthesial robusticity (Hawkey & Merbs, 1995; Villotte, et al., 2010). What this means for the reconstruction of activity from entheses is that not all enthesial robusticity differences can be interpreted in the same way. Entheses of the upper limb appear to be more sensitive to changes in muscle use compared to those of the lower limb (Drapeau, 2006). As a result, aggregating muscle scores should be avoided if at all possible since it results in an unnecessary loss or muddling of information.

To further complicate matters, biological thresholds change over time. It is thought that as entheses lay down bone to strengthen the muscle attachment, the threshold needed for change increases so that greater force is needed to induce further change (Frost, 1990, 2007). This may be the result of either the increased bone changing the mechanical environment, dissipating strain better, or by actually recalibrating the osteogenesis threshold in osteocytes. At the same time, the muscle is increasing in strength and efficiency, so that it can theoretically pull with more force over time. The effect of this process is that, as long as the muscle(s) continue to be used throughout life, enthesial robusticity is likely to increase over time until it reaches a maximum robusticity and plateaus. Even more force is applied beyond what this maximum robusticity can bear, muscle tears may occur, resulting in the pathological development of osteophytes. The result of all this is that this marker usually correlates strongly with age. There is also some debate as to when entheses begin to develop robusticity. Some appear to begin development in childhood while others only seem to begin when the bone to which it is attached is fully fused and/or all other adaptive mechanisms have been exhausted (Zumwalt, 2006). Age is a major confounding factor of enthesial studies, unless an enthesis has reached maximum robusticity, and must be controlled for.

Additionally studies suggest sex and body size may also affect enthesial robusticity (Weiss, 2003; Zumwalt, 2006). Bioarchaeological studies have shown females tend to have less robust entheses than males (Hawkey & Merbs, 1995; Weiss, 2003). It has been suggested that this is due to hormonal differences between the sexes. Females' high level of estrogen is hypothesized to downregulate modeling and remodeling processes (Saxon & Turner, 2005). Many of the same studies also point to the possibility that the difference in body size between males and females is also a confounding factor. Larger bodied individuals appear to have larger and more robust entheses (Zumwalt, 2006). These observations might be expected since larger-bodied individuals are likely to have larger muscles contracting with more force. However, there is some debate about the role body size plays in enthesial robusticity. One study has found that although enthesis size correlates with body size, it does not correlate with muscle size (Zumwalt, 2006). Until the nature of these relationships is understood, these variables should be evaluated within the sample populations, controlled for, if possible, or considered when interpreting the data.

The biology of the musculoskeletal system as a whole also has implications for the interpretation of enthesial robusticity data. Muscles work together to perform specific actions with the skeletal system. However, it is not a one-to-one muscle-action ratio. Many muscles are often recruited to perform one action and most muscles can assist with multiple actions. For example, the gluteus maximus can extend, laterally rotate, and abduct the thigh as well as stabilize the trunk while thigh abduction can also be done with the gluteus medius, gluteus minimus, or the tensor fascia latae (Gray, 1974). Additionally, a given activity usually requires more than one muscle action, and a given muscle action may be performed during a variety of different activities. The implication of these considerations is that combinations or suites of entheses must be studied. People perform multiple activities routinely, all of which may increase various entheses' robusticity. It is unlikely that a single enthesis would sufficiently separate the skeletal effects of a specific activity from all other activities an individual engages in. In contrast, by evaluating suites of entheses, one is much more likely able to identify performers of a specific activity.

In addition to biological considerations, there may be cultural differences in how an activity is performed, e.g., English vs. Western riding. Available technology and historical precedent affect how people physically perform a task (Merbs, 1983). For example, when riding a horse, a rider may use a saddle and stirrups or ride bareback, use a long saddle or a high cantled one, ride with extended or with bent legs, post or not. All such options affect what physical actions are required to perform an activity. Just as these options impact comparative studies of cross-sectional geometry, so they do comparative studies of enthesial robusticity. Different physical actions mean different muscles are recruited which may lead to different suites of entheses to identify the same activity in different cultures (Merbs, 1983), that is they should be considered culture-specific. The implication is that suites of entheses developed to identify an activity in one culture may not translate to other cultures.

Chapter Summary

Bone tissue is capable of adapting to its mechanical environment. Bone cells, such as osteocytes and osteoblasts, can sense mechanical loads, and activate mechanisms that result in local or systemic changes in bone structure and geometry. Stress can lead to changes in cross-sectional geometry, which measures the amount and distribution of cortical bone in the shafts of long bones. Recent research suggests cross-sectional geometry is less useful for identifying specific activities than previously thought. By comparison, increases in enthesial robusticity, are thought to indirectly measure specific muscle usage. Though there are several biological variables that can influence enthesial robusticity, and therefore interpretations of data, research suggests this type of activity marker has the greatest potential for identifying performers of a specific activity. This research will evaluate horse riding, a specific activity, to examine how social dynamics impact the day-to-day lives of individuals and will employ enthesial robusticity to help identify horse riders in the sample populations under study.

Chapter 4

Materials & Methods

The goal of this research is to examine the social dynamics of mobility in complex prehistoric nomadic societies. However, it must first be determined if horse riders can be identified in these societies using their skeletal remains. Such an endeavor requires comparison of known riding and non-riding samples. Provided that these two samples are derived from genetically similar populations with relatively similar lifeways, the most significant differences seen between them should be the result of habitual horse riding. This comparison would allow for the development of a suite of riding markers that could be used to identify horse riders from their skeletal remains.

As discussed in previous chapters, riding horses has a large impact on social dynamics. Therefore, attempts are often made to identify horse riders cross-culturally using activity markers that are implied to be universal. Yet, this universality has not been tested. Before activity markers can be applied cross-culturally, their applicability to multiple styles of riding must first be tested. If this universal applicability does not exist, culturally-specific suites of entheses must then be developed before horse riding can be used to study social dynamics in any society.

Prior to any analysis of activity markers taking place, confounding factors must be addressed. In addition to activity, age, sex, and body size are all thought to contribute to the robusticity of activity markers. Therefore, these variables must be determined for all individuals prior to their inclusion in any activity analysis. Lastly, a system must be described for scoring the robusticity of entheses. Such a system should have low inter- and intraobserver error rates while being applicable to both fibrous and fibrocartilaginous entheses. By controlling for age, sex, body size, and culture-specific activity styles, the impact of social dynamics on activities can hypothetically be studied.

Horse Riding Samples

As discussed in the previous chapter, culturally specific ways of performing an activity can change how that activity impacts the skeleton. This is also true of horse riding. There are many styles of horse riding. Despite this fact, many attempts have been made to apply markers of horse riding cross-culturally with variable success (Erickson, et al., 2000; Garofalo, 2004; Hollimon, 2000). In an effort to address whether there is a "universal" suite of entheses to identify horse riders, several styles of riding will be analyzed. This analysis does require identifying "known" riders and nonriders from the same genetic background and, preferably, the same lifeways. Differences observed between such riding and nonriding groups would then be assumed to come from habitual horse riding rather than from either genetic or other activity-related factors.

Bareback Riders

The samples used for the study of bareback riding are derived from Pre- and Post-Contact Arikara populations. Though horses are thought to have originally evolved in the Americas and crossed to the Old World over the Bering land bridge, they became extinct in the Americas around 10,000-8,000 years ago for unknown reasons. They were not seen again until Europeans brought them during the Contact period, ca. 1715 (Jantz & Owsley, 1984). As a result, the Pre-Contact Arikara male sample is thought to represent a non-riding population. Post-Contact Arikara, on the other hand, were considered great horsemen and are known for breeding and selling horses (Jantz & Owsley, 1984; Wescott, 2001). In most analyses of horse riding among Native Americans of the Plains, it is the

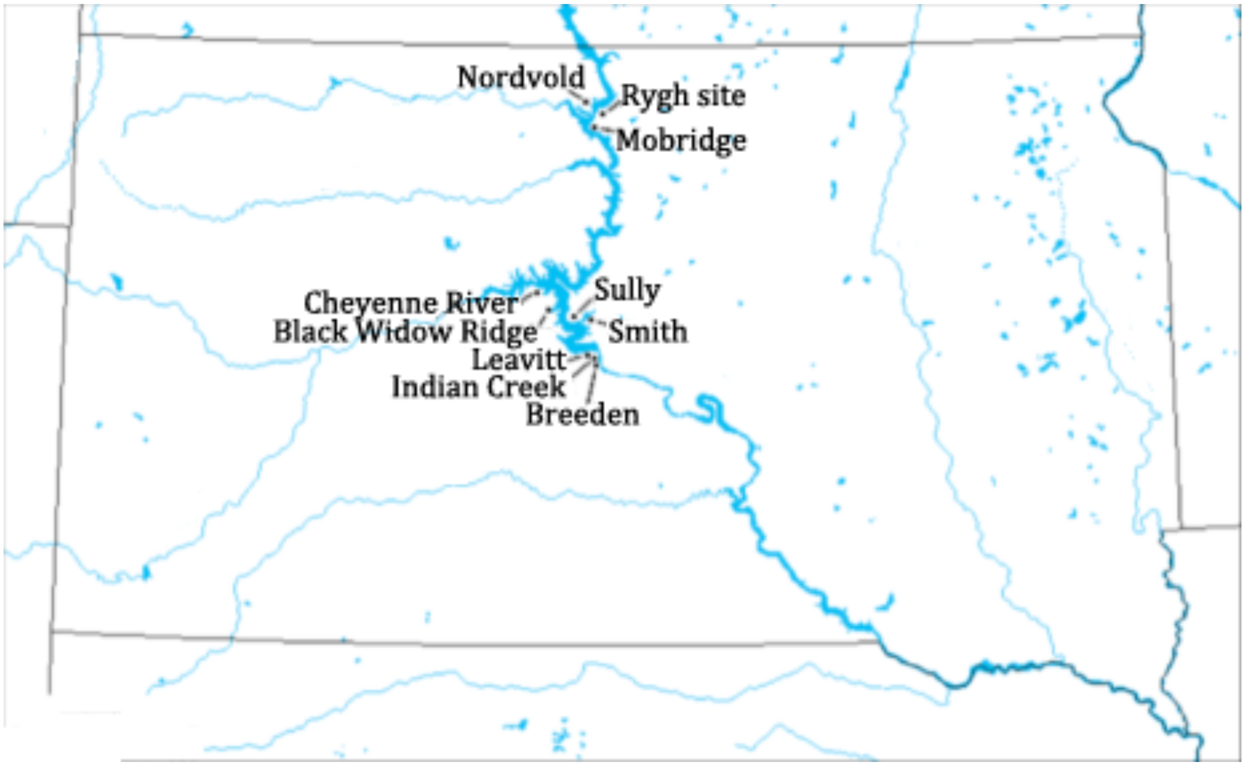


Figure 1. Location of sites contributing to the Arikara riding and non-riding samples.

males that are assumed to be habitual riders (Erickson, et al., 2000). Females may also be riding in these societies but they are not assumed to do so habitually, as males are. So, the Post-Contact male Arikara sample is used here to represent a habitual bareback riding population.

The samples used here are derived from ten different sites in South Dakota (Figure 1) containing components from the Initial Middle Missouri (AD 1000-1300), Extended Middle Missouri (AD 1200-1400), Extended Coalescent (AD 1400-1650) and Post-Contact Coalescent (AD 1650-1866) (Johnson, 2007). In an effort to limit the amount of background noise introduced by the performance of different activities in different villages, these samples were derived from the sites with the largest number of recovered human remains in the Arikara collections housed at the Smithsonian. Most of individuals in the samples were from excavations at the Mobridge and Sully sites. The Mobridge site consisted of a village and a cemetery from the Extended Coalescent and Post-Contact Coalescent. Due to this extensive occupation, individuals assigned to both the Pre- and Post-Contact period are included from this site in the study samples. The Sully site consisted of a village and cemeteries also from the Extended Coalescent and Post-Contact Coalescent. So, both Pre- and Post-Contact individuals are included from this site as well in the study sample (Billeck, et al., 2005).

Additional individuals in the Pre-Contact sample come from four different sites: Black Widow Ridge, the Rygh site, the C.B. Smith site, and the Breeden site. The Black Widow Ridge site was comprised of several burials within pit features in a village complex. Though the site contains components from the Extended Middle Missouri, Extended Coalescent, and Post-Contact Coalescent, the individuals included in this study are likely associated with the Extended Middle Missouri component and so are included in the Pre-Contact sample. The Rygh site contained several burials from the Extended Coalescent and Post-Contact Coalescent. The individuals included in this project are all associated with the Extended Coalescent and incorporated in the Pre-Contact sample. Only one individual was excavated from the C.B. Smith site and associated with either the Extended Middle Missouri or Extended Coalescent components, so is placed in the Pre-Contact sample. Additionally, a few individuals were included from the Breeden site. This site had at least two occupations: one during the Initial Middle Missouri and one during the Post-Contact Coalescent. The individuals included in this study are associated with the Initial Middle Missouri component and are thought to be affiliated with the Mandan, not the Arikara. This society was thought to share a similar lifeway to the Arikara, so these individuals were included in the Pre-Contact sample (Billeck, et al., 2005).

In addition to some individuals from the Mobridge and Sully sites, the Post-Contact sample includes individuals from four other sites: the Nordvold site, Indian Creek, Cheyenne River, and Leavitt. The Nordvold site comprises three villages and two cemeteries from the Extended Coalescent or Post-Contact Coalescent. All the individuals included from this site are associated with the Post-Contact Coalescent component, so are included in the Post-Contact sample. The Indian Creek site is made up of a village and associated cemetery belonging to the Post-Contact Coalescent. Though there is an Extended Middle Missouri component to this site, the historic artifacts associated with the burials indicates the cemetery belongs to the Post-Contact Coalescent. The Cheyenne River site is comprised of a village and associated cemetery. The village has components belonging to the Extended Middle Missouri, Extended Coalescent and Post-Contact Coalescent however, the funerary objects suggest that the cemetery only belongs to the Post-Contact Coalescent. The Leavitt cemetery consists solely of a Post-Contact cemetery. The association of historic artifacts suggests all these individuals belong to the Post-Contact Coalescent period and so are included in the Post-Contact sample (Billeck, et al., 2005).

The assignment of individuals into Pre- or Post-Contact samples was based primarily on the presence of European goods in burials. This is not a perfect system as at least some Post-Contact individuals will be assigned to the Pre-Contact sample simply because they have few or no burial goods. However, this method was chosen because it minimized the effects on the rest of the study. The combination of Pre- and Post-Contact individuals may result in a lack of significant differences between riding and nonriding groups, making the development of a suite of entheses for bareback riding difficult. Yet, this sorting method will prevent Pre-Contact individuals from being assigned to the Post-

Contact group, so inter-style analyses will not be affected. A summary of the number, average age, and average body size of the samples is given in Table 3.

British-style Riders

Table 3. Sample sizes, average age, and average size for each subsample in the analyses.

Sample	N	Average Age	Average Size
Pre-Contact Arikara	25	44.32	46.5
Post-Contact Arikara	67	39.1	46.6
Post-Medieval British City Males	24	43.92	47.6
Post-Medieval British City Females	27	46	41.37
Post-Medieval British Country Males	29	50.69	46.57
Post-Medieval British Country Females	23	45.22	42.22
Xiongnu Males	31	40.36	46.73
Xiongnu Females	23	41.9	41.43
Mongol Males	16	41.94	47.74
Mongol Females	16	32.57	41.46

The samples used for the study of English-style riding are derived from country- and city-dwelling Post-Medieval British populations. During the Post-Medieval period, wealthy country-dwelling estate owners and farmers likely used horses to work the land. So, the country-dwelling sample was used as the British riding sample. By contrast, the city-dwelling sample was derived from a population of poor Londoners who were unlikely to own or ride horses. So, this sample is used as the comparative British non-riding sample. This is not an ideal comparative population since wealthy country-dwellers probably had different diets and performed different activities. However, this study focuses on entheses in the lower limb and these muscles were likely used similarly between these two groups, with the exception of horse riding. Material culture and written and artistic sources show that these riders used high-cantle saddles and stirrups (Garofalo, 2004). As a result, the British rider sample can be used as a "known" saddle-riding population for comparison between riding styles.

The country-dwelling sample was excavated from the site at Chelsea Old Church. During the Post-Medieval period, this area was transitioning from wealthy country estates to a suburb of London (Cowie, et al., 2008). The portion of the population buried at the churchyard appears to be the wealthier upper class from the area. Many of the coffins found with this burial population were lead lined and/or had evidence of decoration. Additional burial goods also suggest that this population was from the wealthier classes (Cowie, et al., 2008). The gender roles of the time suggest that it was only the males who were riding horses in this society. So, the males from this sample are used as the British rider sample.

The city-dwelling sample was excavated from the site of Lower St. Bride's Churchyard on Farringdon Street in London. This cemetery was in use from 1770 to 1849. During the Post-Medieval period, this area was considered one of the poorer districts of the city mentioned in historical documents for overcrowded conditions and poor sanitation (Miles, 2010). Individuals were buried in wooden coffins that were stacked one on top of each other up to nine coffins deep in ten rows. Records show this cemetery was one of the cheapest places in the area to be buried and many later burials intruded on earlier burials (Miles, 2010). Since only the males from Chelsea Old Church were used as a "known" riding samples, only males from Farringdon were used as the comparative non-riding British sample. By only using males, sex is eliminated as a confounding factor in studying enthesial robusticity.

Both of the samples just described are housed at the Museum of London. An attempt was made to gather data from a random, stratified sample from each cemetery. However, all of the male skeletal remains from the Chelsea Old Church sample, which exhibited adequate preservation and the presence of the required skeletal elements, were used for the study in order to get an adequate sample. As a result, the Chelsea Old Church sample had an older average age than the Farringdon sample. Table 3 provides a summary of the number, average age, and average body size of the riding and non-riding British samples.

Mongolian Samples

The samples used for the study of Mongolian-style riding are derived from Xiongnu and Mongol populations. These two societies were the largest and most expansive polities to develop on the steppe. The Xiongnu (3rd c. B.C. – 2nd century A.D.) created the first expansive steppe polity. At its height, the Xiongnu controlled territory from Manchuria in the east to Kazakhstan in the west, southern Siberia in the north to Inner Mongolia in the south (Honeychurch & Amartuvshin, 2006). The Mongol empire (13th-14th century A.D.) was the largest steppe polity in history. At its largest, the Mongols controlled territory from China to the Middle East and much of Central Asia and Russia (Honeychurch & Amartuvshin, 2006).

Individuals were placed in either the Xiongnu or Mongol sample based on their associated mortuary data. Xiongnu burials exhibit a high degree of variation, ranging from simple pit burials with no grave inclusions to lavishly furnished tomb complexes surrounded by sacrificial interments (Honeychurch, 2004; Miniaev & Sakharovskaia, 2008). They are usually found in groups of 5 to 400 burials located near rivers, on low sloping mountainsides, and in the forests of the northern central steppe. These groups form distinct cemetery clusters throughout the landscape, which DNA suggests are family groups (Honeychurch, 2004; Keyser-Tracqui, et al., 2003). This includes groupings of intercultural families (Linduff, 2008). Individuals are usually buried in a supine position oriented north (Honeychurch, 2004).

Some of the variation seen in Xiongnu burials is due to status differentiation. Larger surface feature size and exotic goods, such as Chinese goods and beads from societies to the west, are often associated, suggesting that these individuals were of a more elite status than others in the local area (Honeychurch, 2004). More rare and spectacular are the burials of nobles. Miniaev and Sakharovskaia (2008) excavated the central burial mound in an elite cemetery in the Tsaraam Valley. This burial mound, called a kurgan, was 32 meters on each side, 1.5 meters high, with a 20 meter ramp sloping south, and surrounded by a low wall of vertical stone slabs and 10 sacrificial burials. Within the kurgan, four wooden covers lie over a triple burial chamber of outer frame, inner frame, and coffin. Between these two frames were iron objects, 2 dolls made in part with children's skulls, saddle parts and silver and bronze badges. A chariot was found on the fourth cover, just above the burial chamber (Miniaev & Sakharovskaia, 2008). Such noble elite burials stand in stark contrast to the burials of more common individuals.

Ordinary Xiongnu burials consist of a surface feature, made of local stones in a roughly circular ring with a depression in the center, and a rectangular burial pit that may be up to 4 meters deep (Honeychurch, 2004). A few layers of local rocks interspersed with soil fill covers one of a variety of internal constructions, including wood plank coffin, a full wooden chamber and coffin, or a chamber constructed from stone slabs with or without a coffin. Ordinary elites can be differentiated from commoners by the larger size of their surface features and the inclusion of luxury goods, such as gold brooches and headdresses and ornate bronze (Honeychurch, 2004). More common grave goods found in all levels of burials include local ceramics, bow pieces made of bone, tools and weapons, bones of domesticated animals and horse paraphernalia, and beads and other decorative items (Honeychurch, 2004; Linduff, 2008; Miniaev & Sakharovskaia, 2008).

Mortuary practices in the Mongol period appear to vary more and exhibit less standardized differentiation than in the Xiongnu period. Four types of mortuary practices are known from written sources in the Mongol period: burial, cremation, exposure to wild animals, or in trees – the last three of which can be followed by secondary burial (Crubézy, et al., 2006). Surface features for burials are typically oval-shaped mounds of local stone oriented north and located on slopes of small, enclosed valleys (Crubézy, et al., 2006; Honeychurch, 2004). Elite and urban cemeteries tend to be more variable than rural or ordinary ones, however, this variation is not well-patterned (Honeychurch, 2004). Burial inclusions may include iron tools, ceramic vessels, birch bark containers and quivers, stone beads, bones of sheep, goat, and deer, and cremains of additional humans (Crubézy, et al., 2006; Honeychurch, 2004). External goods, usually from China, are rare and only found in elite burials. The lack of formal arrangements or patterned variation suggests less of an emphasis on corporate group identity in the mortuary sphere during the Mongol period.

