
December 2015

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Recommended Citation

Alioto, Anna (2015) "Controversy in Skeletal Biology: the Use of Pathological and Osteological Markers as Evidence for Activity Patterns," *The Hilltop Review*. Vol. 8 : Iss. 1 , Article 19.

Available at: <https://scholarworks.wmich.edu/hilltopreview/vol8/iss1/19>

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Controversy in Skeletal Biology: the Use of Pathological and Osteological Markers as Evidence for Activity Patterns

Runner-Up, 2015 Graduate Humanities Conference

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-Introduction-

In recent decades, work on the topic of skeletal biology has been increasingly important. Despite its origins in biological anthropology in the early twentieth century with the work of Franz Boas, Aleš Hrdlička and others, recent work in paleoanthropology, the creation of bioarchaeology and the continuing interest in human biology has pushed studies on the human skeleton further than ever before. As with any studies that deal with the past, these advances oftentimes pose issues and controversies within the scientific and academic communities. One of these major advances and controversial topics in skeletal biology is the use of osteological and pathological markers as evidence for activity patterns within individuals and populations (Jurmain et al., 2011). Because of early studies on the differences between skeletal populations in pre- and post- agricultural communities, skeletal biologists have noticed that the amount of physical activity as well as activity patterns can leave stress markers on the bone (Ruff et al., 1984). As a result, skeletal biologists among others have turned their attention to what could possibly be another way to try to reconstruct past human biology and culture.

While the majority of biological anthropologists agree that there is a correlation between the skeletal system, stress and physical activity, there is much debate on how to standardize methodology, establish definitive markers and relate these biological aspects to specific cultural traits (Buikstra and Pearson, 2006). As a result, studies on this topic have brought to light questions about the practicality and accuracy of such an examination. (Jurmain et al, 2011). This paper seeks to address the controversy on this topic, critically analyze it and make an argument for how activity patterns could be utilized effectively within the biological anthropological community if various recommendations were put into place. Through an analysis of historic and current literature on the topic, the paper will highlight why this topic is important yet controversial within the biological anthropological community, give a critical analysis on the importance of this topic within the field of skeletal biology, offer solutions to help alleviate the controversy, standardize the methodology and finally reestablish the underlying issues with studying the past.

-Types of Activities-

One of the reasons why the use of pathological and osteological markers as evidence for activity patterns is important and could be extremely beneficial to the scientific community is that it offers a way to recreate how much physical activity past communities engaged in and the types of activities they performed based on merely the human skeleton. Because almost all of the research conducted in biological anthropology looks at past populations, anything that can be discovered from bones creates an important link between the past and the present. Multiple scientists researched this topic over the past few decades and they have mostly agreed upon the types of information that can be taken from skeletal material in regards to activity. One of the major types of activities that was first researched by skeletal biologists was the difference in bone shapes, more specifically long bones between pre- and post-agricultural societies (Ruff et al, 1984). Significant work in this topic arose with Larsen et

al.'s 1984 research regarding structural changes in the femur with the transition to agriculture on the Georgian coast (Ruff et al, 1984). This specific study looked at the cross-sectional geometric patterns on the femur as an indicator of the change in stress on the body between pre- and post- agriculture (Ruff et al, 1984). In conjunction with this development, additional researchers looked at other ways in which skeletal information could inform about levels of and specific activities. One of these ideas was looking at the differences between activity patterns/stress on one side of the body versus the other (Auerbach and Raxter, 2008). Studies such as Auerbach and Raxter's (2008) work on patterns of bilateral asymmetry on the clavicle demonstrates how it is possible that there could be wear on the bones, in their case the clavicle, that does not match on both sides of the body. In other words, through their study and many others, it was found that in the analysis of activity patterns among populations, there is oftentimes a difference in osteological/pathological markers, which is attributed to a favoring of one side of the body over the other (Auerbach and Raxter, 2008).