Three sites from Mongolia provide both the Xiongnu and Mongol skeletal samples, shown on the map in Figure 3.2. Aggregated samples sizes by sex and time period are given in Table 3. All sites lie in the northern half of the country. Chandman is a site in the northwest, lying in the plain on the west side of the lake Uvs Nuur near Ulaangom. It contains burials from the Bronze Age through the Early Iron Age and the Xiongnu period (pers. comm. D. Tumen & M. Erdene). Egiin Gol is a river valley in the north-central region. On the higher elevations are dense forests, which give way to grasslands and meadows toward the river (Wright, 2006). Burials have been found in this valley dating from the

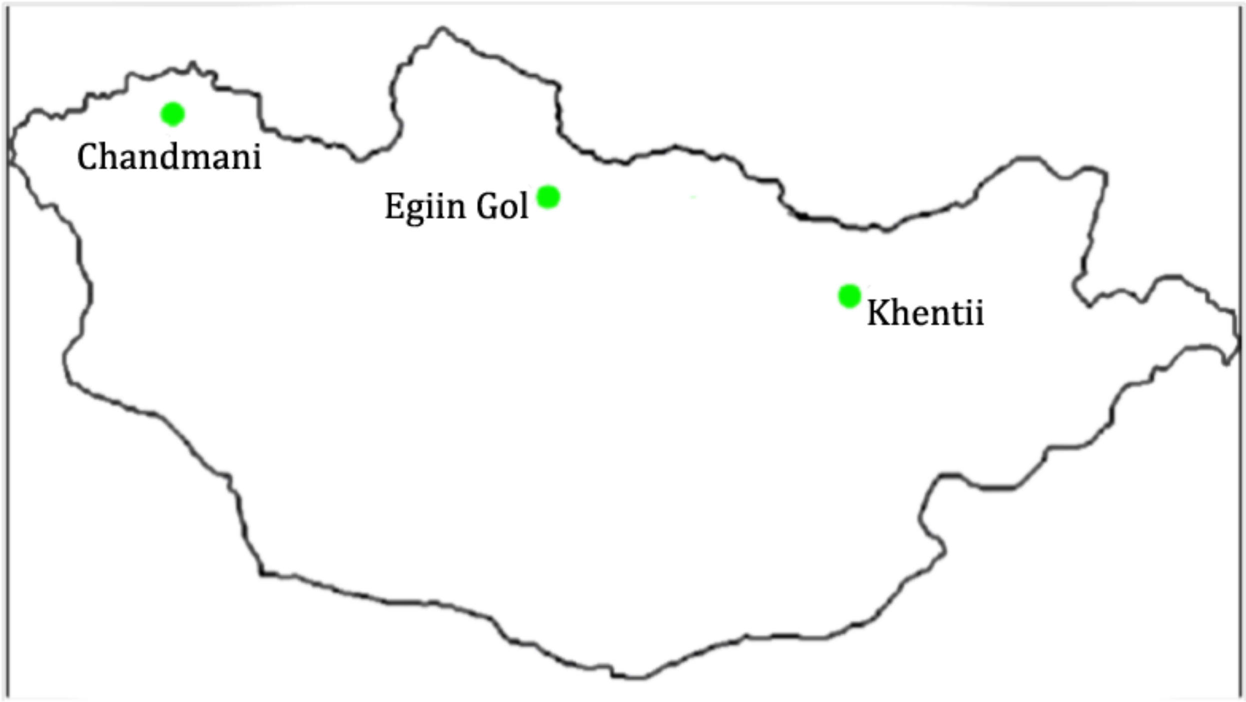


Figure 2. Location of sites contributing to the Mongolian samples in the analyses.

Bronze and Early Iron Age through the Historic Mongol period (Honeychurch, 2004; Honeychurch & Amartuvshin, 2006). Khentii lies on the east side of the hills near the town of the same name. It is also a river valley though not as steep or as forested as Egiin Gol. The burials excavated at this site are primarily Mongol with only a relative minority from the Xiongnu period (pers. comm. T. Amagalantugs).

A special note needs to be made about the designation of individuals as being from the "Mongol" period. Chronology is assigned to skeletal remains based on the mortuary context in which they are found. As a result, all individuals identified as being from the Mongol period may not be from the height of the Mongol empire (13th-14th century AD). They were labeled as "Mongol period" based on the similarity of their mortuary context to those seen at the height of the Mongol empire (pers. comm. J. Wright). This may include burials radiocarbon dated to as early as the 11th century AD. Consequently, though there is likely some cultural continuity between what is referred to here as the Mongol society and the Mongol empire, not all individuals identified as "Mongol" were imperial citizens. The sample may also include some individuals from other societies that shared the eastern steppe with those from the Mongol society and due to a variety of factors, such as intermarriage, may have been buried in the Mongol style. This happened during the Xiongnu period (Linduff, 2008), therefore it is reasonable to assume it occurred during the Mongol period as well. As a result, there may also be individuals from the Uigher or Khitan societies intermixed in the "Mongol" sample mentioned here. These individuals are thought to be a minority of the population and, though imperfect, it is assumed that if these individuals were buried in the Mongol style, that they were assimilated into the culture and would exhibit the same social organization of mobility.

Symbolic Activity Samples

British and Mongolian derived samples were used to test the relationship between the symbolic meaning of horse riding and the social organization of horse riding. In order to determine if a relationship exists between symbolic meaning and organization, samples were collected from a society where the symbolic meaning of horse riding is known. In Post-Medieval Britain, horse riding symbolized high status; the maintenance of horses requires significant resources, which would typically be only available to high status individuals (Garofalo, 2004). Therefore, comparisons between males and females and between high-status and low-status population samples should bear this out. The British male riding and non-riding samples used to identify markers of horse riding for the British riding style were used for this analysis. Associated city-living and country-living female samples were used for comparison. The female sample size, average age, and average body size are listed in Table 3.

If the predictions of comparisons between subsamples from a society with a known symbolic meaning of horse riding are borne out, then comparisons between the Mongolian samples will be used to examine the meaning of horse riding in this culture. As this is a diachronic analysis, males and females from different time periods with known social dynamics are necessary. The male samples represent the Xiongnu and Mongol samples that were used to identify markers of Mongolian-style horse riding above. The associated female samples were used for comparison. The female sample size, average age, and average body size are listed in Table 3.

Skeletal Data

This study focuses primarily on the robusticity of various entheses. However, enthesial robusticity appears to be affected by age, sex, and body size, in addition to muscle use. Thus, in addition to collecting data on various entheses, age, sex, and body size must be estimated for each individual.

Age

For two of the samples, the Arikara and the British samples, estimated age ranges were available from previous studies. This data was used in an effort to allow for future comparisons and re-analyses of this data. For the Mongolian samples, age was estimated for each individual using one or some combination of three different aging methods: pubic symphyseal aging, sternal rib end aging, and a new method utilizing entheses on the femur. Entheses used for aging were excluded from the activity analysis. Though the first two methods are commonly used in bioarchaeological studies, the third was developed specifically for this study as a result of the poor preservation of crania, os coxae and ribs in the Mongolian samples.

Age is the most commonly cited and problematic of potential confounding factors in studies of enthesial robusticity. This strong association between age and enthesial robusticity was investigated in this study as a way to provide necessary age estimations and allow for the inclusion of more individuals in the analyses. These individuals would otherwise have to be excluded from the analysis of enthesial robusticity for the identification of horse riders.

This analysis utilized a sample of 488 individuals of known age from the Hamann-Todd collection. Nine entheses on the femur were examined for correlation with age. If enthesial robusticity was bilaterally asymmetric, the higher robusticity grade was used. Partial correlations were used to calculate the correlation between enthesial robusticity and age for each entheses, while controlling for body size (estimated using the method below).

Only two entheses were found to have a moderate correlation with age: the proximal and middle linea aspera. Age ranges were created for each robusticity grade by using the two standard deviations from the average age in both directions for all the individuals with that robusticity grade. These entheses were used to age individuals in the Mongolian sample whose age was otherwise not able to be estimated. As a result of the use of this aging method, these two entheses were removed from the rest of the activity study analysis.

Sex

Though two of these sample groups, the Arikara and the British samples, have well-established and published sex estimates for each individual, the Mongolian samples do not. Sex for these samples was estimated using primarily nonmetric pelvic traits: the greater sciatic notch, pubic body shape, and the Phenice (1969) method. These methods have been shown to be reasonably accurate, cross-culturally applicable, with low inter- and intraobserver error (Lovell, 1989). When the necessary elements of the os coxae were not preserved, femoral head diameter was used to estimate sex according to Bass (1995). The cut-off point for indicating an individual as male versus female was tested using individuals whose sex was estimated using the nonmetric pelvic traits listed above. Males exhibited an average femoral head diameter of 47.03mm with a range of 43.6-52.6mm. Females exhibited an average femoral head diameter of 41.37mm with a range of 30-9-44.65mm. Individuals with an average femoral head diameter falling within the overlapping range of 43.6-44.65mm either had their sex estimated using pelvic traits or were excluded from sex-based analyses. Only three individuals fell within this range and all three had associated pelvic skeletal elements preserved and these were used instead of femoral head diameter to estimate sex.

Body Size

There is some evidence for body size being a confounding factor in activity studies. In an effort to address this potential problem, three measures of body size are used in activity studies: a clavicular index, a humeral index, and articular surface area. The clavicular index is usually calculated by dividing the antero-posterior midshaft diameter by the supero-inferior midshaft diameter. The humeral index is calculated either by dividing the antero-posterior midshaft diameter by the medio-lateral midshaft diameter or by using some combination of metaphyseal or epiphyseal measurements (Weiss, 2003). Midshaft measurements are not the ideal index to use because the midshaft remodels more readily than other parts of the humerus (Ruff, et al., 1991). However, components of the midshaft were the most frequently available for measurement. Clavicular and humeral indices are commonly used in activity studies as measures of body size (Weiss, 2004; 2007).

The current project, however, focuses on horse riding, which is thought to primarily affect the lower limb; therefore, a measure of body size derived from lower limb bones was more appropriate. Femoral head diameter was found to be a useful measure of body size in paleoanthropological studies (Lieberman, et al., 2001). This association with body size is the reason femoral head diameter can be used to estimate sex, because females tend to have less robust skeletons, and thus smaller body size, than males. Table 4 gives the significance of the correlation between femoral head diameter and each of the individual measurements used in to estimate body size in previous studies. This study found no correlation between activity and articular surface area, so this measure would not be confounded by activity.

Table 4. Correlations of average femoral head diameter with traditional measures of body size. Significance of less than 0.05 are in bold.

	Corr. Coeffic.	Sig.
Right clavicular antero-posterior diameter	0.093	0.078
Left clavicular antero-posterior diameter	0.424	**0.000**
Right clavicular supero-inferior diameter	0.431	**0.000**
Left clavicular supero-inferior diameter	-0.071	0.187
Right humeral antero-posterior diameter	0.18	**0.000**
Left humeral antero-posterior diameter	0.439	**0.000**
Right humeral medio-lateral diameter	0.496	**0.000**
Left humeral medio-lateral diameter	0.562	**0.000**
Right clavicular index	-0.041	0.446
Left clavicular index	0.016	0.774
Right humeral index	0.929	**0.000**
Left humeral index	0.231	**0.000**
average clavicular index	-0.03	0.570
average humeral index	0.823	**0.000**

Robusticity Scores

Horse riders must use multiple muscles; however, specific riding techniques stress the use of certain muscles over others (O'Connor, 1990). The specific muscles used by riders are often *assumed* in attempts to study horse riding (Angel, et al., 1987; Garofalo, 2004; Molleson & Blondiaux, 1994). There have been studies of upper limb muscle use by riders (Terada, 2000; Terada, et al., 2004); however, no study has demonstrated which lower limb muscles riders *actually* use. Consequently, this study examined the entheses of muscles involved in performing every possible action the lower limb (Table 5). These included both fibrocartilaginous and fibrous entheses.

The most commonly used method for scoring enthesial robusticity is the method proposed by Hawkey and Merbs (1995). This method provides scoring systems for osteophytes, bone resorption, and bone deposition at muscle attachment sites. Though not explicitly mentioned in the article, their descriptions of the scoring systems used both fibrous and fibrocartilaginous entheses. Later studies produced other scoring methods based on the original grading system developed by Hawkey and Merbs. Some of these methods combine elements (Galtés, et al., 2006), while others use only robusticity (Cardoso

Table 5. Summary of entheses examined in the current study, which muscles attach to them, the actions of those muscles, and what type of entheses each is.

Enthesis Name	Muscles Involved	Actions	Type of Enthesis
Greater Trochanter	Vastus lateralis, Gluteus medius, Gluteus minimus, Piriformis	Abducts, extends & rotates thigh	Fibrocartilaginous
Trochanteric Fossa	Obturator externus, Obturator internus, Superior gemellus	Adducts & laterally rotates thigh	Fibrocartilaginous
Trochanteric Crest	Quadratus femoris	Adducts & laterally rotates thigh	Fibrocartilaginous
Lesser Trochanter	Iliopsoas	Flexes thigh, hip, and trunk	Fibrocartilaginous
Gluteal Tuberosity	Gluteus maximus	Extends thigh, hip, and trunk	Fibrous
Pectinate Line	Pectineus, Adductor brevis	Adducts & flexes thigh	Fibrous
Adductor Tubercle	Adductor magnus	Adducts, flexes, and extends thigh	Fibrous

& Henderson, 2010), add a robusticity grade (Garofalo, 2004), or distinguished between healthy versus pathological changes (Villote, et al., 2010).

Most studies employ the Hawkey and Merbs (1995) system,in whole or part. It has been found to have no significant inter- or intraobserver error (Cardoso & Henderson, 2010). The current study will also use this system with the most common modification: two additional grades for fibrocartilaginous entheses: Grade 0 for gracile or absent and Grade 4 for strong, well developed entheses that have begun to breakdown. The original system had such grades for the fibrous, but not fibrocartilaginous, entheses. The modification used here produces two 5 grade systems, one for fibrous entheses and one for fibrocartilaginous entheses.

Chapter Summary

It is often assumed that horse riding has the same impact on the skeleton regardless of the style of riding used. However, different styles use different muscles and should, hypothetically, result in the development of different activity markers on the skeleton. Arikara (N=67) and British (N=29) samples are used here in addition to the male Mongolian samples (N=47) to test whether there are universal markers of horse riding. These were compared to genetically and culturally similar non-riding samples (N=25, 24, 25, respectively) to determine if each style produced the same or different entheses. To test whether the social organization of horse riding can be indicative of its symbolic meaning, the associated female samples for the British and Mongolian samples were used. When traditional skeletal elements used for estimating age were not available, a newly developed method using the linea aspera was used to estimate the age of individuals. Body size was estimated using femoral head diameter. A modified Hawkey & Merbs (1995) scoring method was used to score fibrocartilaginous and fibrous entheses separately. Both male and female Mongolian samples will be used to test the relationship between activity and social dynamics.

Chapter 5

Results

Evaluation of skeletal indicators of physical activity can serve as a proxy for the study of social dynamics in a society. Activity impacts biology and is itself impacted by societal dynamics; it lies at the junction of the social and the biological realms. Consequently, the study of activity can provide a means for developing a perspective on how social dynamics and social structure impact the lives of individuals. Physical anthropology, which also straddles these realms, is ideally suited to studying this dynamic. This is particularly true in the study of past societies in which the means to directly identify the specific individuals who performed a given activity are inherently limited and most attempts to do so must rely on indirect evidence, such as grave goods. As this evidence is open to manipulation by other members of a society, it may not always provide an accurate record of the activity an individual performed in life.

Horse riding is a highly symbolic activity among nomadic pastoralists. It figures prominently in constructions of identity and power relations in these societies. As such, identifying horse riders within nomadic pastoralist societies can offer new insight into the social dynamics of these peoples; however, this is easier said than done. The translation of physical activity into observable and quantifiable skeletal alterations involves complex biological processes that are difficult to analyze and interpret.

Data Processing

As a result of differential preservation, both right and left femora were not always available for analysis. Although some studies have analyzed only one side, this poses potential problems when activities involve handedness or produce bony manifestations that are otherwise asymmetrical (Ruff, et al., 1994; Trinkaus, et al., 1994). To determine if asymmetry was a factor, a Wilcoxon signed rank test was performed on all the study samples collectively. This test was used instead of a paired samples t-test because the data were nonparametric ordinal values and did not meet the assumptions of a t-test. There were no differences expected between right and left femora, therefore a Wilcoxon signed rank test was used.. A sign test would have been more appropriate if side differences were expected to exist and were predicted to be stochastic.

Table 6. Results of Wilcoxon signed rank tests for asymmetry in each enthesis

Enthesis	N	Sig.
Greater Trochanter	176	**0.015**
Trochanteric Fossa	186	0.702
Trochanteric Crest	150	0.612
Lesser Trochanter	183	**0.022**
Gluteal Tuberosity	194	0.892
Pectinate Line	209	0.088
Adductor Tubercle	150	**0.035**

Three entheses were found to be significantly asymmetrical: greater trochanter, lesser trochanter, and adductor tubercle (Table 6). This result indicates that side is a factor, i.e., right and left femora are not interchangeable in the analysis.

Intraobserver error was also evaluated using Wilcoxon signed rank tests. The data used to calculate intraobserver error were derived from a sample of 47 individuals in the Hamann-Todd collection. This population was used because it was available for two scoring sessions separated by a period of three years. Each enthesis was scored for both the right and left femur, when available, for all 47 individuals. Though the Wilcoxon signed rank tests show that there was significant intraobserver error, sign tests show that this error

Table 7. Results of Wilcoxon signed rank tests for intraobserver error for each side and the higher robusticity score for each enthesis.

Enthesis	Right	Left	Higher
Greater Trochanter	**0.006**	**0.012**	0.070
Trochanteric Fossa	0.850	0.850	0.813
Trochanteric Crest	0.655	0.317	1.000
Lesser Trochanter	0.181	0.423	0.181
Gluteal Tuberosity	0.394	0.405	0.216
Pectinate Line	0.083	**0.046**	0.071
Adductor Tubercle	**0.032**	0.367	0.216

was random in nature (Table 7). The second scoring was usually a grade higher or lower than the original assessment. When considering only the higher robusticity grade for each enthesis, no significant intraobserver error was found. Consequently, when both sides were available for analysis, this project uses the higher of the two scores. When only one side was available, the enthesis score for that side was used. Use of this approach in the analysis of activity allowed for simultaneously maximizing the number of individuals available for analysis while minimizing or eliminating significant intraobserver error in enthesis scoring.

Statistical analysis of ordinal data, such as enthesial robusticity scores, requires an additional consideration. Many multivariate statistical tests assume a normal distribution of data. The most common method for testing normality of any variable is the Shapiro-Wilk measure of skew. A significant value means that, for the variable tested, the data are skewed from normality in that sample. For small samples, this statistical test tends not to be significant, as most small samples appear to approximate a normal distribution. As shown in Table 8, nearly all variables have significant skew in each study sample and in all samples collectively. This result precludes the use of any statistical test that requires data to be normally distributed.

Hypothesis Testing

Most of the hypotheses in this project were tested using two statistical methods: partial correlations and logistic regressions. Partial correlations provide a means to determine the correlation between two variables while controlling for confounding variables. Figure 3 provides an illustration of the information gained from partial correlations. This method does not require any sample data to be either interval scale or

Table 8. Measures of skew for each enthesis in each sample and in the total study sample.

Enthesis		Arikara riders	Arikara nonrider	British riders	British nonrider	Xiongnu males	Mongol males	Xiongnu females	Mongol females	Total sample
Greater Trochanter	W	0.776	0.744	0.842	0.605	0.914	0.939	0.805	0.791	0.869
	Sig.	**0.000**	**0.000**	**0.002**	**0.000**	0.086	0.487	**0.008**	**0.004**	**0.000**
Trochanteric Fossa	W	0.505	0.630	0.902	0.859	0.851	0.800	0.649	0.297	0.874
	Sig.	**0.000**	**0.000**	**0.024**	**0.005**	**0.007**	**0.009**	**0.000**	**0.000**	**0.000**
Trochanteric Crest	W	0.619	0.634	0.621	0.412	0.733	0.465	0.628	0.646	0.670
	Sig.	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Lesser Trochanter	W	0.800	0.848	0.847	0.677	0.844	0.894	0.851	0.810	0.884
	Sig.	**0.000**	**0.002**	**0.002**	**0.000**	**0.005**	0.134	**0.029**	**0.007**	**0.000**
Gluteal Tuberosity	W	0.903	0.917	0.877	0.770	0.796	0.729	0.856	0.882	0.896
	Sig.	**0.000**	**0.045**	**0.007**	**0.000**	**0.001**	**0.002**	**0.034**	0.061	**0.000**
Pectinate Line	W	0.723	0.721	0.735	0.746	0.862	0.768	0.709	0.652	0.783
	Sig.	**0.000**	**0.000**	**0.000**	**0.000**	**0.011**	**0.004**	**0.001**	**0.000**	**0.000**
Adductor Tubercle	W	0.850	0.868	0.867	0.883	0.845	0.873	0.888	0.801	0.884
	Sig.	**0.000**	**0.004**	**0.005**	**0.014**	**0.006**	0.072	0.091	**0.005**	**0.000**

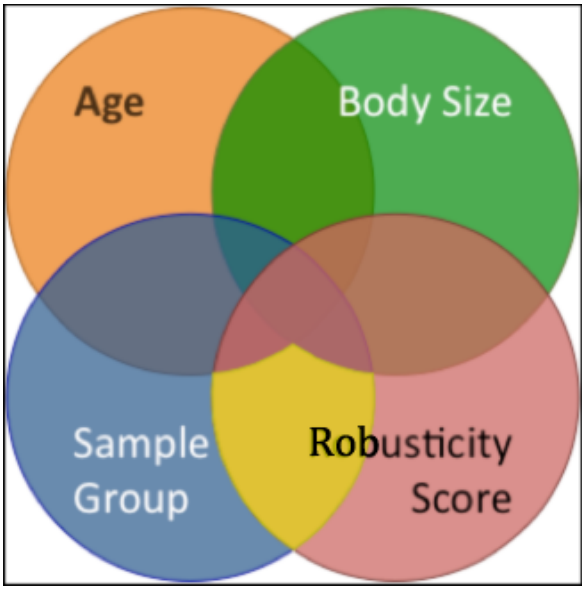


Figure 3. Illustration of the information gained from partial correlations. By removing the contributions of both age and body size, the amount of variation in robusticity scores associated with differences between sample groups for a particular enthesis (shown in yellow) can be calculated.

normally distributed, and is therefore useful for the ordinal data used in this project. This method was used to determine the degree to which enthesis robusticity could be related to age, body size, or horse riding.

Logistic regression was employed in this analysis in much the same way as discriminant function analysis is often used, as both an exploratory technique and a predictive method. Both logistic regression and discriminant function analyses can be used in an exploratory manner to determine which variables are most useful for discriminating between the particular groups under study. Once the relevant variables are determined, an equation can be created to assign group membership to an individual, thereby allowing these methods to also be predictive. A relevant difference between these two analytical methods is that discriminant function analysis fits a linear regression to the data, making it able to accommodate multiple outcomes, while logistic regression fits an S-curve to the data, allowing it to only accommodate a binary or dichotomous outcome. Logistic regression was used in this study, instead of the more powerful discriminant function analysis, because most of the assumptions required for discriminant function analysis were not met by the study samples and the outcome variable was dichotomous.

The significant skew observed in nearly all the study data is prohibited in discriminant function analysis.

SPSS does not contain an algorithm to perform a forward stepwise logistic regression analysis, as it does for discriminant function analysis. Therefore, in order to emulate this method, all seven activity-related entheses were included in the first regression for each set of samples. Then, the factor with the smallest coefficient and the highest significance value was removed from the next iteration. This method allowed for the factor that contributed the least to the model to be removed. The result was seven models ranging from seven factors to one factor, with varying percentages of sensitivity, specificity, and overall accuracy. These were calculated by SPSS when performing the logistic regressions. Sensitivity refers to the likelihood of obtaining a true negative versus a false positive. In most of the analyses presented here, it refers to the likelihood of accurately identifying a non-rider as a non-rider. Specificity is the opposite, referring to the likelihood of getting a true positive versus a false negative, or identifying a rider as a rider in the ensuing analyses. The overall accuracy is simply the percentage of riders and non-riders that were correctly classified using a particular model. Logistic regression analysis uses the maximum likelihood estimation technique to determine coefficients. This technique tends to emphasize specificity over sensitivity. As a result of this artifact, high specificity can skew the overall accuracy of a model. Therefore, all accuracy measures need to be examined to determine which models best describe the enthesial suites for identifying horse riders.

Principle component analysis (PCA) is a third method used to determine which variables are most relevant for discriminating between groups. The goal of PCA is to create aggregated components of variables that are more discriminatory than any single variable. This was attempted with the study data. However, the algorithms used in SPSS for PCA use all variables provided and does not remove variables with no predictive value. The PCA result may then create component variables that are less discriminatory than any single variable. This phenomenon was seen with the study data. Furthermore, PCA requires that no variables covary. The goal of this study is to identify variables that covary with an activity. The result of this statistical foray was that PCA was not used in these analyses. The testing of each hypothesis will be discussed separately, though some may share the same statistical information.

Hypothesis 1a: Enthesial robusticity can be used to separate horse riding and non-horse-riding groups.

To test this hypothesis all horse riders, regardless of riding style, were compared to all non-riders. This comparison tests if there is a "universal" suite of entheses to identify horse riders. Partial correlations were used to determine if there was a difference between riders and non-riders for any single enthesis. Logistic regressions were used to determine if these entheses, or any combination of entheses would be useful for discriminating between riders and non-riders. There has been some debate about whether or not saddle use would affect the development of entheses. Therefore, saddle rider samples (British and Mongolian riders) were compared with their respective non-rider samples to determine if different entheses would become more robust as a result of saddle use versus those of horse riding in general. This comparison would be a further test of the "universality" of horse riding markers.

Table 9 displays the results of partial correlations for each enthesis between the combined riding and combined non-riding samples. As the results show, age and body size did significantly correlate with some entheses. However, even when controlling for age and body size, two entheses still had significant correlations with horse riding: the gluteal tuberosity and the adductor tubercle. The gluteal tuberosity exhibited a weak-to-moderate correlation while the adductor tubercle exhibited a weak correlation. Horse riding only accounted for 7.5% of the variation in gluteal tuberosity robusticity and 5.3% of the adductor tubercle robusticity. Given the size of the samples and that these are partial correlations, these results, though not strong, are enough to demonstrate a difference between horse riders and non-riders. The significance of these two entheses is not surprising. These are two of the most commonly used "markers" of horse riding (Angel, et al., 1987; Molleson & Blondiaux, 1994).

There has been some discussion of whether these markers are the result of using a saddle. Therefore, the combined saddle riding samples (the British and Mongolian rider samples) were tested against their respective non-riding samples. As Table 9 shows, the gluteal tuberosity was still significantly more robust in riders than in non-riders. In fact, horse riding accounts for 10.3% of the variation in the gluteal tuberosity in these samples. However, the adductor tubercle robusticity was no longer significant. This suggests that the adductor tubercle is not used as much in saddle riding.

One of the functions often ascribed to a saddle is to help the rider maintain his or her seat on the horse, thereby reducing use of the adductor muscles to hold on while riding. Additionally, certain styles of riding, specifically the British style tested here, instruct against using the adductors to "grip" the horse (O'Connor, 1990).

Table 9. Partial correlation results for aggregated riding and non-riding samples. Significance of R^2 values below the 0.05 level are in bold.

		Age			Body Size			Horse Riding		
Samples	**Enthesis**	**r**	**r^2**	**Sig.**	**r**	**r^2**	**Sig.**	**r**	**r^2**	**Sig.**
Horse riders vs. nonriders	Greater Trochanter	0.238	0.057	**0.002**	0.118	0.014	0.126	0.017	0.000	0.828
	Trochanteric Fossa	0.363	0.132	**0.000**	0.129	0.017	0.094	0.081	0.007	0.295
	Trochanteric Crest	0.042	0.002	0.601	0.026	0.001	0.741	0.128	0.016	0.109
	Lesser Trochanter	0.106	0.011	0.168	0.171	0.029	**0.026**	0.087	0.008	0.261
	Gluteal Tuberosity	0.131	0.017	0.095	0.188	0.035	**0.016**	0.273	0.075	**0.000**
	Pectinate Line	0.172	0.030	**0.023**	0.057	0.003	0.456	0.086	0.007	0.258
	Adductor Tubercle	0.027	0.001	0.741	0.035	0.001	0.669	0.231	0.053	**0.004**
Saddle riders vs. nonriders	Greater Trochanter	0.267	0.071	**0.006**	0.097	0.009	0.328	0.028	0.001	0.778
	Trochanteric Fossa	0.316	0.100	**0.001**	0.126	0.016	0.201	0.168	0.028	0.089
	Trochanteric Crest	0.010	0.000	0.925	0.050	0.003	0.634	0.120	0.014	0.249
	Lesser Trochanter	0.063	0.004	0.528	0.218	0.048	**0.026**	0.026	0.001	0.794
	Gluteal Tuberosity	0.051	0.003	0.604	0.214	0.046	**0.028**	0.321	0.103	**0.001**
	Pectinate Line	0.144	0.021	0.138	0.054	0.003	0.578	0.001	0.000	0.995
	Adductor Tubercle	0.004	0.000	0.973	0.068	0.005	0.516	0.160	0.026	0.124

Table 10 shows the results of the forward stepwise logistic regression analysis. This table exhibits the order in which variables were removed from the model. Most of the coefficients are listed as not significant. This result is likely due to the use of Wald's test to determine significance, which is better suited to large samples (Agresti, 1996). Since only small samples were used here, Wald's test may not provide an accurate assessment of the coefficients' significance.

The gluteal tuberosity was the final factor in both analyses. This result echoed those of the partial correlations. The adductor tubercle, however, was removed in the three-factor model for all horse riders. This result was surprising because this enthesis was significant for horse riding in the partial correlations. Each set of models removed entheses in a different order. Since the only difference between the samples used in these analyses was that one included bareback riders and the other did not, such a result suggests that bareback riding is sufficiently different from saddle riding so as to result in the development of completely different entheses.

Table 10 provides the accuracy measures for each model. The overall accuracy of the general horse riding models suggests that these models are better predictors than the saddle riders-only models; however, this interpretion is misleading. Comparison of the models' sensitivities show that the general horse riding model cannot discriminate well between riders and non-riders. This finding suggests that horse riders cannot be identified by a universal or cross-cultural suite of entheses.

Table 10. Logistic regression results for aggregated riding and non-riding samples. X^2 "goodness of fit" results significant at the 0.05 level are in bold.

		7 Factors		6 Factors		5 Factors		4 Factors		3 Factors		2 Factors		1 Factor	
		Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Horse riders vs. nonriders	Greater Trochanter	-0.07	0.803												
	Trochanteric Fossa	0.18	0.409	0.18	0.420	0.18	0.418								
	Trochanteric Crest	0.52	0.137	0.51	0.140	0.51	0.136	0.55	0.105	0.58	0.089	0.51	0.126		
	Lesser Trochanter	0.34	0.180	0.32	0.180	0.32	0.165	0.31	0.171	0.36	0.108				
	Gluteal Tuberosity	0.30	0.064	0.30	0.065	0.31	0.061	0.33	0.043	0.36	0.157	0.39	0.014	0.39	0.010
	Pectinate Line	0.12	0.686	0.12	0.696										
	Adductor Tubercle	0.18	0.198	0.18	0.191	0.18	0.181	0.18	0.185						
	Goodness of Fit		0.073		**0.048**		**0.030**		**0.022**		**0.023**		**0.035**		**0.036**
	Sensitivity	19.1%		17.0%		17.0%		17.0%		14.9%		6.4%		2.0%	
	Specificity	92.9%		92.0%		92.0%		92.9%		95.6%		94.7%		99.2%	
	Accuracy	71.1%		69.8%		69.8%		70.6%		71.9%		68.8%		72.3%	
Saddle riders vs. nonriders	Greater Trochanter	-0.14	0.654	-0.14	0.655	-0.04	0.880								
	Trochanteric Fossa	0.36	0.133	0.36	0.134	0.17	0.423	0.20	0.340	0.20	0.336	0.21	0.312		
	Trochanteric Crest	0.17	0.710	0.16	0.718										
	Lesser Trochanter	0.15	0.591	0.14	0.597	0.09	0.724	0.05	0.828						
	Gluteal Tuberosity	0.71	0.003	0.70	0.002	0.66	0.002	0.66	0.002	0.67	0.001	0.55	0.004	0.59	0.001
	Pectinate Line	-0.59	0.166	-0.59	0.166	-0.52	0.162	-0.56	0.125	-0.55	0.363				
	Adductor Tubercle	-0.02	0.924												
	Goodness of Fit		**0.032**		**0.019**		**0.034**		**0.015**		**0.008**		**0.010**		**0.007**
	Sensitivity	70.2%		70.2%		63.3%		61.2%		61.2%		61.2%		55.1%	
	Specificity	64.6%		67.4%		71.4%		71.9%		70.2%		70.2%		75.4%	
	Accuracy	67.4%		67.4%		67.6%		67.0%		66.0%		66.0%		66.4%	

The saddle-riding model has better sensitivity with similar overall accuracy, and is better able to distinguish between riders and non-riders. Yet, all measures of accuracy clustered around 66%. Therefore, misclassification was likely to occur one-third of the time with any of these models. These results suggest one of two possibilities: (1) Horse riders cannot be identified using entheses, or (2) Culturally-specific suites of entheses are necessary even when considering technologically similar riding styles.

Hypothesis 1b: Regular horse riding in different riding styles results in increased robusticity of different entheses.

It is assumed that different lifeways result in the development of robusticity in different entheses, and that this influences the entheses that can be used to identify the horse riders of a particular society. To test whether different riding styles affect different entheses, the rider samples from each riding style were compared to their respective non-riders. This comparison allows determination of whether culturally-specific riding styles produce culturally-specific suites of entheses that can be used to identify horse riders in any particular society. Partial correlations were used to determine if there were any differences between each set of riders and non-riders for any single enthesis. Logistic regressions were used to determine if these entheses, or combination of entheses, would be useful for discriminating between riders and non-riders in each society.

Table 11 displays the results of the partial correlations for each enthesis for each riding style. Again, several entheses had significant correlations with age or body size but these were not consistent across groups. If either age or body size were a primary source of variation in enthesial robusticity, it should be correlated in all groups. The Arikara samples exhibited no significant differences between riders and non-riders for any enthesis.

Table 11. Partial correlation results for each riding style. Significance of R^2 values below the 0.05 level are in bold.

		Age			Body Size			Horse Riding		
Samples	**Enthesis**	**r**	**r^2**	**Sig.**	**r**	**r^2**	**Sig.**	**r**	**r^2**	**Sig.**
Arikara riders vs. nonriders	Greater Trochanter	0.229	0.052	**0.031**	0.088	0.008	0.414	-0.099	0.010	0.355
	Trochanteric Fossa	0.388	0.151	**0.000**	0.052	0.003	0.633	-0.009	0.000	0.933
	Trochanteric Crest	0.070	0.005	0.519	-0.009	0.000	0.934	0.004	0.000	0.974
	Lesser Trochanter	0.238	0.057	**0.025**	-0.061	0.004	0.573	-0.002	0.000	0.984
	Gluteal Tuberosity	0.262	0.069	**0.020**	0.252	0.064	**0.025**	-0.047	0.002	0.683
	Pectinate Line	0.287	0.082	**0.000**	0.096	0.009	0.366	-0.044	0.002	0.682
	Adductor Tubercle	0.123	0.015	0.280	0.108	0.012	0.341	0.115	0.013	0.311
British riders vs. nonriders	Greater Trochanter	0.349	0.122	**0.013**	0.032	0.001	0.825	0.034	0.001	0.817
	Trochanteric Fossa	0.233	0.054	0.107	0.143	0.020	0.326	0.181	0.033	0.214
	Trochanteric Crest	0.044	0.002	0.775	0.037	0.001	0.808	0.221	0.049	0.144
	Lesser Trochanter	0.280	0.078	**0.049**	0.287	0.082	**0.044**	0.170	0.029	0.237
	Gluteal Tuberosity	0.226	0.051	0.115	0.241	0.058	0.092	0.342	0.117	**0.015**
	Pectinate Line	0.078	0.006	0.590	0.002	0.000	0.989	0.183	0.033	0.203
	Adductor Tubercle	-0.054	0.003	0.730	0.060	0.004	0.698	0.217	0.047	0.157
Mongolian riders vs. nonriders	Greater Trochanter	0.173	0.030	0.220	0.148	0.022	0.294	-0.036	0.001	0.801
	Trochanteric Fossa	0.397	0.158	**0.003**	0.146	0.021	0.295	0.210	0.044	0.132
	Trochanteric Crest	0.036	0.001	0.809	0.108	0.012	0.472	0.018	0.000	0.906
	Lesser Trochanter	-0.160	0.026	0.258	0.163	0.027	0.249	-0.165	0.027	0.242
	Gluteal Tuberosity	0.258	0.067	0.062	0.245	0.060	0.077	0.383	0.147	**0.005**
	Pectinate Line	0.285	0.081	**0.033**	0.201	0.040	0.137	-0.139	0.019	0.305
	Adductor Tubercle	0.186	0.035	0.205	0.118	0.014	0.426	0.127	0.016	0.389

This finding suggests that bareback riding, as compared to day-to-day living among the Arikara, did not result in increased robusticity of any of the entheses analyzed. Interestingly, nearly all the correlations were negative. This may be hypothetically due to bareback riding in this society resulting in less muscle use than would otherwise be expected. The only significant riding-related robusticity difference observed in the British samples was the gluteal tuberosity, in which riding contributed 11.7% to the variation in robusticity. The Mongolian samples produced a similar finding, though with 14.7% of the variation being attributed to riding. Given that the gluteal tuberosity was significantly larger when testing both saddle-using groups together, this was not surprising.

Table 12 shows the results of the forward stepwise logistic regression analysis for each riding style. This table exhibits the order in which variables were removed from the model. Each riding style removed variables in a different order. Yet, there were many similarities between these various styles. The most obvious of these is that all three styles have the same variables in their two-factor model. The overall rider-non-rider partial correlations performed in testing the first hypothesis show the gluteal tuberosity and adductor tubercle to differ significantly for all riders compared to non-riders. Therefore, it should not be surprising that these are the two variables in all the two-variable models. Yet, it is worth noting that in the Arikara regressions, the gluteal tuberosity has a negative correlation coefficient implying, as the partial correlations did, that riders actually had less robust gluteal tuberosities than non-riders in this society. The trochanteric fossa and the pectinate line were also seen in later iterations for more than one comparison. This result suggests that there are some similarities in muscle use between styles.

Table 12. Logistic regression results for riding style. Chi-square "goodness of fit" results significant at the 0.05 level are in bold.

		7 Factors		6 Factors		5 Factors		4 Factors		3 Factors		2 Factors		1 Factor	
		Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Arikara riders vs. nonriders	Greater Trochanter	-0.08	0.842	-0.08	0.826										
	Trochanteric Fossa	-0.13	0.731	-0.11	0.762	-0.11	0.756								
	Trochanteric Crest	-0.03	0.937												
	Lesser Trochanter	0.12	0.737	0.13	0.720	0.11	0.743	0.07	0.835						
	Gluteal Tuberosity	-0.25	0.272	-0.26	0.253	-0.26	0.237	-0.28	0.213	-0.28	0.209	-0.27	0.228		
	Pectinate Line	-0.21	0.635	-0.21	0.625	-0.22	0.603	-0.21	0.622	-0.21	0.630				
	Adductor Tubercle	0.27	0.149	0.28	0.134	0.28	0.130	0.30	0.106	0.30	0.104	0.30	0.100	0.27	0.130
	Goodness of Fit		0.662		0.521		0.419		0.270		0.184		0.121		0.121
	Sensitivity	16.0%		16.0%		16.0%		16.0%		16.0%		16.0%		0.0%	
	Specificity	98.4%		96.9%		100.0%		98.5%		97.0%		97.0%		97.0%	
	Accuracy	75.3%		74.4%		76.7%		76.1%		75.0%		75.0%		70.7%	
British riders vs. nonriders	Greater Trochanter	-0.11	0.855												
	Trochanteric Fossa	0.64	0.236	0.61	0.233	0.62	0.224	0.62	0.228	0.36	0.399				
	Trochanteric Crest	0.81	0.476	0.87	0.424	0.80	0.435	0.78	0.433						
	Lesser Trochanter	0.12	0.845	0.11	0.851										
	Gluteal Tuberosity	1.17	0.072	1.18	0.066	1.21	0.052	1.31	0.029	0.96	0.057	1.13	0.023	1.14	0.021
	Pectinate Line	0.46	0.598	0.46	0.601	0.48	0.573								
	Adductor Tubercle	0.46	0.291	0.48	0.247	0.50	0.220	0.47	0.242	0.47	0.159	0.40	0.218		
	Goodness of Fit		**0.008**		**0.004**		**0.002**		**0.001**		**0.004**		**0.002**		**0.002**
	Sensitivity	86.4%		86.4%		86.4%		86.4%		83.3%		79.2%		75.0%	
	Specificity	75.0%		75.0%		75.0%		75.0%		74.1%		75.0%		75.0%	
	Accuracy	80.4%		80.4%		80.4%		80.4%		78.4%		76.9%		75.0%	
Mongolian riders vs. nonriders	Greater Trochanter	-0.39	0.476	0.09	0.849										
	Trochanteric Fossa	0.16	0.675	0.12	0.707	0.15	0.597	0.15	0.605						
	Trochanteric Crest	0.18	0.815												
	Lesser Trochanter	0.34	0.520	-0.16	0.697	-0.17	0.598								
	Gluteal Tuberosity	1.48	0.005	1.05	0.007	1.04	0.006	1.07	0.005	0.90	0.005	0.85	0.007	0.79	0.008
	Pectinate Line	-0.64	0.350	-0.81	0.157	-0.87	0.113	-0.92	0.091	-0.46	0.340				
	Adductor Tubercle	0.20	0.499	0.30	0.242	0.33	0.211	0.29	0.240	0.32	0.174	0.35	0.137		
	Goodness of Fit		**0.024**		**0.018**		**0.008**		**0.004**		**0.009**		**0.006**		**0.008**
	Sensitivity	84.0%		68.0%		68.0%		68.0%		68.0%		80.0%		64.0%	
	Specificity	79.2%		86.2%		86.7%		83.3%		87.9%		78.8%		78.8%	
	Accuracy	81.6%		77.8%		78.2%		76.4%		79.3%		79.3%		72.4%	

In Table 12, the accuracy measures are given for each riding style model. As mentioned previously, a forward stepwise method tends to emphasize increased specificity with little regard to sensitivity, consequently, examining the sensitivity of these models may be a better gauge of how useful the model is compared to the overall accuracy. As Table 12 shows, the Arikara models have very low sensitivity. The low sensitivity but high specificity means that though most riders would be correctly classified with any of these models, most nonriders would be misclassified as riders. This problem renders these models essentially useless, implying that riders cannot be identified using these entheses in this population. Both the British and Mongolian sets of models had higher percentages for both sensitivity and overall accuracy than the Arikara set. These percentages combined with high specificity imply that riders can be identified in these two populations. In the British set of models, there is no change in any measure of accuracy until the three-factor model, when these measures begin to fluctuate. This suggests that the first three variables removed from these models (greater trochanter, lesser trochanter, and pectinate line) had no predictive value for identifying horse riders in this society. The pectinate line remains in the three-factor model for both the Arikara and Mongolian sets, exhibiting again that there are important differences between riding styles that impact the development of enthesial robusticity.

Results from both the partial correlations and logistic regression analyses between riding and nonriding samples strongly suggests that there are inter-cultural differences in enthesial markers of horse riding. When controlling for age and body size, only the British and Mongolian samples had significant results and only for the gluteal tuberosity. The differing order of variable removal and differing measures of accuracy for each set of logistic regression models also strongly implies that differences in horse riding style can impact the development of entheses. These findings suggest that evaluation of the role of horse riding in a specific culture must employ culturally-specific suites of markers to identify riders.

Hypothesis 2: The social organization of horse riding in 17th- to 19th-century Britain mirrors the status system of the time period.

To test the hypothesis that there is a direct relationship between horse riding and social status, all the British subsamples were compared to each other. It was expected that the Farringdon samples (referred to as "City" samples) would be non-riders, as they represented a low-status population that could not afford to keep horses. By comparison, the Chelsea Old Church sample (referred to as "Country" samples) would be riders, as they represented a high-status country-dwelling population that would have ridden and used horses frequently. Males and females were expected to be similar to each other within each status group and to be different from their counterparts in the opposite status group.

In order to test hypothesis 2, the "best" equation for identifying British horse riders was selected based on several considerations, such as degree of specificity, sensitivity and overall accuracy. In examining the models for identifying British riders (see Table 12), the first four models all share the same accuracy measures. However, since not all entheses could be recorded for each individual, it was decided that the model that included the least number of factors and that also did not compromise accuracy would be considered "best." In the case of the British riding samples, this is the 4-factor model. The equation is given below:

$$p=0.071[age]-0.526[size]+1.313[gluteal\ tuberosity]+0.469[adductor\ tubercle]+0.618[trochanteric\ fossa] + 0.782[trochanteric\ crest] + 17.782$$

This equation was developed using two samples with different age and body size profiles. In an effort to ensure that the equation tests only group differences in enthesial robusticity, female ages and body sizes were adjusted to match their male counterparts.

Since this is a logistic regression equation, the result is the logged odds and equals the probability that an individual is a rider divided by the probability that the individual is not a rider. To transform this calculation into the simple probability that an individual is a rider, the following equation is used: Odds = $1/(1-e^{-p})$.

Table 13. Number and percentage of riders and non-riders in each British subsample as classified by logistic regression.

Subsample	# of Riders	#of Non-riders	% of Riders
City Females	9	16	36.00
City Males	4	16	20.00
Country Females	12	8	60.00
Country Males	15	6	71.40

The cut-off value for deciding if an individual is a rider is 0.5. Therefore, if an individual's odds are equal or less than 0.5, they would be classified as a non-rider. If greater than 0.5, they would be classified as a rider. The number and percentage of rider and non-rider males and females for both the City and Country samples are given in Table 13. As expected, the percentage of riders in the City group is less than in the Country group. In addition, females appear to ride as much, or as little, as their associated male samples. The higher percentage of female "riders" in the City sample may be due to a generally more demanding lifestyle, which may have resulted in more robust entheses even in the absence of horse riding. It is also

Table 14. Results of T-test in comparison of the calculated probability of being a rider between British subsamples.

Samples Compared	t	df	Sig.
City Females vs. Males	0.546	43	0.588
Country Females vs. Males	1.239	39	0.224
City vs. Country Females	-1.604	43	0.116
City vs. Country Males	4.517	39	0.000

possible that these females assisted in transporting goods, a low status occupation that involved working and possibly riding horses. These results support hypothesis 2.

In order to test for statistical differences between the City and Country subsamples, Student T-tests were performed using the calculated probability of being rider for each individual. Results are given in Table 14. The only significant difference (p=0.05) was between City and Country males. The difference between City and Country females was near significant (ρ=0.116). There were no significant male-female differences in either status group. This result supports the hypothesis.

Table 15. Chi-square results comparing the frequency of riders to non-riders in each British subsamples.

Samples Compared	X^2	df	Sig.
City Females vs. Males	1.385	1	0.327
Country Females vs. Males	0.600	1	0.520
City vs. Country Females	2.571	1	0.140
City vs. Country Males	10.896	1	0.002

The logistic regression analysis was used to assign an individual to one of two predetermined groups, rider or non-rider. The calculated probability only applies to the reference group; it is the probability of being placed in one reference group over another. In this context, the t-test is not the most appropriate statisitical method to evaluate group differences; therefore, the numbers of riders and non-riders provided in Table 13 were subjected to a chi-square analysis. The results are given in Table 15. As before, the only significant difference was between City and Country males.

The results of the above analyses suggest that riding (or not riding) did not vary between the sexes in either status group, i.e., there was sexual equality in riding. Consequently, the logistic regression analyses are expected to demonstrate relatively low accuracy when used to classify males and females within each status group. In other words, if there are no significant differences between subsamples for these markers, the logistic

Table 16. Logistic regression results using British horse riding markers for examining differences between subsamples. Significant chi-square "goodness of fit" results at the 0.05 level are in bold.

	City vs. Country Males		City Males vs. Females		Country Males vs. Females		City vs. Country Females	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Gluteal Tuberosity	1.214	0.043	-0.178	0.749	0.343	0.415	0.083	0.871
Adductor Tubercle	0.496	0.229	0.355	0.358	0.557	0.144	0.106	0.817
Trochanteric Fossa	0.468	0.341	-0.199	0.649	1.064	0.022	-1.272	0.022
Trochanteric Crest	0.626	0.529	0.762	0.466	-0.456	0.598	1.569	0.172
Goodness of Fit		**0.013**		0.922		0.069		**0.038**
Sensitivity	85.0%		84.0%		75.0%		80.0%	
Specificity	71.4%		45.0%		61.9%		75.0%	
Accuracy	78.0%		66.7%		68.3%		77.8%	

regression should not be able to accurately classify individuals into one subsample or another. On the other hand, the logistic regression should be able to classify the males into their respective status groups, given the significant differences seen between these subsamples in previous analyses. The four entheses used to identify horse riders (trochanteric fossa, trochanteric crest, gluteal tuberosity, and adductor tubercle) were also used in the logistic regression analysis. The analysis controlled for variation in age and body size. The results are presented in Table 16.

As expected, the logistic regression analysis was unable to accurately separate males from females within each status group. Also as expected, the analysis was able to classify males into their respective status groups reasonably well. This was the most significant model. Surprisingly, the model separating City versus Country females model was significant at the $\rho = 0.05$ level. The previous analyses did not show a significant difference between these groups, nevertheless, this model was only slightly less accurate than the model separating City and Country males, and demonstrated a better balance between specificity and sensitivity. These results also support the hypothesis.

Hypothesis 3a: Females and males were both habitual horse riders in Mongolian societies.

Due to preservation issues with the Mongolian samples, many individuals did not have the necessary skeletal elements available to use traditional skeletal aging methods. As a result, a new method using the linea aspera was developed to estimate age (see previous chapter). Only one standard deviation was used to estimate ages using this method, therefore, it is likely that not all individuals' ages are accurately estimated (one standard deviation only encompasses 75% of the variation). However, using an admittedly small sample, this method was tested for accuracy and found to be more likely to overestimate rather than underestimate an individual's are. Over-aging results in overcorrection of enthesial robusticity scores, which would tend to decrease apparent variation and thereby make it more likely to identify an individual as a non-rider versus a rider.

To test this hypothesis, the "best" equation for identifying Mongolian horse riders was used. As discussed previously, due to problems with sample preservation, the model used for predicting who is riding horses in these societies is that which requires the least amount of factors while simultaneously providing the best compromise on measures of accuracy. Examination of the Mongolian riding models from Table 12 reveals that all are statistically significant (p=0.05). The 7-Factor model demonstrates the highest accuracy, as would be expected, given that it uses all available information. However, this model is not ideal, because it requires all seven entheses to be present, which would reduce the sample size available for analysis. Both the 3-Factor and 2-Factor models demonstrate the next highest accuracy. Though both have an overall accuracy of 79.3%, their sensitivity and specificity

Table 17. Number and percentage of riders and non-riders in each Mongolian subsample as classified by logistic regression.

Subsample	# of Riders	#of Non-riders	% of Riders
Xiongnu Females	15	4	78.90
Xiongnu Males	18	6	75.00
Mongol Females	10	4	71.40
Mongol Males	10	2	83.33

differ. The 3-Factor model has higher specificity (87.9%) but lower sensitivity (68.0%), which means that this model is more likely to classify individuals as riders, even if they are not. The 2-Factor model, by comparison, has nearly equal sensitivity and specificity, which means that it is equally good at accurately identifying riders and non-riders. Consequently, the 2-Factor model was deemed "best" for identifying Mongolian horse riders. The equation is given below:

p=-0.08[age]-0.013[size]+0.851[gluteal tuberosity]+0.345[adductor tubercle]+1.191

As this is logistic regression, the results are logged odds and the adjustment and cut-offs given for the British riding samples were used.

Using this equation and cut-off point, the number and percentage of rider and non-rider males and females for both the Xiongnu and Mongol samples is given in Table 17. The percentage of riders in the Xiongnu period is less than in the Mongol period. There also appears to be greater sexual inequality in riding during the Mongol period than during the Xiongnu period. However, it appears that both males and females rode horses in both societies.

In order to test for statistical differences between these subsamples, Student T-tests were performed using the calculated probability of being a rider for each individual, as in the analysis for Hypothesis 2. The results are given in Table 18. No significant differences were found between males and females in either society or within sexes over time, suggesting that females and males were both likely to be horse riders in either society.

Table 18. T-test results for comparing the calculated probability of being a rider between Mongolian subsamples.

Samples Compared	t	df	Sig.
Xiongnu Females vs. Males	-0.799	41	0.429
Mongol Females vs. Males	0.527	24	0.603
Xiongnu vs. Mongol Females	0.316	31	0.754
Xiongnu vs. Mongol Males	-0.358	34	0.723

As in the analysis of British

samples above, the classification numbers given in Table 17 were subjected to a chi-square analysis. The results are given in Table 19. There are no significant differences between subsamples.

Table 19. Chi-square results comparing the frequency of riders to non-riders in each Mongolian subsamples.

Samples Compared	X^2	df	Sig.
Xiongnu Females vs. Males	0.093	1	1.000
Mongol Females vs. Males	0.516	1	0.652
Xiongnu vs. Mongol Females	0.248	1	0.695
Xiongnu vs. Mongol Males	0.321	1	0.691

The results of the above analyses suggest there was sexual equality in riding for both societies; therefore, as before, it would be expected that the logistic regression analyses would demonstrate relatively low accuracy. The two entheses used to identify horse riders (gluteal tuberosity and adductor tubercle) were used in the logistic regression. The analysis controlled for age and size. The results are presented in Table 20.

The logistic regression analysis did have difficulty classifying males into either the Xiongnu or Mongol groups. It tended to classify nearly all the males as Xiongnu, as indicated by the high sensitivity but low specificity. This result was to be expected, as all males were thought to be horse riders, based on archaeological evidence, and were used collectively to generate the identifying equation. The logistic regressions were not much better for differentiating between males and females in the Xiongnu period. In this case, the equations tended to identify every individual as a male. The model for differentiating males

Table 20. Logistic regression results using Mongolian horse riding markers for examining differences between subsamples. Significant chi-square "goodness of fit" results at the 0.05 level are in bold.

	Xiongnu vs. Mongol Males		Xiongnu Males vs. Females		Mongol Males vs. Females		Xiongnu vs. Mongol Females	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Gluteal Tuberosity	-0.166	0.690	0.310	0.496	0.272	0.501	-1.495	0.024
Adductor Tubercle	0.467	0.233	0.323	0.220	-0.100	0.812	1.318	0.015
Goodness of Fit		0.438		0.573		0.660		**0.022**
Sensitivity	87.5%		36.8%		57.1%		78.9%	
Specificity	16.7%		83.3%		50.0%		64.3%	
Accuracy	63.9%		62.8%		53.8%		72.7%	

from females in the Mongol period was only slightly more accurate than flipping a coin to place individuals in one group or another. However, it does have a better balance between sensitivity and specificity than either the male-male comparison or the Xiongnu male-female comparison, as would be expected from the previous analyses. The only model with any significance was the model for classifying females into different time periods. The negative coefficient for the gluteal tuberosity (Table 20), the single best marker of horse riding, is the result of Xiongnu females being more likely to be riders than Mongol females. The Mongol sample would have been labeled as the "1" in the analysis, due to how SPSS codes the dichotomous variables for logistic regression. Therefore, the negative correlation means that the gluteal tuberosity robusticity increases as the sample is more likely to be classified as a Xiongnu female. These results are not surprising and support the previous analyses.

Hypothesis 3b: The social organization of horse riding over the life course differed between the Xiongnu and the Mongol period.

To test this hypothesis, graphs were generated to facilitate a visual examination of enthesial robusticity over the life span. Enthesial robusticity scores had to be adjusted by age and body size. This was done by subtracting an adjustment value from each enthesial robusticity score. For example, each individuals' gluteal tuberosity score was adjusted using the equation below:

$$\text{adjusted score} = [\text{raw score}] - (0.08[\text{age}]+0.013[\text{size}])$$

Age was included in the adjustment in an effort to ensure that only robusticity that results from horse riding is included in the curves. The correction factor assumes that the robusticity grades are equally spaced. The result is that in a Mongolian society, regardless of whether one is riding or not, there is an increase in robusticity scores of approximately a 0.08 every year.

Figure 4 shows the robusticity of the gluteal tuberosity over the adult life span, ages 15 through 65, for males and females in both the Xiongnu and Mongol societies. Third degree polynomial trendlines were fitted to each subsample of data; R^2 values are listed in Table 21. Although these R^2 values are low, the third degree polynomial was consistently the simplest trendline where the R^2 value began to plateau.

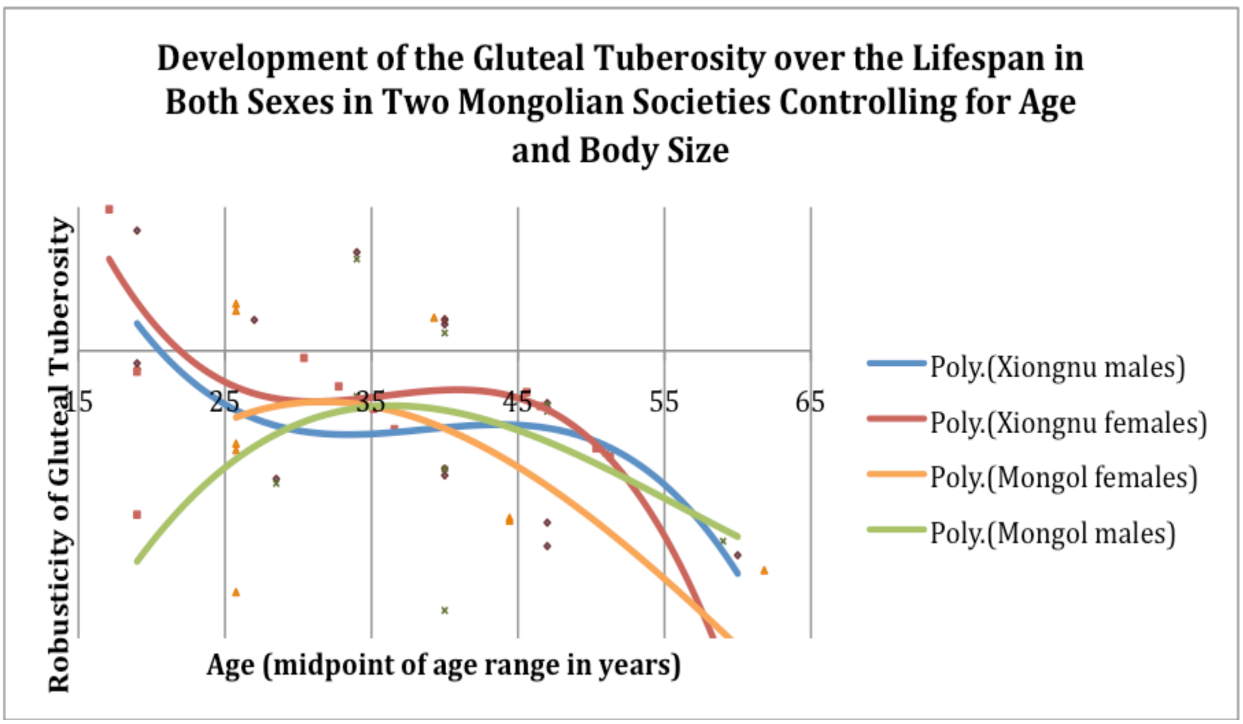


Figure 4. Graph of the robusticity curves for the gluteal tuberosity over the course of the life span for each subsample.

Table 21. R^2 values for the gluteal tuberosity and adductor tubercle curves for each subsample.

Trendline	Xiongnu Females	Xiongnu Males	Mongol Females	Mongol Males
Gluteal Tuberosity	0.3553	0.1679	0.4888	0.1475
Adductor Tubercle	0.5760	0.3649	0.3062	0.5728

The Xiongnu males and females appear to follow a similar life course when it comes to horse riding. Both males and females have very high robusticity scores coming out of adolescence. This starting point suggests that children rode horses during this period as they do in modern times. The decline in robusticity that happens in the third decade of life is likely the result of both a decline in the amount of riding and the age correction factor (the slope is steeper than -0.08). The robusticity scores level off until the mid-forties, which implies that robusticity increased at the same rate as the age correction factor (the slope on the graph is zero). The decline in the slope of robusticity after the middle of the fifth decade is again steeper than -0.08, indicating enthesis resorption possibly due to older individuals decreasing their amount of horse riding.

Mongol males and females, in contrast, appear to follow a different horse-riding life course than the Xiongn; both males and females exit adolescence with a lower score, suggesting that they did not ride as much during childhood and adolescence. Among Mongols, robusticity peaks in early adulthood. After the mid to late twenties, female robusticity scores descrease slightly faster than the age correction factor. One possible interpretation of this downward trajectory is that female Mongols, although still riding horses, are not riding enough to maintain their gluteal tuberosity robusticity, thereby causing the enthesis to be resorbed. The loss of robusticity may also be due to changes in nutrition or health during later child-bearing and child-rearing years or hormonal differences resulting from pregnancies and lactation. After the Mongol males peak, their decline in robusticity is gradual (the slope of the curve is less steep than the -0.08 correction factor). One possible interpretation of this is that males continue riding to such an extent that the gluteal tuberosity continues to increase in robusticity thereby mitigating the effects of the age correction.

Figure 5 depicts the development of robusticity of the adductor tubercle over the adult life span for males and females in both the Xiongnu and Mongol societies. The R^2 values are listed in Table 21. Unavoidably, a smaller sample size was used to derive the trendlines of the adductor tubercle graph. The adductor tubercle is a relatively slender and fragile bony projection from the distal end of femur, and is often not preserved well. The resultant smaller sample size produces more exaggerated curves making interpretation difficult. Nevertheless, the graph of the adductor tubercle differs noticeably from the gluteal tuberosity and provides strong visual confirmation that these two variables do not

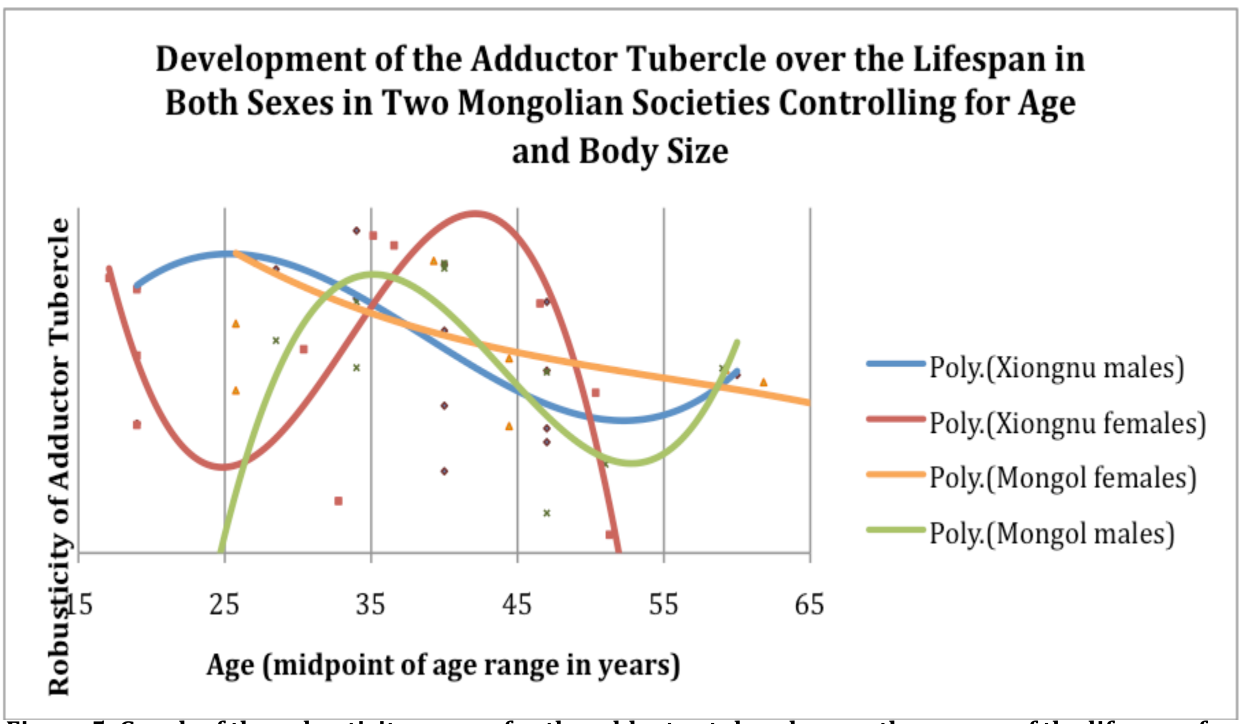


Figure 5. Graph of the robusticity curves for the adductor tubercle over the course of the life span for each subsample.

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The curves of both male samples bear a similar shape, though the Mongol male curve is much more exaggerated. The Xiongnu male curve suggests that the adductor tubercle did not gain its maximum robusticity in adolescence and so did not peak until the mid-20s. The Mongol male curve also suggests a delay in the development of adductor tubercle robusticity compared to gluteal tuberosity. However, once development began, it peaked rapidly. In both groups, following the peak, enthesial robusticity declined through middle age. The upswing seen in both curves in old age may be the result of small sample sizes skewing the results. These results suggest that while individuals maintained gluteal tuberosity robusticity, they did not maintain adductor tubercle robusticity. Such a discrepancy could be the result of either improved riding ability – as saddle riding styles tend to de-emphasize using the knees to grip the horse – or the result of increased sensitivity in the adductor tubercle. If the adductor tubercle is more sensitive to loading, then a slight decrease in adductor use may result in a more rapid decrease in robusticity.

The Xiongnu and Mongol female curves do not resemble either the male curves or each other. The Xiongnu female curve appears to be an exaggeration of its associated gluteal tuberosity curve. Whereas the Xiongnu female gluteal tuberosity curve levels out in middle age, the adductor tubercle curve rises steeply to a peak before declining in old age. This rise may be due to increased use of the adductors during this time, possibly due to either (1) the need to grip the horse – suggesting that these females were not using saddles - or (2) some other gender-specific activity that amplified the effect of riding.

The Mongol female robusticity curve for the adductor tubercle suggests that these females reached maximum robusticity for the adductor tubercle in adolescence. The slope of the descent of this curve is likely due to the 0.08 correction factor for age. This result suggests that once these females achieved maximum robusticity of their adductor tubercles, they maintained it. As this does not resemble the gluteal tuberosity curve for these individuals, and given the possibility that this enthesis is very sensitive to load, it is possible that this enthesis is being affected by some other gender-related activity unrelated to horse riding that requires thigh adduction and was done throughout life. Many food preparation activities in modern nomadic Mongolian life requires squatting with the knees together. Such activities may also be responsible for the very robust adductor tubercles observed in Mongol-period females.

Chapter Summary

Entheses are part of a complex biological system however, with some considerations, they can be used to identify performers of activities in past populations. The analyses performed here provide new insight into changes in the amount of horse riding over the life course and into the social dynamics of horse riding in nomadic societies. Due to preservation, asymmetry, and intraobserver error tests, the higher enthesial robusticity score for each enthesis was used in analyses. Since all the enthesial robusticity data was ordinal and demonstrated significant skew, nonparametric statistical tests were used for most analyses. Nearly all hypotheses were tested using partial correlations and/or logistic regressions. Since SPSS lacks an algorithm for performing a forward stepwise logistic regression analysis, this procedure was emulated by beginning with all seven enthesial variables and removing the one that contributing the least to the model at each iteration. Though the gluteal tuberosity was found to be the most useful for identifying horse riders in any society, which other entheses were useful identifiers differed in each culture studied. This suggests that there are culturally-specific identifying suites of features for different styles of horse riding. Specifically, Mongolian horse riders can be identified using the gluteal tuberosity and adductor tubercle. Using these features, females were found to be as likely as males to ride horses. However, in the Xiongnu societies, females rode about as much over the life course as males while in the Mongol society there appear that females only rode horses habitually into early adulthood while males rode throughout their lives. Though there appears to be a sexual equality in horse riding in both societies when examining them at a coarse level, this disappears in the Mongol society when examining horse riding over the life course.

Chapter 6

Discussion

Behavioral reconstruction includes identifying both how an activity was physically performed as well as the social factors that impacted its performance. Archaeological research has been studying the social aspects of activity for decades. However, skeletal data can provide direct evidence for who performed specific activities, information that can be studied only indirectly with material culture remains. Integrating skeletal data with the archaeological data can provide a new perspective on how individuals' choices of day-to-day activities reproduce and alter social dynamics in their society.

The goals of the current study were threefold: 1) to gain a better understanding of how regular horse riding affected enthesial robusticity in the skeleton; 2) to determine if differences in enthesial robusticity could be used to identify the social organization of horse riding in a society; and 3) to examine the meaning of horse riding and its social dynamics in nomadic Mongolian societies. In order to address these goals, samples of known riders and non-riders from three different horse riding societies were studied: the Arikara, Post-Medieval British, and Mongolians. Known riders were compared to known non-riders to develop a suite of features for identifying horse riders from their skeletal remains. This was then used on additional Post-Medieval British and Mongolian samples to study how the social organization of horse riding related to larger social dynamics. The cross-cultural comparisons of horse riding presented in this study provide new information on several biological and cultural considerations commonly discussed in interpretations of entheses, offer new data for the discussion of social age and its influence on activity reconstructions, and suggest that activity performance may be subject to the same manipulations as any other symbol.

Use of Entheses for Identifying Activity Performers

Most activity reconstructions focus on a set of activities within a single population (e.g. al-Oumaoui, et al., 2004; Chapman, 1997; Hawkey & Merbs, 1995; Molnar, 2006; Steen & Lane, 1998; Toyne, 2003; Weiss, 2007). Though such focus has its advantages, it prevents researchers from observing how a single activity affects multiple populations. By examining samples derived from multiple populations, the first goal of this study was to better understand how a single activity, horse riding, impacts enthesial robusticity in the skeleton.

Biological Considerations

Entheses are physical manifestations of a complex biological system. This system is not entirely understood so any insight into its impact on the development of enthesial robusticity is useful for future activity studies. The cross-cultural study of horse riding presented here offers new insights into this complex system and how it may potentially impact interpretations of entheses in activity reconstructions.

<u>Age and Body Size</u>

All studies of activity reconstruction using entheses note the need to control for age and size. Age is nearly always significantly correlated to enthesial robusticity (e.g. Hawkey & Merbs, 1995; Molnar, 2006; Villotte, et al., 2010; Weiss, 2003, 2007; Wilczak, 1998). This relationship is thought to be the result of muscles constantly being used in the course of everyday life, though some researchers think increased robusticity may be a form of degenerative change (Cardoso & Henderson, 2010). In some cases this relationship is so consistently significant as to lead some researchers to claim that robusticity should be used for estimating age rather than reconstructing activity (Milella, et al., 2011).

Similarly, body size is often correlated with enthesial robusticity, though never as strongly as age. Body size refers to skeletal robusticity, not muscularity. Zumwalt (2006) found that enthesial robusticity is not related to muscle size or force but enthesis size is related to general skeletal robusticity. Other studies have found enthesial robusticity to also be significantly correlated with body size (e.g. al-Oumaoui, et al., 2004; Chapman, 1997; Hawkey & Merbs, 1995; Weiss, 2003, 2007). As with age, this correlation has led to researchers suggesting that activity reconstruction not be attempted except in the extreme case, i.e. where females' entheses are more robust than males' (Weiss, et al., 2012).

There are two large problems with these suggested interpretive limitations: (1) age and body size can be controlled for in nearly any analysis and (2) a correlation can be significant without being particularly strong. For example, in the partial correlation results for Hypothesis 1a presented in the previous chapter comparing horse riders to non-riders, the pectinate line was found to have a significant correlation with age (p=0.023) with a correlation R-value of only 0.172. This R-value would not be considered even a weak correlation. This R-value is the extreme example however, no age or size correlation found in this study would be considered more than a weak correlation. If age and body size were primary sources of enthesial robusticity, they should be consistently and significantly correlated with robusticity for all entheses. As seen in this study, that was not the case. No single enthesis was highly correlated with either age or body size and none were significantly correlated for all comparisons. There is no reason these confounding factors should prevent the examination and interpretation of differences in enthesial robusticity between groups.

Additionally, there is the problem of sample composition. Partial correlations between the Xiongnu and Mongol male and female samples used in this study demonstrate consistently significant correlations between enthesial robusticity and body size, and all these correlations would be considered moderate to strong correlations (R-values greater than 0.5). If these correlations were the result of sex, (1) this association between robusticity and size would be consistent for the comparison of all male and female groups and (2) controlling for body size would still result in consistently significant correlations between male and female groups. As Table 22 shows, neither of these conditions is met. Therefore, the correlation between body size and robusticity must be the result of body size and not sex. This lack of consistency in correlations also suggests that body size is not inherently a primary source of variation in robusticity, as would be required for the extreme interpretive limitation suggested by Weiss, et al. (2012). Rather, examination of all the comparisons presented in this study suggests that a significant average body size difference between populations makes a significant correlation between body size and enthesial robusticity nearly three times more likely. This finding suggests that consistently high correlations between enthesial robusticity and body size may be an artifact of sample

Table 22. P-values of partial correlations for size and sex between male and female subsamples, controlling for age. Significant values (p=0.05) are in bold.

Male to Female Subsamples Compared	Significance Values for Size Controlling for Age and Sex						Significance Values for Sex Controlling for Age and Size					
	GTr	TF	LTr	GlT	PL	AT	GTr	TF	LTr	GlT	PL	AT
British Country	0.38	0.24	**0.02**	0.17	0.62	0.50	0.55	0.61	0.74	0.45	0.16	0.26
British City	0.07	0.62	0.24	0.97	0.65	0.36	0.22	0.75	0.39	0.69	0.71	0.90
Arikara Pre-Contact	0.45	0.89	0.06	0.18	0.72	0.25	0.61	0.83	0.07	0.33	0.78	0.46
Arikara Post-Contact	0.29	0.20	0.38	0.15	0.21	0.69	0.68	0.44	**0.05**	0.62	0.99	**0.01**
Xiongnu	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.70	0.30	0.30	0.88	0.13	0.80
Mongol	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.68	0.51	0.74	0.38	0.91	0.22

compositions and the mathematics of computing partial correlations. Interestingly, this effect was not observed with age, suggesting that the more consistently significant correlations seen across nearly all activity studies between age and robusticity is not an artifact of the statistical test.

Type of Enthesis

Recently, there has been some debate about using different types of entheses in activity reconstructions. Fibrous and fibrocartilaginous entheses differ in their organization, cell types, and in how robusticity develops at their attachment points (Benjamin, et al., 1986, 2002; Villote, et al., 2010). All these differences have led to suggestions that these types of entheses may not develop robusticity at the same rate or as a result of the same stimuli, leading to problems with comparisons and interpretations between types. However, this potential discrepancy in the development of robusticity has not been tested. Most studies only compare robusticity between groups (e.g. al-Oumaoui, et al., 2004; Chapman, 1997; Hawkey & Merbs, 1995; Molnar, 2006; Steen & Lane, 1998; Toyne, 2003; Weiss, 2007), making it impossible to differentiate between whether each type of enthesis develops differently or whether the differences are simply the result of the various muscles not being used regularly.

In the study presented here, the suite of entheses developed in Hypothesis 1b for identifying British riders used four different markers: trochanteric fossa, trochanteric crest, gluteal tuberosity, and adductor tubercle. The first two are fibrocartilaginous attachments while the second two are fibrous attachments. Results for the adductor tubercle in all of the study samples suggest this attachment operates differently than all other entheses examined here, possibly due to differences in thresholds discussed in the next section and, consequently, will not be discussed further here. Of the three remaining entheses, the results of this study suggest that development of robusticity is thought to relate to horse riding. That is why they can be used to identify horse riders. If type of enthesis affects the rate of robusticity development, then the trochanteric fossa and trochanteric crest should act differently than the gluteal tuberosity over the life course.

Figures 6 and 7 illustrate the robusticity curves for these three markers over the life course for both country males and females, respectively. Though the curves do not always overlap, nearly all bear a similar shape and change slope at the same time in the life course as the others within their groups. The trochanteric crest curve for females (Figure 7) does appear to differ from the other two female curves but there is similarity in the timing of slope changes. This finding suggests that though there are differences in how each type of enthesis develops robusticity, they do so at similar rates and do so in response to

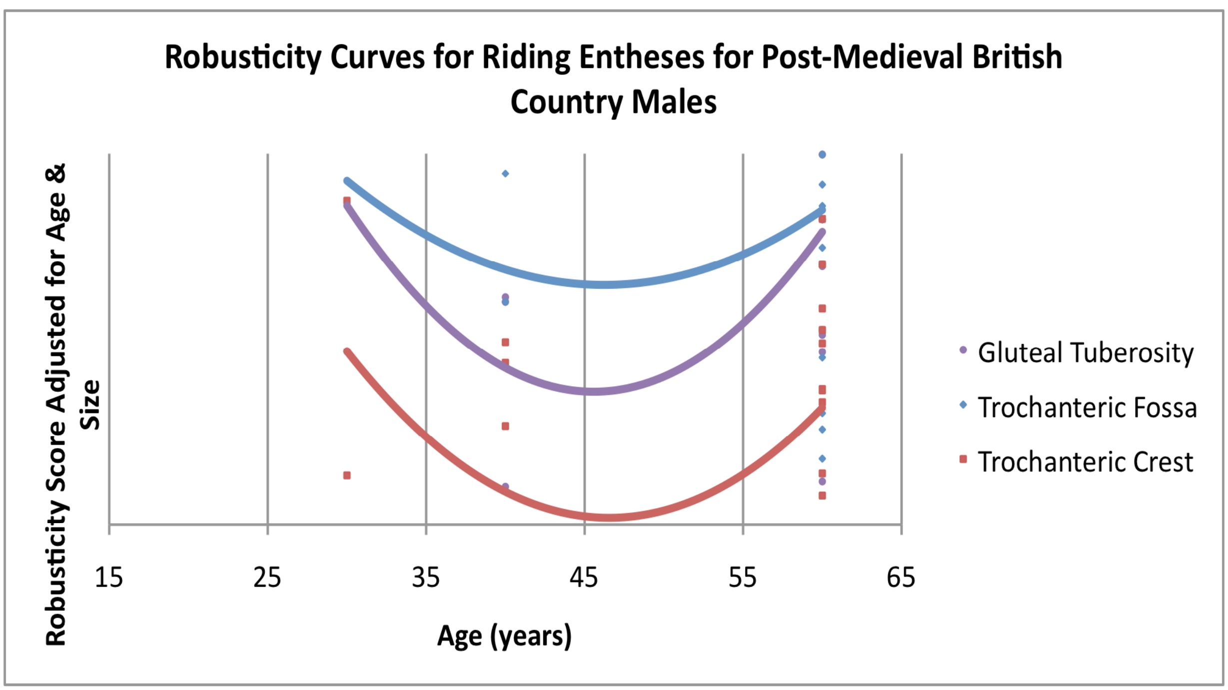

Figure 6. Robusticity curves for three riding entheses for Post-Medieval British Country males, controlling for age and body size.

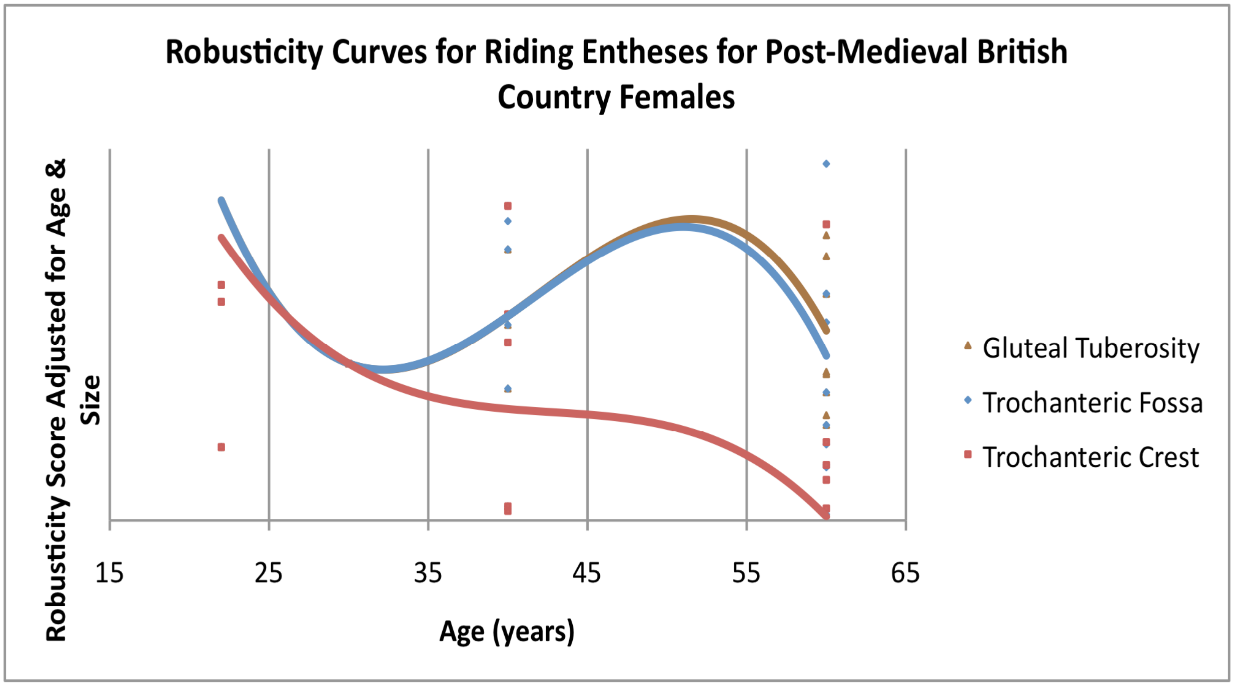

Figure 7. Robusticity curves for three riding entheses for Post-Medieval British Country females, controlling for age and body size.

the same stimulus: regular muscle use. Though this is only one case, in provides evidence that despite the biological differences between fibrous and fibrocartilaginous entheses that require methodological considerations, these differences do not appear to present difficulties for the use of entheses in activity reconstruction.

Thresholds

Several studies examining bone from the cellular level to the tissue and organ level suggest that a specific threshold of strain must be reached to stimulate an osteogenic response (Binderman, et al., 1984; Frost, 1987; Rubin & Lanyon, 1984). There is also evidence that these thresholds vary within and between bones (Currey, 2002; Hsieh, et al., 2001). Since many cellular processes require surpassing some sort of chemical or physical threshold before a response is induced, the idea that osteoblasts at muscle attachment sites would also require a specific level of strain before they proliferate is reasonable.

Thresholds may explain the exaggerated robusticity curves of the adductor tubercle as compared to the other curves. It is possible that the adductor tubercle has a much lower threshold than the other entheses, making it more sensitive to load than the other attachment points. This lower threshold could hypothetically be the result of the small surface area of the tubercle not being able to dissipate muscle force as well as other attachment points, making it more susceptible to and in need of more protection from muscle tears. This sensitivity would compound any effect resulting from horse riding, leading to exaggerated robusticity curves compared to other horse riding markers. Such might be the case for the gluteal tuberosity and adductor tubercle robusticity curves for Xiongnu females, as seen in Figure 8. Furthermore, any effects from non-horse riding activities that also use the adductor magnus would also be compounded, leading to large distortions in the robusticity curves and severely limiting the information they can offer on horse riding over the life course. This situation could explain the large discrepancies

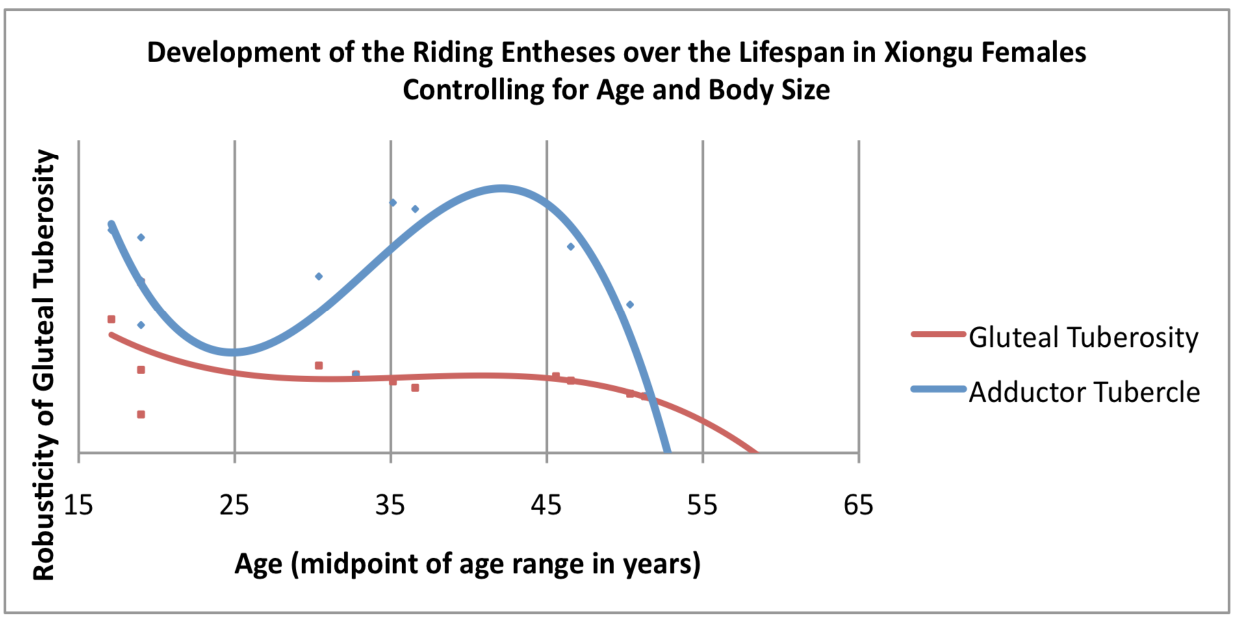

Figure 8. Robusticity curves for Mongolian riding entheses for Xiongnu females, controlling for age and body size.

between the gluteal tuberosity and adductor tubercle robusticity curves for Mongol females (Figure 9).

Additionally, all other entheses studied here are primary distal attachment points for their associated muscles. However, the adductor tubercle is not the primary distal attachment area for the adductor magnus, the linea aspera is. Only a small portion of the muscle is attached to the adductor tubercle. It is hypothetically possible for the adductor magnus to contract without utilizing the specific muscle fiber bundles attached to the adductor tubercle. The tubercle is also a very small surface area, so what few muscle fiber bundles are attached to the tubercle have a much smaller area over which to dissipate their force on the bone. The result of all this may be that the adductor tubercle is only strained under very strong contractions of the adductor magnus and thus, only experiences very high strains. This mechanical environment would be more extreme than that of all the other entheses studied here, again leading to an exaggeration of the robusticity curves.

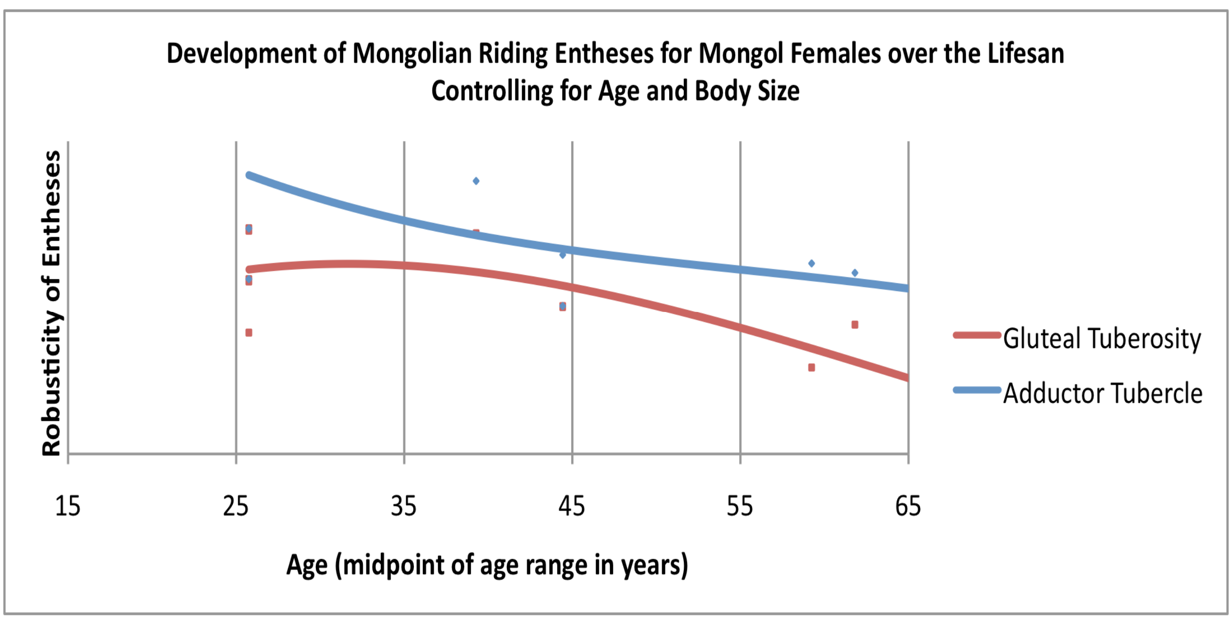

Figure 9. Robusticity curves for Mongolian riding entheses for Mongol females, controlling for age and body size.

Either or both of these scenarios may explain the discrepancy between the adductor tubercle curves and all other robusticity curves for riding markers. Given the hypothetical compounded and exaggerated effects of the musculoskeletal system at the adductor tubercle, or simply the observed discrepancies in the marker's robusticity curve, it is surprising that it would be included in the suites of markers for horse riding. It seems that despite these complexities, regular horse riding still has enough of an impact on adductor tubercle robusticity to differentiate its performers from nonperformers.

Resorption

Most activity reconstruction studies implicitly assume that enthesial robusticity does not resorb. The default assumption is that once robusticity develops at an enthesis, it can never resorb and can only become more robust. Biologically, this assumption is illogical. It is unlikely that the body would maintain a robust enthesis that it did not need. Maintaining bone requires energy and resources. This idea is seen in the functional adaptation of cortical bone, where unloading a bone results in increased resorption and remodeling of bone (Duncan & Turner, 1995; Rubin & Lanyon, 1984). If a robust enthesis is not necessary for the integrity of the musculoskeletal system at an attachment point, it is far more logical that the body would resorb the enthesis. Therefore, if a person stops performing an activity that uses a specific muscle regularly and does not use that muscle regularly for any other activity, any robusticity that had developed at that muscle's attachment points would resorb.

Figure 9 displays the gluteal tuberosity robusticity curve for Mongol females generated from Hypothesis 3b. The rapid decrease seen in middle and old age is faster than the age correction factor, suggesting that the robusticity is resorbing. These older individuals likely slowed or stopped riding horses regularly. As robust gluteal tuberosities were no longer needed to keep frequently contracting gluteus maximi attached to the femora, the entheses likely resorbed.

Resorption leads to a potentially significant problem with activity reconstructions based on entheses: activity performers who stop performing may look like non-performers. In many societies, as individuals age they pass through various social ages or life stages. These can impact what activities a person performs at each stage and what activities he or she ceases to perform. This cessation of a particularly activity can lead to less regular use of a muscle, less need for a robust enthesis, and the loss of robusticity over time. The result is that older individuals are more likely to appear as non-performers, potentially skewing comparisons between groups. This pattern can also lead to lower correlations between age and enthesial robusticity and to an overcorrection for age in older individuals.

Table 23. The number of identified riders and nonriders for British and Mongolian samples from before (Younger) and after (Older) the decline in robusticity.

	Non-rider	Rider	Total
Older	12	26	38
Younger	18	54	72
Total	30	80	110

In all the samples studied here, regular horse riding appears to decline as individuals got older. This decline was often faster than the age correction factor, suggesting that riding entheses were resorbing. This resorption could potentially skew comparisons between samples. Examining the number of riders versus non-riders for the subsamples before and after the decline in robusticity shows no significant impact of this resorption on the liklihood of an older person being identified as a horse rider (Table 23). In the case of this study, the resorption seen in older individuals had no effect on the outcome. However, this may not be the case for all studies and it is worth examining the effect of resorption before reaching any conclusions in activity reconstruction studies.

Cultural Considerations

Just as entheses are part of a complex biological system that requires certain considerations, they are also the result of performing activities and activities are part of a complex cultural system. This system impacts which entheses individuals will develop and thus, the viability of cross-cultural activity studies. Given the frequency with which activity performance is compared between cultures (e.g. al-Oumaoui, et al., 2004; Molnar, 2006; Steen & Lane, 1998), the viability of this approach deserves discussion.

<u>Cross-Cultural Applicability</u>

Many activity studies use suites of entheses to identify performers of a specific activity that were derived from an unrelated population or are assumed from how modern peoples perform the activity (e.g. al-Oumaoui, et al., 2004; Chapman, 1997; Hawkey & Merbs, 1995; Molnar, 2006; Steen & Lane, 1998; Toyne, 2003; Weiss, 2007). The implication is that these identifying suites of entheses are universally applicable to all societies. Researchers appear to use this method because they have no subsample known to perform the activity they are studying. Though this method can provide some information on activities in a population, it is likely to skew the results that would be seen using a culturally-specific identifying suite of features. There are two possible reasons for this: 1) the society being studied performed the particular activity in a different way, using different muscles, resulting in different entheses; and 2) the society being studied performed several other activities regularly that may render invisible any differences between performers of the activity of interest and non-performers. The cross-cultural nature of the study presented here in Hypotheses 1a and 1b, with known riding and non-riding groups, allowed for the examination of a potentially universal suite of markers for horse riding as well as for the examination of the effects of using suites of markers cross-culturally.

The aggregated sample of known horse riders was compared to the aggregated sample of known non-horse riders to test Hypothesis 1a (that a universal suite of entheses capable of identifying horse riders in any society existed). After controlling for age and body size, the gluteal tuberosity and adductor tubercle were found to be significantly more robust in horse riders than in non-riders. However, none of the logistic regressions used to identify suites of entheses could discriminate between riders and non-riders. Though all models were deemed to be significant ($p=0.05$), all had very poor sensitivity; all models misclassified non-riders as riders. Furthermore, the adductor tubercle was removed by the 3-factor model, suggesting that it did not improve the accuracy of the models when used in combination with other entheses despite its significantly greater robusticity in riders. These results provide evidence against the idea of a universal suite of entheses that could identify horse riders.

There are two possible explanations for this finding: 1) horse riding in a particular style results in increased robusticity in a culturally-specific suite of entheses or 2) horse riding does not result in a suite of entheses sufficiently more robust as to allow differentiation of riders from non-riders. Given the significant differences observed in the partial correlation analyses in this study, the latter seemed unlikely, yet, it was worth determining if culturally-specific suites of entheses, presumably resulting from horse riding, could be found in the samples used in this study as seen in the analysis of

Hypothesis 1b. No such suite of markers could be found for the Arikara (bareback riding) sample. However, the British and Mongolian riding samples both exhibited significantly more robust gluteal tuberosity than their respective non-riding samples as well as very different models, all of which were significant (p=0.05) and reasonably accurate. Aggregating these samples diminished the differences seen between riders and non-riders in each society. These findings support the existence of culturally-specific suites of entheses for identifying horse riders.

Differences in logistic regression models may not necessarily result in skewed results. These models may simply offer different ways to reach the same conclusion. In an effort to determine if different models led to significantly different results, the best model (according to accuracy measures and least amount of features required) was used on the British and Mongolian riding samples to compare the resulting classifications. Table 24 shows the results of these cross-cultural applications. The significance values come from Fisher exact tests comparing the resulting classifications from each cross-cultural equation with the results from the appropriate culturally-specific equation (e.g. Mongolian riders classified using the Mongolian riding equation). Nearly all the equations resulted in significant differences from the culturally-specific equations. These discrepancies could have large impacts on what conclusions, if any, could be drawn about horse riding in these societies.

This idea of culturally-specific suites of features for identifying performers of specific activities is not new. Merbs (1983) discussed how such suites of markers exist within and between societies, though he was using osteoarthritis and not entheses. For

Table 24. The number of riders and non-riders within known British riding and non-riding samples identified using different logistic regression equations. Significance values are given for Fisher's exact test comparing each inappropriate equation to the correct one. Significance values of less than 0.05 are in bold.

		Riders	Nonriders	Sig.
British Riders	British Equation	15	6	
	Mongolian Equation	7	17	**0.007**
	General Equation	18	3	0.454
	Saddle Equation	12	15	0.082
British Nonriders	British Equation	4	16	
	Mongolian Equation	1	21	0.174
	General Equation	15	5	**0.001**
	Saddle Equation	5	19	1.000
Mongolian Riders	Mongolian Equation	27	8	
	British Equation	26	3	0.319
	General Equation	29	0	**0.006**
	Saddle Equation	32	5	0.367
Mongolian Nonriders	Mongolian Equation	5	15	
	British Equation	18	2	**0.000**
	General Equation	19	0	**0.000**
	Saddle Equation	13	9	**0.033**

example, he found that though Sadlermiut males and females may do similar activities (e.g. row a boat) they did so very differently using different technology: males used double-bladed paddles to propel kayaks while females used single-bladed ones to propel umiaks.

The implicit assumption of universal suites of markers for identifying activity performers seen in many more recent activity studies may be a consequence of lacking the necessary information to create culturally-specific suites. It is often difficult to identify known performers and non-performers of an activity within past societies, thus making it difficult to create culturally-specific suites of entheses for identification. Despite this difficulty, these culturally-specific suites are essential to accurate classifications of activity performers and interpretations of activity in the past. At least for horse riding, there is no universal identifying suite of entheses.

Impact of Technology

The role of technology is often discussed in activity studies. Merbs (1983) discussed the different paddles used by the different sexes among the Sadlermiut and how that altered the motions used to regularly row a kayak or umiak. Capasso, et al. (2004) linked particularly robust entheses and hand trauma with a type of boxing "glove" used in Herculaneum in the first century A.D. Peterson (1998) found patterns of enthesial robusticity that suggested spears and atlatls were used more often than bows and arrows in the southern Levant during the Natufian. The use of technology can require standard positions and motions to perform an activity, thus altering what entheses develop as a result of that performance.

Though there are many forms of technology associated with horse riding, saddle use may arguably have had the largest impact on the riders' positions and motions. Saddles help riders maintain their seat on a moving horse without requiring the riders to squeeze the horse with their legs for balance, less thigh adduction is required to stay on the horse. The result is that, though the adductor tubercle was significantly more robust when aggregating all horse riding samples, it was not significant when comparing only saddle riders to non-riders ($p=0.05$) as seen in the analysis for Hypothesis 1a. Further evidence for the effects of saddle use was seen in the logistic regression analyses. Looking at the two sets of logistic regressions in Hypothesis 1a, the saddle rider samples differed from the general rider samples in the order of factor removal as well as having better sensitivity and overall accuracy.

Differences seen between the British and Mongolian samples in the analysis of Hypothesis 1b in terms of identifying suites of entheses further suggests that, though societies may use the same form of technology, there are sufficient cultural differences in positions and motions required for riding (and shape of the saddle) for even this technologically-specific suite of features to lack universal applicability. Table 24 shows how even the classifications from this more specific suite of features differ significantly from those of the culturally-specific suites of entheses. The use of similar technology may allow for more accurate cross-cultural comparisons of activity however, the specific forms this technology takes still requires the use of culturally-specific suites of entheses to identify activity performers.

Activity Over the Life Course

Activity studies based on either material culture or ethnography often discuss how the activities one performs regularly can change over the life span (e.g. Hanks, 2008; Levy, 1999; Spector, 1983; Wells, 1998). These changes are often associated with changes in social ages and moving to new life stages, though they could potentially be related to changes in economic or social status, gender, or other social categories. The performance of specific activities is one way individuals can embody their new social identities (Conkey & Spector, 1984; Hanks, 2008; Joyce, 2005; Levy, 1999; Wells, 1998; Wengrow, 2006). Consequently, any attempt at behavior reconstructions of past societies requires examining how activity changed over the life course.

These changes in regularly performed activities throughout life have the potential to greatly impact the results and interpretations of enthesial robusticity comparisons within and between societies. For example, if an activity is only performed in middle adulthood, then a sample composed primarily of young adults or old adults may not appear to have performed that particular activity regularly. Some activities may not begin until later in life while the performance of others ends in early adulthood. As discussed earlier, entheses can resorb. Thus, cessation of a particular activity several years before death may result in an individual not appearing to have performed that activity regularly. Therefore, the performance of activities over the life span and the age profiles of study samples become extremely important for any study of enthesial robusticity.

Social Age

There are many ways to categorize age in populations, the most important of which for activity studies are biological age and social age. Biological age relates to physical changes associated with human growth, maturity, and senescence (Sofaer, 2011). Aging methods used in bioarchaeology try to correlate these changes in the skeleton with chronological age, the amount of time in months or years since birth. Since individuals age at different rates, and thus manifest age-related changes at different rates, these methods can only provide a range of likely chronological ages associated with a specific biological change. Social age refers to culturally constructed, age-appropriate attitudes and behaviors (Halcrow & Tayles, 2008; Sofaer, 2011). Moving between social ages is not necessarily related to chronological age, but may relate to a number of other factors, such as biological events (menarche, menopause), functional abilities (walking, talking), physical appearance (grey hair, wrinkles), or changes in familial composition (becoming a parent or grandparent).

Biological age of an individual can be estimated from skeletal aging methods; however, social age is more difficult to ascertain. Grave goods may provide some evidence of social age categories but are not always a direct and passive reflection of an individual's social identity in life (Joyce, 2001; Parker Pearson, 1999; Shanks & Tilley, 1982; Stoodley, 2000). There is not a direct relationship between chronological age and social age in all societies and the number of different social ages differs between societies (Halcrow & Tayles, 2008; Sofaer, 2011). As a result, attempting to classify individuals into particular social ages is difficult. However, social age is the most likely type of age related to changes in what activities an individual performs frequently in day-to-day life. This theoretical connection between social age and activity may allow the study of a specific activity over the life course to provide new information on social ages in adulthood within a particular society.

One method for identifying possible transitions in social age is to graph the robusticity curves of activity-related entheses over the life course. This method was used in the present study with the horse riding entheses for the British and Mongolian riders. The robusticity curves for the gluteal tuberosity of the Mongolian subsamples from the analysis for Hypothesis 3b are redisplayed here as Figure 10. The changes in the slope of a robusticity curve over time may relate to transitioning to different social ages, thus resulting in changes to the frequency of horse riding by individuals. The two changes in slope seen in the Xiongnu male and female curves suggest that in Xiongnu society there were transitions to different social ages in the latter half of the third and fifth decades of

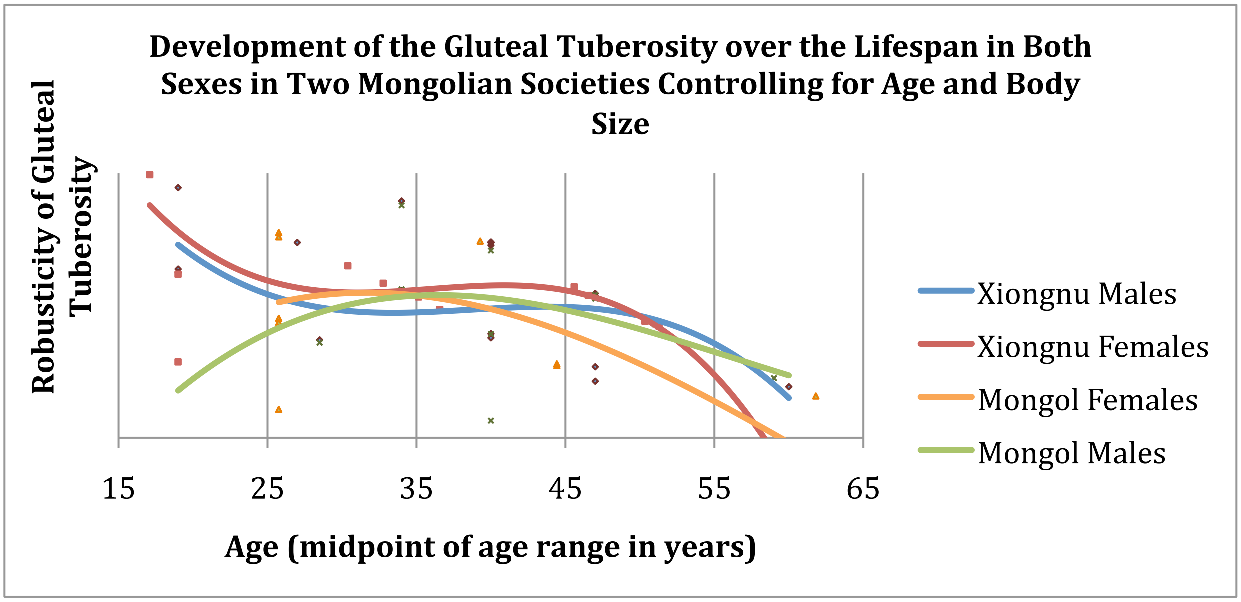

Figure 10. Robusticity curves for the gluteal tuberosity for all Mongolian samples, controlling for age and body size.

life. In contrast, the Mongol male and female curves suggest that there was only one shift in social age in the fourth decade of life. Though chronological ages are used here for descriptive purposes, it is unlikely that these ages were rigid time points for transitions and are more likely a broad time period when some maturational event took place that marked a change in an individual's social age.

The differences in the potential social age transitions seen in these Mongolian societies point to significant differences in age-appropriate behavior and how age may have been defined in these groups. Though these differences are easily observed in the graphs presented here, only the logistic regression model for classifying Xiongnu and Mongol females was significant; no other analysis found a statistically significant difference between any set of subsamples in the analysis of Hypothesis 1a. Examining the robusticity of horse riding entheses over the adult life span elucidated differences between the Xiongnu and Mongol societies that could not be captured with statistical tests.

Entheses and Symbolic Activities

The second goal of this study was to determine if entheses could be used as a proxy for the study of social dynamics. By using samples from a society where horse riders could be identified through their skeletal remains and where the symbolic value of horse riding was known, the hypothetical relationship between the meanings of symbolic activities and their social organization could be tested.

The Post-Medieval British samples were used to test this theoretical relationship in Hypothesis 2, since horse riding is known to be a status symbol in that society. Using the British riding equation, the number of horse riders was compared in a wealthy country-dwelling sample of males and females and poor city-dwelling sample of males and females. There were no significant differences found within status groups while differences were seen between them. Given the Post-Medieval British status system, where both males and females of high status could exhibit status symbols, these results are expected. Both high status males and females should be riding horses regularly while low status males and females should not.

The idea that activities have symbolic meaning has been discussed in archaeological activity studies for years. However, this idea has not been imported to bioarchaeological behavioral reconstructions. Given the methodological and interpretive considerations needed for the use of entheses in activity reconstructions, it is worth testing if these markers could be used as a proxy to study the relationship between the social organization of an activity and its symbolic meaning within a society. This sub-study essentially functioned as an assay control for the final goal of this study.

Mobility in Mongolian Societies

The final goal of this project was to study the symbolic meaning of horse riding and the social dynamics of nomadic Mongolian societies. Though the general view of nomadic societies has changed from one of static homogeneity to one of dynamic heterogeneity, little is known about the social dynamics in these highly fluid social systems. The current study focuses on the sexual equality, or lack thereof, of horse riding in Mongolian societies. Riding horses in nomadic Mongolian societies is not about status, the space and food resources needed to care for horses are relatively cheap and plentiful. Horse riding in these societies provides access to power through the ability to network, build alliances, and gain access to new resources, though excellent horsemanship was likely also a point of pride for individuals and a symbol of nomadic identity to outsiders (Honeychurch & Amartuvshin, 2006; Salzman, 2004; Sneath, 1999).

Power and identity are strong symbolic forces in individuals' lives. Increases in social complexity tend to result in increased segmentation within social systems, including power and identity systems, reducing access to these systems for some groups, thus increasing social tensions (Bovin, 1990; Ibrahim, 2004; Kent, 1989; Little, 1985; Morgan, 2007; Tavakolian, 1984). Sex and/or gender groups may be segmented apart in this process, causing one group to lose access to a particular symbolic system. Since horse riding is of great importance to nomadic Mongolian societies, its organization can offer insight into the social dynamics of these societies as they increased in complexity.

Sexual Equality Over the Life Course

Both males and females rode horses regularly in Mongolian societies. No significant differences were seen in the number of horse riders between males and females within societies or over time. This ubiquity in horse riding supports the hypothesis that riding symbolized nomadic identity to this culture throughout time. Most of the sedentary cultures these societies came into contact with identified them as “other” due to their horse riding and the inclusion of horse paraphernalia among burial inclusions also support this symbolic meaning of horse riding (Anthony & Brown, 2003; Crubézy, et al., 2006; Garofalo, 2004; Honeychurch, 2004; Linduff, 2008; Miniaev & Sakharovskaia, 2008).

Logistic regression analyses used in Hypothesis 3a were able to separate females into their respective societies when both riding entheses were used together. These results suggest that, though males and females both rode regularly, females in the Mongol period were beginning to ride less than their male counterparts. The negative coefficient for the gluteal tuberosity in the Xiongnu vs. Mongol females model further points to Xiongnu females riding more often than Mongol females, and thus developing more robust gluteal tuberosities. Despite the lack of significant differences seen in other analyses, this result suggests that sexual inequality in horse riding was beginning to develop in the Mongol period.

Examining the robusticity curves for the gluteal tuberosity for these subsamples generated in the analysis for Hypothesis 3b further suggests that sexual inequality was beginning to develop (Figure 10). Xiongnu males and females rode in the same pattern over the life course. The female robusticity curve likely appears higher than the male curve because female body size is generally smaller, so their scores were less adjusted for body size. In contrast, the Mongol female robusticity curve peaks sooner than the Mongol male curve, and declines faster. It is likely that males and females began riding at the same time; however, females slowed or ceased riding in the early half of their fourth decade while males did not. This finding suggests that differential access to riding, and its associated power-building capabilities, began in middle to late adulthood in the Mongol period. This differential access may be related to different constructions of age-appropriate behavior in the Mongol period compared to the Xiongnu period, particularly in older ages.

Mongol histories indicate that men and women had differential access to power. Women could not hold political office and accounts suggest that their familial networks were not as highly regarded or as useful as men's networks (Morgan, 1986). Mongol female burials tend to be less elaborate than male burials with very different burial assemblages (Crubézy, et al., 2006). Conversely, though less is known from the Xiongnu period, male and female burials were similar in both elaboration and burial assemblages (Honeychurch, 2004; Linduff, 2008). The mortuary analysis suggests that females lost power between the Xiongnu and the Mongol periods. The results presented here support this shift in power, though not to the level seen in the mortuary realm.

Social Complexity

The subtle differences observed in the organization of horse riding between the Xiongnu and Mongol societies may signify a symbol in flux. As histories, iconography, and burial assemblages show, horse riding was considered a symbol of identity in the nomadic Mongolian culture (Anthony & Brown, 2003; Crubézy, et al., 2006; Honeychurch, 2004; Linduff, 2008; Miniaev & Sakharovskaia, 2008). The symbols of identity in this culture, particularly those related to horsemanship, appear to be relatively stable over time (Crubézy, et al., 2006; Honeychurch, 2004; Linduff, 2008). Additionally, riding is often equated to power within horse-riding nomadic societies either directly as a symbol of power or due to the opportunities mobility provides (Honeychurch & Amartuvshin, 2006;

Salzman, 2004; Sneath, 1999). The power systems of the Xiongnu and Mongol periods appear to shift with the increase in social complexity in these societies over time.

Social complexity has several definitions, the most general of which simply refers to an increase in segmentation within a society (Kent, 1990). This segmentation can take the form of increased number of political offices, economic roles, and available identities, as well as more differentiated sexual division of labor, burial elaborations, and architecture (Crumley, 1999; Kent, 1990; Levy 1999). Compared to the Xiongnu society, the Mongol society had a larger political hierarchy with more offices, greater number of possible economic roles, more differentiation in burial construction and assemblages, and hierarchical gender roles (Barfield, 1989; Honeychurch, 2004; Morgan, 1986; Onon, 2001). Consequently, an increased segmentation of the social organization of horse riding would be expected. Given its association with power, this segmentation should be between the sexes, as the rest of the power system was.

There are several possibilities for the subtlety of this difference. The samples used in the analysis were small and may have introduced sample bias to the study. Differences in the age profiles of the samples studied may have also made a difference. The Mongol female sample was an average of ten years younger than the other three Mongolian samples. Given the robusticity curve of the Mongol female gluteal tuberosity created in the analysis of Hypothesis 3b (Figure 10), this younger bias may have altered differences that might otherwise have been seen in the sample. A third possibility is that there is only a subtle difference between the samples. Horse riding can be linked to both nomadic Mongolian identity and to power within nomadic Mongolian societies. A symbol related to the relatively stable identity system and to the highly fluid power system is likely to be contested, without a clear transition from one to another. The subtle differences seen in this study between the Xiongnu and Mongol societies may be the result of trying to negotiate the segmentation of the power system with an activity system also tied to people's identity as nomads.

Limitations of this Study

Despite the ambitions of this study, there are several limitations that should be noted, including sampling bias, small sample sizes, and the difficulties of doing bioarchaeology in regions with different theoretical traditions. This study uses samples from nomadic pastoralist populations. These populations were more mobile and less densely settled than sedentary agrarian populations. As a result, there were simply fewer individuals over a larger area in these nomadic pastoralist societies than is typically seen in bioarchaeological studies of agrarian societies. Of these smaller populations, only a fraction of individuals were buried. At least four mortuary practices were known in the particular societies used here: burial, cremation, leaving out for animals and the elements, and leaving in trees (Crubézy, et al., 2006; Miniaev & Sakharovskaia, 2008; Tseveendorj, et al., 2003). Of the last two, secondary burial was also a possibility. This variety of options further decreased the number of individuals who would be buried. Preservation was also a problem in sampling bias. Burials were often looted in antiquity, with skeletal remains being disturbed and removed in the looters' attempts to retrieve artifacts. Burials were often placed in valleys where the high water table also took a toll on the preservation of remains. Not all burials are likely to be identified, due to disturbance of surface features over the centuries, or excavated, due to limited resources and a preference for expending resources on only the largest and most impressive looking burials. All of these events likely resulted in sampling biases that may prevent these samples from accurately representing a cross-section of these societies.

Among the other samples used, these recovery biases were also present. Additionally, these samples were mostly large enough to warrant the need for a sampling strategy. Due to the nature of the analyses involved, a stratified random sample of adult males and females from all life stages was attempted from these collections. The Arikara samples were also biased in that an attempt was made to limit their geographic origins. Since different lifeways can impact activity reconstructions, geographic restrictions that limited the amount of activity variation induced by the environment were necessary. These additional sampling strategies may have also prevented these samples from representing their source populations accurately.

The difficulties detailed above also resulted in smaller sample sizes of the nomadic pastoralist samples. This is particularly problematic for performing statistical analyses. Though much effort was expended to include as many individuals as possible in the analyses, including the development of a new aging method, preservation issues resulted in several individuals being excluded. These issues included the preservation of specific features on the femur, of specific skeletal elements necessary for analysis, and of the notes needed to attribute individuals to a particular society. This last issue leads me to a limitation not usually seen in bioarchaeological studies.

Bioarchaeology in Mongolia, where the nomadic samples in this study originate, is only in its infancy. It is developing out of different theoretical traditions with different histories. For many decades, physical anthropology and archaeology were kept largely separate in this region. It is worth noting that, unlike bioarchaeology in much of the rest of

Asia, both postcranial and cranial skeletal elements were retained from excavations in Mongolia. The result of this separation between physical anthropology and archaeology is that excavation notes and mortuary data were often not able to be linked to skeletal remains of individuals. Without dating each individual's remains, these notes are the only way to separate individuals into their respective time periods. The effect of this problem was that several individuals were excluded from the analysis because there was no foreseeable way to determine what society they belonged to through time without dating each set remains, which this study lacked the resources to accomplish.

There are also limitations in how the results of statistical tests were interpreted. The rapid decline of enthesial robusticity seen in older females, as exhibited in the graphs generated in the analysis of Hypothesis 3b, was interpreted as the entheses resorbing due to the cessation of horse riding. Another potential interpretation is that the degenerative forces that predominate in older females after menopause may have resulted in resorption of bone at muscle attachment points, rather than to a lack of horse riding (Agarwal & Grynpas, 1996; Hawkey & Merbs, 1995; Ruff & Hayes, 1983; Weiss, 2007). If degenerative changes were a primary source for the loss of enthesial robusticity, this decrease should be universal, across all entheses for females in all societies. This was not the case therefore, this study used the interpretation that females stopped riding horses in old age.

An additional limitation is that the enthesial scores used in this study are cross-sectional data, yet were interpreted as longitudinal data. Cross-sectional data represent a single snapshot of a population in time while longitudinal data represent a series of snapshots of a sample over time. The analysis of longitudinal data is better suited to addressing questions of cause-and-effect, such as that implied in this study. Similar issues have been addressed in paleodemography studies (e.g. Wood, et al., 1992) and found that cross-sectional data does not always accurately reflect what might be observed in longitudinal data. However, the interpretations presented in this study were drawn from trendlines of the cross-sectional data. As a result, these trendlines should represent an average of the population activity over time and should minimize individual idiosyncracies. In theory, horse riding was very symbolic in these societies, with potentially strong social controls on who could ride when during the course of their lives, which should also minimize individual differences and allow for a general trend of the amount of horse riding performed by people during their life courses.

Chapter Summary

Activity performance can have symbolic meaning within a society. Like any other symbol, it can be manipulated and contested. Using a cross-cultural approach in this study of a single highly symbolic activity, horse riding, provided new information on several biological and cultural considerations for the use of entheses in activity reconstructions. Mapping enthesial robusticity over the life course presents a potential new source of data on social age. Comparing enthesial robusticity within two nomadic Mongolian societies allowed for an investigation of the sexual division of horse riding and a new perspective on the negotiation of symbolic activity as social complexity increased. The use of skeletal data in behavioral reconstructions, not just activity reconstructions, can offer new insights into the social dynamics of nomadic societies.

Chapter 7

Conclusions

Activity has long been known to have symbolic connotations in archaeological studies; however, this connection is rarely considered in bioarchaeological behavioral reconstructions. Including the possibilities of symbolic meanings in these studies allows for skeletal data to be used for addressing issues of social dynamics, providing a new perspective on the day-to-day lives of people in past societies and their agency in social changes. The study presented here demonstrated how skeletal data can provide new information on the social dynamics of nomadic Mongolian societies, offering several contributions to the use of entheses in activity and behavioral reconstructions.

Contributions of the Study

This study makes several contributions to the bioarchaeological study of activity, nomadic societies, and social dynamics. Entheses can be used to identify horse riders, as long as the necessary comparative groups are available. Horse riding can be used as a proxy for social dynamics in nomadic societies, allowing for new information to be brought to the study of social change. Changes in activity performance over the lifespan can provide new insights into social ages. Activity itself, not just its end products, can be symbolic and thus the study of its performance can offer a new perspective on power struggles and symbol contestations within societies.

Entheses in Behavioral Reconstruction

Despite many confounding factors and biological considerations, entheses can be used to identify performers of some activities. Comparative samples of "known" performers and non-performers are essential to any such study. It is only through the comparison of these samples that a suite of skeletal markers can be developed to separate performers of a specific activity from those of every other activity performed in a society. This method does not require the researcher to assume what muscles are used to perform an activity or to determine if the use of those muscles would result in the development of an enthesis. Although there are correlations with age and body size, the use of logistic regression equations does allow for the identification of both male and female horse riders in both Post-Medieval Britain and Mongolian societies.

Though there were horse riders in both of these societies, no universal equation could be used to identify horse riders in both. Each society required its own identification suite. The implication of this finding is that culturally-specific suites of features are needed to identify activity performers in different societies. Any "universal" suite is unlikely to be completely accurate for different societies and could potentially skew any cross-cultural analysis. Despite the difficulties of this lack of cross-cultural applicability, differences in how an activity is performed may allow for skeletal data to contribute to studies of cultural transmission of technology.

In addition to differences in how an activity is performed between cultures, there are also changes in the performance of activity over the lifespan. People enter different social ages over the course of their lifetime, with different responsibilities and expectations of age-appropriate behavior. This idea is rarely discussed in bioarchaeological activity reconstructions, though it has the potential to greatly change the interpretations of any results based on the use of entheses. If entheses can resorb and an activity is not continued throughout the lifespan, individuals who have stopped performing an activity regularly may appear to not have performed that activity at all. Samples with significantly different age profiles may appear to represent one group of performers and one of non-performers when in reality, one group may simply consist primarily of those for whom the performance of the activity in question is proper behavior while the other has transitioned to an age where it is not. Any attempt at behavior reconstructions of past societies requires examining how activity changed over the life course. Graphing the robusticity curves can provide necessary information on changes in activity over the lifespan and on the timing of social age transitions, data that is difficult to determine through other methods.

Social Dynamics in Mongolian Societies

By mapping changes in robusticity of horse riding markers over the lifespan for males and females in two Mongolian societies, differences not otherwise observable were seen between these samples. Archaeological evidence suggests that the Mongol society is more complex than the Xiongnu society. With increased complexity comes increased segmentation within social systems, including activity systems. This increased segmentation would be expected in the performance of an activity as symbolically important as horse riding and yet, any difference would have been unobservable without mapping robusticity over the life course.

The slight differences in the sexual equality of horse riding seen between the Xiongnu and Mongol period mirror the more extreme differences seen in burial data. This data suggests that there was a horizontal gender heterarchy in the Xiongnu period that transitioned to a vertical gender hierarchy by the Mongol period. Given that horse riding is symbolic to these societies, greater sexual inequality in horse riding might be expected in the Mongol period, however this was not found. This discrepancy may be due to horse riding being a symbol of both identity *and* power, thus access to riding would have to be negotiated between these two systems.

Activity as Symbol

The performance of an activity itself can be symbolic and thus, its performance can be used and manipulated like any other symbol. Therefore, who is performing a symbolic activity can inform on social changes within a society. This information traditionally has come from indirect inferences of material culture, often from mortuary data; however, this data has an inherent weakness compared to activity reconstructions from skeletal data. Whereas burial inclusions are chosen by others to represent how they want an individual remembered in a society, activity performance allowed individuals to manipulate how they themselves were perceived. As a result, the study of activity performance over the life span can provide new information on individuals' agency in social change. Activity performance can be treated as a symbol and can be used analytically like any other symbol, including as a proxy for social dynamics.

Future Work

This study provides two case studies of how activity can act as a proxy for social dynamics. However, in order to gain a better understanding of how horse riding relates to social dynamics, particularly in Mongolian societies, larger samples are necessary. Given the small sample sizes used in this study, sample bias is a large concern. A reanalysis with a larger sample and a non-riding Mongolian sample, preferably from the societies studied, would likely provide a more accurate riding equation and a better picture of changes in the sexual equality of riding over time. Bronze Age samples may provide the required "known" Mongolian non-riders. Samples with associated mortuary remains may also provide a clearer picture of what horse riding meant to these societies and how that may have been contested.

In addition to these sample-based considerations, there are biological concerns in the use of entheses for activity reconstruction that need to be addressed. There is still some debate about the relationship between regular muscle use and enthesial development and the idea of biological thresholds has not been tested. Both of these could be addressed with animal studies. A few long-term studies using a specific stereotyped activity on animals that develop entheses similar to humans could provide the necessary evidence for the use of these markers.

Furthermore, what muscles are used in the performance of any specific activity are still largely unknown. Studies using electromyography or surface electromyography to determine which muscles are contracting, and with how much force, would provide useful data on this point. This information could also be used for studies of thresholds needed for enthesial development in humans, settling the debate of whether entheses develop under normal or pathological physiological loads.

Lastly, if activities are symbolic and can be used as a proxy for social dynamics, there needs to be further testing of other activities in other societies. Other activities are likely to be symbolic in other societies, as well as being sufficiently unique compared to the rest of the activities performed by the population so as to make identifying activity performers from their skeletal remains possible. Fishing, rowing, some forms of dancing, various beautification processes, and different types of food preparation are some possible activities that may be worth investigating for such studies. If this premise that activity performance can be symbolic is correct, then it should hold for other activities in other societies, not just for horse riding. As long as an activity is symbolic, changes in its performance should follow the social dynamics of the associated symbol. Thus, allowing for the use of skeletal data to provide necessary, and often difficult to infer, information on who performed activity and what an activity meant to the people who performed it.

The performance of activities has meaning to people. Though its meaning can vary between societies and over time, activity performance can be manipulated and its meaning contested just like any other symbol. These changes and contentions provide insight into the social dynamics within societies. By using skeletal remains to directly identify activity performers, new information on the social organization, social dynamics, and symbolism of activity can be brought to bear on behavioral reconstructions, providing new insights on past societies.

REFERENCES

REFERENCES

Agarwal SC, and Grynpas MD. 1996. Bone quantity and quality in past populations. Anatomical Record 246(4):423-432.

Agresti A. 1996. An Introduction to Categorical Data Analysis. New York: Wiley.

al-Oumaoui I, Jiménez-Brobeil S, and du Souich P. 2004. Markers of activity patterns in some populations of the Iberian Peninsula. International Journal of Osteoarchaeology 14(5):343-359.

Angel JL, Kelley JO, Parrington M, and Pinter S. 1987. Life stresses of the free Black community as represented by the First African Baptist Church, Philadelphia, 1823-1841. American Journal of Physical Anthropology 74:213-229.

Anthony DW, and Brown DR. 2003. Eneolithic horse rituals and riding in the steppes: New evidence. In: Levine M, Renfrew C, and Boyle K, editors. Prehistoric steppe adaptation and the horse. Cambridge: McDonald Institute for Archaeological Research. p 55-68.

Barfield TJ. 1989. The Perilous Frontier. Tilly C, editor. Cambridge, MA: Basil Blackwell.

Barnard H. 2008. Suggestions for a *Chaîne Opératoire* of nomadic pottery sherds. In: Barnard H, and Wendrich W, editors. The Archaeology of Mobility. Los Angeles: Cotsen Institute of Archaeology, University of California. p 413-440.

Bass WM. 1995. Human osteology: A laboratory and field manual. Springfield, MO: Missouri Archaeological Society.

Benjamin M, and Ralphs JR. 1998. Fibrocartilage in tendons and ligaments - an adaptation to compressive load. Journal of Anatomy 193:481-494.

Benjamin M, Evans EJ, and Copp L. 1986. The histology of tendon attachments to bone in man. Journal of Anatomy 149:89-100.

Benjamin M, Kumai T, Milz S, Boszczyk BM, Boszczyk AA, and Ralphs JR. 2002. The skeletal attachment of tendons—tendon 'entheses'. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology 133(4):931-945.

Benjamin M, Toumi H, Ralphs JR, Bydder G, Best TM, and Milz S. 2006. Where tendons and ligaments meet bone: attachment sites ('entheses') in relation to exercise and/or mechanical load. Journal of Anatomy 208(4):471-490.

Berryman HE, and Symes SA. 1998. Recognizing gunshot and blunt cranial trauma through fracture interpretation. In: Reichs KJ, editor. Forensic Osteology. 2nd ed. Springfield, IL: Charles C. Thomas. p 333-352.

Billeck WT, et al. 2005. Inventory and assessment of human remains and funerary objects potentially affiliated with the Arikara in the National Museum of Natural History, Smithsonian Institution. Washington, D.C.: Repatriation Office, national Musem of Natural History, Smithsonian Institution.

Binderman I, Shimshoni Z, and Somjen D. 1984. Biochemical pathways involved in the translation of physical stimulus into biological message. Calcified Tissue International 36(supplement):S82-S85.

Binford LR. 1980. Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. American Antiquity 45(1):4-20.

Bonewald LF, and Johnson ML. 2008. Osteocytes, mechanosensing and Wnt signaling. Bone 42(4):606-615.

Bovin M. 1990. Nomads of the drought: Fulbe and Wodabee Nomads between power and marginalization in the Sahel of Burkina Faso and Niger Republic. In: Bovin M, and Manger L, editors. Adaptive strategies in African arid lands. Uppsala, Sweden: The Scandinavian Institute of African Studies. p 29-57.

Bradley R. 1998. The significance of monuments. London: Routledge.

Bridges PS. 1991. Skeletal evidence of changes in subsistence activities between the Archaic and Mississippian time periods in northwestern Alabama. In: Powell ML, Bridges PS, and Mires AMW, editors. What Mean These Bones? Studies in the Southeastern Bioarchaeology. Tuscaloosa: University of Alabama Press. p 89-101.

Bridges PS, Blitz JH, and Solano MC. 2000. Changes in long bone diaphyseal strength with horticultural intensification in west-central Illinois. American Journal of Physical Anthropology 112:217-238.

Brown JA. 2003. The Cahokia Mound 72-Sub 1 burials as collective representation. A deep-time perspective: Studies in symbols, meaning, and the archaeological record - Papers in honor of Robert L Hall 84(1 & 2):81-98.

Buikstra JE. 1995. Tombs for the living ... or ... for the dead: The Osmore ancestors. In: Dillehay TD, editor. Tombs for the living: Andean mortuary practices. Washington, D.C.: Dumbarton Oaks Research Library and Collection. p 229-280.

Buikstra JE, and Charles DK. 1999. Centering the ancestors: Cemeteries, mounds, and sacred landscapes of the ancient North American midcontinent. In: Ashmore W, and

Knapp AB, editors. Archaeologies of landscape: Contemporary perspectives. Oxford: Blackwell. p 201-228.

Capasso L, Pierfelice L, Michetti E, di Fabrizio A, and D'Anastasio R. 2004. Lesions linked to athletic activities in the ancient Roman population from Herculaneum (Italy, first century AD). Anthropologie 42(2):181-187.

Cardoso FA, and Henderson CY. 2010. Enthesopathy formation in the humerus: Data from known age-at-death and known occupation skeletal collections. American Journal of Physical Anthropology 141(4):550-560.

Chamay A, and Tschantz P. 1972. Mechanical influences in bone remodeling. Experimental research on Wolff's Law. Journal of Biomechanics 5(2):173-180.

Chang C. 2006. The grass is greener on the other side: A study of pastoral mobility on the Eurasian steppe of southeastern Kazakhstan. In: Sellet F, Greaves R, and Yu P-L, editors. Archaeology and Ethnoarchaeology of Mobility. Gainesville: University Press of Florida. p 184-200.

Chang C, and Koster HA. 1986. Beyond bones: Toward an archaeology of pastoralism. Advances in Archaeological Method and Theory. p 97-148.

Chapman NEM. 1997. Evidence for Spanish influence on activity induced musculoskeletal stress markers at Pecos Pueblo. International Journal of Osteoarchaeology 7(5):497-506.

Charles DK, and Buikstra JE. 2002. Siting, sighting, and citing the dead. In: Silverman H, and Small D, editors. The space and place of death. Arlington, VA: American Anthropological Association. p 13-25.

Conkey MW, and Spector JD. 1984. Archaeology and the study of gender. In: Schiffer MB, editor. Advances in archaeological method and theory. Orlando: Academic Press. p 1-38.

Cowie R, Bekvalac J, and Kausmally T. 2008. Late 17th- to 19th-century burial and earlier occupation at All Saints, Chelsea Old Church, Royal Borough of Kensington and Chelsea. London: Museum of London.

Crubézy E, Ricaut FX, Martin H, Erdenebaatar S, Coqueugnot H, Maureille B, and Giscard P-H. 2006. Inhumation and cremation in medieval Mongolia: analysis and analogy. Antiquity 80(310):894-905.

Crumley CL. 1999. Sacred landscapes: Constructed and conceptualized. In: Ashmore W, and Knapp AB, editors. Archaeologies of landscape: Contemporary perspectives. Malden, MA: Blackwell Publishers. p 269-276.

Currey JD. 2002. Bones: Structure and Mechanics. Princeton: Princeton University Press.

Davydova A (1996) The Ivolga Archaeological Complex. St. Petersburg: Center for Oriental Studies.

Di Cosmo N. 1994. Ancient Inner Asian nomads: Their economic basis and its significance in Chinese. The Journal of Asian Studies 53(4):1092-1126.

Di Cosmo N. 2002. Ancient China and Its Enemies. Cambridge: Cambridge University Press.

Drapeau MSM. 2006. Upper- and lower-limb skeletal muscle site variability in modern humans. American Journal of Physical Anthropology 129(S42):84.

Duncan RL, and Turner CH. 1995. Mechanotransduction and the functional response of bone to mechanical strain. Calcified Tissue International 57(5):344-358.

Erdenebaatar B. 1996. Socio-economic aspects of the pastoral movement patterns of Mongolian herders. In: Humphrey C, and Sneath D, editors. Culture and Environment in Inner Asia. Cambridge: The White Horse Press. p 58-110.

Erickson JD, Lee DV, and Bertram JEA. 2000. Fourier analysis of acetabular shape in Native American Arikara populations before and after acquisition of horses. American Journal of Physical Anthropology 113(4):473-480.

Fisher G, and Loren DD. 2003. Introduction: Embodying Identity in Archaeology. Cambridge Archaeological Journal 13(2):225-230.

Frost HM. 1987. Bone "mass" and the "mechanostat": a proposal. Anatomical Record 219(1):1-9.

Frost HM. 1990. Skeletal structural adaptations to mechanical usage (SATMU): 1. redefining Wolff's law: the bone modeling problem. The Anatomical Record 226:403-413.

Frost HM. 2001. Does the anterior cruciate have a modeling theshold? A case for the affirmative. Journal of Musculoskeletal and Neuronal Interactions 2(2):131-136.

Galtés I, Rodríguez-Baeza A, and Malgosa A. 2006. Mechanical morphogenesis: A concept applied to the surface of the radius. The Anatomical Record 288A(7):794-805.

Garofalo EM. 2004. The osteologic markers of horseback riding: An examination of two medieval English populations [Thesis]. Bradford, UK: University of Bradford.

Gilchrist R. 1999. Gender and Archaeology. London: Routledge.

Gray H. 1974. Gray's Anatomy. Philadelphia: Running Press Book Publishers.

Halcrow SE, and Tayles N. 2008. The bioarchaeological investigation of childhood and social age: Problems and prospects. Journal of Archaeological Method and Theory 15(2):190-215.

Hanks B. 2008. Reconsidering warfare, status, and gender in the Eurasian steppe Iron Age. In: Linduff KM, and Rubinson KS, editors. Are All Warriors Male? Lanham: AltaMira Press. p 15-34.

Hanks B. 2010. Archaeology of the Eurasian steppes and Mongolia. Annual Review of Anthropology 39:469-486.

Hastorf CA. 1991. Gender, space, and food in prehistory. In: Gero JM, and Conkey MW, editors. Engendering Archaeology. Cambridge: Basil Blackwell. p 132-159.

Hawkey DE, and Merbs CF. 1995. Activity-induced musculoskeletal stress markers (MSM) and subsistence strategy changes among ancient Hudson Bay Eskimos. International Journal of Osteoarchaeology 5(4):324-338.

Hendon JA. 2000. Having and holding: storage, memory, knowledge, and social relations. American Anthropologist 102(1):42-53.

Hollimon SE. 1992. Health consequences of sexual division of labor among Native Americans: The Chumash of California and the Arikara of the Northern Plains. In: Claassen C, editor. Exploring Gender Through Archaeology. Madison, Wisconsin: Prehistory Press. p 81-88.

Hollimon SE. 2000. Sex, health, and gender roles among the Arikara of the Northern Plains. In: Rautman AE, editor. Reading the Body. Philadelphia: University of Pennsylvania Press. p 25-37.

Honeychurch W. 2004. Inner Asian warriors and khans : a regional spatial analysis of nomadic political organization and interaction [dissertation]. Ann Arbor: University of Michigan.

Honeychurch W, and Amartuvshin C. 2006. States on horseback - The rise of Inner Asian confederations and empires. In: Stark M, editor. Archaeology of Asia. Cambridge: Blackwell. p 364.

Honeychurch W, and Amartuvshin C. 2007. Hinterlands, urban centers, and mobile settings: the "new" Old World archaeology from the Eurasian steppe. Asian Perspectives 46(1):36-64.

Hsieh Y-F, Robling AG, Ambrosius WT, Burr DB, and Turner CH. 2001. Mechanical loading of diaphyseal bone in vivo: The strain threshold for and osteogenic response varies with location. Journal of Bone and Mineral Research 16:2291-2297.

Humphrey C. 1979. The uses of genealogy: A historical study of the nomadic and sedentarised Buryat. In: pastorales LEéeads, editor. Pastoral production and society. Cambridge: Cambridge University Press. p 235-260.

Ibrahim F. 2004. No place like home: history, politics and mobility among a pastoral nomadic community in western India. Nomadic Peoples 8(2):168-190.

Jantz RL, and Owsley DW. 1984. Long bone growth variation among Arikara skeletal populations. American Journal of Physical Anthropology 63(1):13-20.

Johnson CM. 2007. A Chronology of Middle Missouri Plains Village Sites. Washington, D.C.: Smithsonian Institution Scholarly Press.

Joyce RA. 2001. Burying the dead at Tlatilco: Social memory and social identities. In: Chesson MS, editor. Social memory, identity, and death : anthropological perspectives on mortuary rituals. Washington, DC: American Anthropological Association. p 12-26.

Joyce RA. 2005. Archaeology of the Body. Annual Review of Anthropology 34:139-158.

Joyce RA, Davis W, Kehoe AB, Schortman EM, Urban P, and Bell E. 1993. Women's work: Images of production and reproduction in Pre-Hispanic southern Central America. Current Anthropology 34(3):255-274.

Keith K. 2005. Childhood learning and the distribution of knowledge in foraging societies. Archeological Papers of the American Anthropological Association 15(1):27-40.

Kelly RL. 1992. Mobility/Sedentism: Concepts, Archaeological Measures, and Effects. Annual Review of Anthropology 21:43-66.

Kent S. 1984. Analyzing activity areas. Albuquerque: University of New Mexico Press.

Kent S. 1989. And justice for all: The development of political centralization among newly sedentary foragers. American Anthropologist 91(3):703-712.

Kent S, editor. 1990. Domestic architecture and the use of space. Cambridge: Cambridge University Press.

Kent S. 1991. The relationship between mobility strategies and site structure. In: Kroll EM, and Price TD, editors. The Interpretation of Archaeological Spatial Patterning. New York: Plenum Press. p 33-59.

Kent S. 1999. Egalitarianism, equality, and equitable power. In: Sweely TL, editor. Manifesting Power. London: Routledge. p 30-48.

Keyser-Tracqui C, Crubézy E, and Ludes B. 2003. Nuclear and Mitochondrial DNA Analysis of a 2,000-Year-Old Necropolis in the Egyin Gol Valley of Mongolia. American Journal of Human Genetics 73(2):247-260.

Khazanov AM. 1984. Nomads and the Outside World. Goody J, editor. Cambridge: Cambridge University Press.

Kopytoff K. 1986. The cultural biography of things: Commoditization as process. In: Appadurai A, editor. The social life of things: Commodities in cultural perspective. Cambridge: Cambridge University Press. p 64-91.

Krader L. 1978. The origin of the state among the nomads of Asia. In: Claessen HJ, and Skalník P, editors. The Early State. The Hague: Mouton Publishers. p 93-107.

Kuijt I. 2000. People and Space in Early Agricultural Villages: Exploring Daily Lives, Community Size, and Architecture in the Late Pre-Pottery Neolithic. Journal of Anthropological Archaeology 19(1):75-102.

Kuijt I. 2001. Place, death, and the transmission of social memory in early agricultural communities of the near eastern Pre-Pottery Neolithic. In: Chesson MS, editor. Social memory, identity, and death : anthropological perspectives on mortuary rituals. Washington, DC: American Anthropological Association. p 80-99.

Lanyon LE, Magee PT, and Baggott DG. 1979. The relationship of functional stress and strain to the processes of bone remodelling. An experimental study on the sheep radius. Journal of Biomechanics 12(8):593-600.

Larsen CS. 1987. Bioarchaeological interpretations of subsistence economy and behavior from human skeletal remains. In: Schiffer MB, editor. Advances in Archaeological Method and Theory. San Diego: Academic Press, Inc. p 339-445.

Larsen CS. 2002. Bioarchaeology: The Lives and Lifestyles of Past People. Journal of Archaeological Research 10(2):119-166.

Levy JE. 1995. Heterarchy in Bronze Age Denmark: Settlement pattern, gender, and ritual. In: Ehrenreich RM, Crumley CL, and Levy JE, editors. Heterarchy and the Analysis of Complex Societies. Arlington, VA: American Anthropological Association. p 41-53.

Levy JE. 1999. Gender, power, and heterarchy in middle-level societies. In: Sweely TL, editor. Manifesting Power. London: Routledge. p 62-78.

Li KC, Zernicke RF, Barnard RJ, and Li AF. 1991. Differential response of rat limb bones to strenuous exercise. Journal of Applied Physiology 70(2):554-560.

Lieberman DE, Devlin MJ, and Pearson OM. 2001. Articular surface area responses to mechanical loading: effects of exercise, age and skeletal location. American Journal of Physical Anthropology 116:266-277.

Linduff KM. 2008. The gender of luxury and power among the Xiongnu in eastern Eurasia. In: Linduff KM, and Rubinson KS, editors. Are All Warriors Male? Lanham: AltaMira Press. p 175-211.

Little PD. 1985. Social differentiation and pastoralist sedentarization in northern Kenya. Africa 55(3):243-261.

Loitz BJ, and Zernicke RF. 1992. Strenuous exercise-induced remodelling of mature bone: relationships between in vivo strains and bone mechanics. Journal of Experimental Biology 170(1):1-18.

Lovell NC. 1989. Test of Phenice's technique for determining sex from the os pubis. American Journal of Physical Anthropology 79:117-120.

Makarewicz C, and Tuross N. 2006. Foddering by Mongolian pastoralists is recorded in the stable carbon (δ13C) and nitrogen (δ15N) isotopes of caprine dentinal collagen. Journal of Archaeological Science 33(6):862-870.

Martin RB, Burr DB, and Sharkey NA. 1998. Skeletal Tissue Mechanics. New York: Springer.

Matyas JR, Bodie D, Andersen M, and Frank CB. 1990. The development morphology of a “periosteal” ligament insertion: Growth and maturation of the tibial insertion of the rabbit medial collateral ligament. Journal of Orthopaedic Research 8(3):412-424.

Merbs CF. 1983. Patterns of Activity-Induced Pathology in a Candian Inuit Population. Ottawa, Canada: National Museum of Canada. 199 p.

Meskell LM. 2000. Writing the body in archaeology. In: Rautman AE, editor. Reading the Body. Philadelphia: University of Pennsylvania Press. p 13-21.

Milella M, Mariotti V, and Belcastro MG. 2011. You can't judge a book by its cover: The effects of age, sex and physical activity on entheseal changes in an Italian contemporary skeletal collection. Annual Meeting of the American Association of Physical Anthropologists. Minneapolis, MN. p 215.

Miles, A. 2010. A Post-medieval population from London: Excavations in the St Bride’s Lower Churchyard. Museum of London. Unpublished.

Miller D. 1982. Structures and strategies: An aspect of the relationship between social hierarchy and cultural change. In: Hodder I, editor. Symbolic and structural archaeology. Cambridge: Cambridge University Press. p 89-98.

Miniaev SS, and Sakharovskaia LM. 2008. An elite complex of Xiongnu burials in the Tsaraam Valley. Anthropology & Archeology of Eurasia 46(4):71-84.

Molleson TI, and Blondiaux J. 1994. Riders' bones from Kish, Iraq. Cambridge Archaeological Journal 4(2):312-316.

Molnar P. 2006. Tracing prehistoric activities: Musculoskeletal stress marker analysis of a stone-age population on the Island of Gotland in the Baltic sea. American Journal of Physical Anthropology 129(1):12-23.

Morgan D. 1986. The Mongols. Malden, MA: Blackwell Publishing.

Morgan D. 2007. The Mongols. Malden, MA: Blackwell Publishing.

Nicolella DP, and Lankford J. 2002. Microstructural strain near osteocyte lacuna in cortical bone *in vitro*. Journal of Musculoskeletal and Neuronal Interactions 2(3):261-263.

O'Connor S. 1990. Common Sense Dressage: An Illustrated Guide: Half Halt Press.

Onon U (2001) The Secret History of the Mongols. Richmond, Surray: Curzon Press.

Parker Pearson M. 1982. Mortuary practices, society and ideology: An ethnoarchaeological study. In: Hodder I, editor. Symbolic and structural archaeology. Cambridge: Cambridge University Press. p 99-113.

Peterson J. 1998. The Natufian hunting conundrum: spears, atlatls, or bows? musculoskeletal and armature evidence. International Journal of Osteoarchaeology 8(5):378-389.

Peterson JD. 2000. Labor patterns in the Southern Levant in the Early Bronze Age. In: Rautman AE, editor. Reading the Body. Philadelphia: University of Pennsylvania Press. p 38-54.

Pfaffenberger B. 2001. Symbols do not create meanings - activities do: Or, why symbolic anthropology needs the anthropology of technology. In: Schiffer MB, editor. Anthropological Perspectives on Technology. Albuquerque: University of New Mexico Press. p 77-86.

Phenice TW. 1969. A newly developed visual method of sexing the os pubis. American Journal of Physical Anthropology 30:297-302.

Rapoport A. 1990. Systems of activities and systems of settings. In: Kent S, editor. Domestic architecture and the use of space. Cambridge: Cambridge University Press. p 9-20.

Rautman AE. 1993. Resource Variability, Risk, and the Structure of Social Networks: An Example from the Prehistoric Southwest. American Antiquity 58(3):403-424.

Richards JE. 1999. Conceptual landscapes in the Egyptian Nile Valley. In: Ashmore W, and Knapp AB, editors. Archaeologies of landscape: contemporary perspectives. Malden, MA: Blackwell Publishers. p 81-100.

Rogers JD. 2007. The contingencies of state formation in Eastern Inner Asia. Asian Perspectives 46(2):249-274.

Rogers JD, Ulambayar E, and Gallon M. 2005. Urban centres and the emergence of empires in Eastern Inner Asia. Antiquity 79(306):801-818.

Rubin CT, and Lanyon LE. 1984. Regulation of bone formation by applied dynamic loads. Journal of Bone and Joint Surgery 66(3):397-402.

Ruff CB. 1987. Sexual dimorphism in human lower limb bone structure: relationship to subsistence strategy and sexual division of labor. Journal of Human Evolution 16(5):391-416.

Ruff CB, and Hayes WC. 1983. Cross-sectional geometry of Pecos Pueblo femora and tibiae - a biomechanical investigation. II. Sex, age and size differences. American Journal of Physical Anthropology 60:382-400.

Ruff CB, and Larsen CS. 1990. Postcranial biomechanical adaptations to subsistence strategy changes on the Georgia Coast. In: Larsen CS, editor. The Archaeology of Mission Santa Catalina de Guale, 2. New York: Anthropological Papers of the American Museum of Natural History. p 94-120.

Ruff CB, Scott WW, and Liu AY-C. 1991. Articular and diaphyseal remodeling of the proximal femur with changes in body mass in adults. American Journal of Physical Anthropology 86:397-413.

Ruff CB, Walker A, and Trinkaus E. 1994. Postcranial robusticity in Homo. III: Ontogeny. American Journal of Physical Anthropology 93:35-54.

Ruff C, Holt B, and Trinkaus E. 2006. Who's afraid of the big bad Wolff?: Wolff's law and bone functional adaptation. American Journal of Physical Anthropology 129(4):484-498.

Salzman PC. 2004. Pastoralists: Equality, hierarchy, and the state. Boulder, CO: Westview Press.

Saxon LK, and Turner CH. 2005. Estrogen receptor β: the antimechanostat? Bone 36(2):185-192.

Shanks M, and Tilley C. 1982. Ideology, symbolic power and ritual communication: A reinterpretation of Neolithic mortuary practices. In: Hodder I, editor. Symbolic and structural archaeology. Cambridge: Cambridge University Press. p 129-154.

Shelach G. 2008. He who eats the horse, she who rides it? Symbols of gender identity on the eastern edges of the Eurasian steppe. In: Linduff KM, and Rubinson KS, editors. Are All Warriors Male? Lanham: AltaMira Press. p 93-109.

Shombodon D. 1996. The division of labour and working conditions of herdsmen in Mongolia. In: Humphrey C, and Sneath D, editors. Culture and Environment in Inner Asia. Cambridge: The White Horse Press. p 207-237.

Sneath D. 1999. Kinship, networks and residence. In: Humphrey C, and Sneath D, editors. The End of Nomadism? Durham: Duke University Press. p 136-178.

Sofaer J. 2011. Towards a social bioarchaeology of age. In: Agarwal SC, and Glencross BA, editors. Social Bioarchaeology. Malden, MA: Wiley-Blackwell. p 285-311.

Spector JD. 1983. Male/Female task differentiation among the Hidatsa: Toward the development of an archaeological approach to the study of gender. In: Albers P, and Medicine B, editors. The Hidden Half. Washington, DC: University Press of America. p 77-99.

Stadelmann VA, Terrier A, and Pioletti DP. 2008. Microstimulation at the bone-implant interface upregulates osteoclast activation pathways. Bone 42(2):358-364.

Steen SL, and Lane RW. 1998. Evaluation of habitual activities among two Alaskan Eskimo populations based on musculoskeletal stress markers. International Journal of Osteoarchaeology 8(5):341-353.

Stenning DJ (1994) Savannah Nomads. Munster-Hamburg: LIT Verlag.

Stine LF. 1992. Social differentiation down on the farm. In: Claassen C, editor. Exploring Gender Through Archaeology. Madison, Wisconsin: Prehistory Press. p 103-109.

Stirland AJ. 1998. Musculoskeletal evidence for activity: problems of evaluation. International Journal of Osteoarchaeology 8(5):354-362.

Stoodley N. 2000. From the cradle to the grave: Age organization and the early Anglo-Saxon burial rite. World Archaeology 31(3):456-472.

Tan SD, de Vries TJ, Kuijpers-Jagtman AM, Semeins CM, Everts V, and Klein-Nulend J. 2007. Osteocytes subjected to fluid flow inhibit osteoclast formation and bone resorption. Bone 41(5):745-751.

Tavakolian B. 1984. Women and socioeconomic change among Sheikhanzai nomads of Western Afghanistan. Middle East Journal 38(3):433-453.

Terada K. 2000. Comparison of head movement and EMG activity of muscles between advanced and novice horseback riders at different gaits. Journal of Equine Science 11(4):83-90.

Terada K, Mullineaux D, Lanovaz J, Kato K, and Clayton HM. 2004. Electromyographic analysis of the rider's muscles at trot. Equine and Comparative Exercise Physiology 1(3):193-198.

Thomas J. 1990. Monuments from the inside: The case of the Irish megalithic tombs. World Archaeology 22(2):168-178.

Thomas N. 1991. Entangled objects. Cambridge, Mass.: Harvard University Press.

Tomka SA. 1993. Site abandonment behavior among transhumant agro-pastoralists: the effects of delayed curation on assemblage composition. In: Cameron CM, and Tomka SA, editors. Abandonment of settlements and regions. Cambridge: Cambridge University Press. p 11-24.

Toyne JM. 2003. Musculoskeletal stress markers (MSM) and weaving activities at a prehistoric coastal site in Peru. American Journal of Physical Anthropology 120(S36):211.

Trinkaus E, Churchill SE, and Ruff CB. 1994. Postcranial robusticity in Homo. II: Humeral bilateral asymmetry and bone plasticity. American Journal of Physical Anthropology 93:1-34.

Tseveendorj D, Bayar D, Tsevendagva Y, and Ochirkhuyag T. 2003. Монголын Археологи. [Mongolian Archaeology]. Ulaanbaatar, Mongolia: Mongolian Academy of Sciences.

Villotte S, Castex D, Couallier V, Dutour O, Knüsel CJ, and Henry-Gambier D. 2010. Enthesopathies as occupational stress markers: Evidence from the upper limb. American Journal of Physical Anthropology 142(2):224-234.

Weiss E. 2003. Understanding muscle markers: Aggregation and construct validity. American Journal of Physical Anthropology 121(3):230-240.

Weiss E. 2004. Understanding muscle markers: Lower limbs. American Journal of Physical Anthropology 125(3):232-238.

Weiss E. 2007. Muscle markers revisited: Activity pattern reconstruction with controls in a central California Amerind population. American Journal of Physical Anthropology 133(3):931-940.

Weiss E, Corona L, and Schultz B. 2012. Sex differences in musculoskeletal stress markers: Problems with activity pattern reconstructions. International Journal of Osteoarchaeology 22(1):70-80.

Wells PS. 1998. Identity and Material Culture in the Later Prehistory of Central Europe. Journal of Archaeological Research 6(3):239-298.

Wendrich W, and Barnard H. 2008. The archaeology of mobility: Definitions and research approaches. In: Barnard H, and Wendrich W, editors. The Archaeology of Mobility. Los Angeles: Cotsen Institute of Archaeology, University of California. p 1-21.

Wengrow D. 2006. The Archaeology of Early Egypt. Yoffee N, editor. Cambridge: Cambridge University Press. 325 p.

Wescott DJ. 2001. Structural Variation in the Humerus and Femur in the American Great Plains and Adjacent Regions: differences in subsistence strategy and physical terrain [Dissertation]. Knoxville: University of Tennessee.

Wilczak CA. 1998. Consideration of sexual dimorphism, age, and asymmetry in quantitative measurements of muscle insertion sites. International Journal of Osteoarchaeology 8(5):311-325.

Woo SL, Kuei SC, Amiel D, Gomez MA, Hayes WC, White FC, and Akeson WH. 1981. The effect of prolonged physical training on the properties of long bone: a study of Wolff's Law. Journal of Bone and Joint Surgery 63(5):780-787.

Wood JW, Milner GR, Harpending HC, and Weiss KM. 1992. The osteological paradox. Current Anthropology 33(4):343-370.

Wright J. 2006. The adoption of pastoralism in Northeast Asia: Monumental transformation in the Egiin Gol Valley, Mongolia [dissertation]. Boston: Harvard University.

Wright J. 2007. Organizational principles of Khirigsuur monuments in the lower Egiin Gol valley, Mongolia. Journal of Anthropological Archaeology 26(3):350-365.

Wright J, Honeychurch W, and Amartuvshin C. 2009. The Xiongnu settlements of Egiin Gol, Mongolia. Antiquity 83(320):372-387.

You L, Temiyasathit S, Lee P, Kim CH, Tummala P, Yao W, Kingery W, Malone AM, Kwon RY, and Jacobs CR. 2008. Osteocytes as mechanosensors in the inhibition of bone resorption due to mechanical loading. Bone 42(1):172-179.

Zumwalt A. 2006. The effect of endurance exercise on the morphology of muscle attachment sites Journal of Experimental Biology 209(3):444-454.