In the subsequent decades, there has been a transition within this topic from a more generalized discussion of activity patterns to a more intricate and conclusive one. The type of activity pattern that really epitomizes this idea is the use of activity patterns in relation to sexual dimorphism, the differences between males and females, among labor patterns (Villotte and Knusel, 2014). Many researchers have looked at osteological/pathological markers between the sexes and have often attributed differences to the social differences between the sexes. Studies have been conducted such as Havelkova et al.'s "Enthesopathies and Activity Patterns in the Early Medieval Great Moravian Population: Evidence of Division of Labour" (2011) which looks at enthesopathies and bone remodeling between the sexes from two different sites and lifestyle patterns between two different social groups, those from the castle and the hinterlands. This type of activity reconstruction has been used mostly by bioarchaeologists in order to reconstruct aspects of culture from past societies but this is also one of the main reasons why such markers have been called into question. Recently, methodology used to score the markers is oftentimes subjective and based on the experience and judgment calls of the bioarchaeologists. (Havelkova et al, 2011). As a result, when attempting to reconstruct life in past cultures, it is important to create the best methodology possible in order to address these issues in an accurate way.

Other activities that have been used in this later period of activity reconstruction are examinations of the development of generalized motion patterns such as those present when riding horseback or throwing a spear (Larsen, 1997). Larsen (1997), among others, looked at such generalized activity as possibly ways to reconstruct culture in his book: *Bioarchaeology: Interpreting behavior from the Human skeleton*. Most recently, skeletal biologists and especially bioarchaeologists have tried to push the boundaries even further by reconstructing specific physical activities from bone in conjunction with other methods of data collecting such as archaeology (Baker et al., 2012). One of the best examples of this type of reconstruction is Baker et al's (2002) work on a woman from the medieval city of Polis in Cyprus. Through both the bioarchaeological as well as archaeological data, they were able to pinpoint her specific occupation as being that of a seamstress (Baker et al., 2012). Based on this knowledge, activity patterns were reconstructed and were found to corroborate this data (Baker et al., 2012).

-Differences Between Markers-

Before delving into the categories, it is prudent to explain why these two categories, osteological and pathological are separated into two distinct ones even when there has been much overlap between the two. In its most simplistic form, the creation of these two categories is representative of the difference between wear and tear on the bones versus not. Osteological markers focus more on the build-up of compact bone such as the robusticity in musculoskeletal markers or the healing process of fractures (Knusel, 2000). Pathological

markers, on the other hand, look at more of the wear and tear process that occurs on bones (Buikstra and Beck, 2006). Rather than focusing on how bone material is recreated and rebuilt because of activity, pathological markers look at how such activities destroy bone and its connecting tissue.

-Osteological Markers-

In order to completely understand how such activity patterns are to be reconstructed using skeletal data, it is important to point out and explain what types of markers, both osteological and pathological, have been used by skeletal biologists to make these reconstructions. Beginning with osteological markers, there is a multitude of different methodologies that skeletal biologists have adapted over the years. The easiest one to decipher on bone, using the naked eye, is asymmetry in the bones. This asymmetry is caused by a variety of different factors, but is most often attributed with a constant repetitious motion, which allows for a stronger build-up of compact bone (Larsen, 1997). While this simply means unevenness in the bones, whether between different bones or on sections of a single bone, there is a variety of different methods that are used which fall under this category (Larsen, 1997). The one that is most often used when looking at the development of asymmetrical bones is cross-sectional geometry and loading modes (Larsen, 1997). This process involves taking a cross-section of the bone in question and looking at the way the bone has been shaped over time (Knusel, 2000). Not only would the researcher look at the cross section to understand shape but they would also look at the length of the shaft, which depicts which loading modes and physical actions created the shape seen in the cross-section of the bone (Maggiano et al., 2008).

Depending on the activities, researchers such as Larsen and Ruff have categorized five different loading modes, which affect the shape of the bone demonstrated by cross-sectional geometry (Ruff et al., 1984) (Larsen, 1997). These include twisting, compression, bending, tension and shear or fracture (Larsen, 1997). All of these modes represent what can happen to bone when impacted by different types of stress from physical activities. The last one, shearing or fracture, is not only one of the most common loading modes but also overlaps two different methodologies in regards to reconstructing activity patterns. It fits within cross-sectional geometry and asymmetry because it is an example of how a loading mode could influence the cross-sectional shape of the bone e.g. if the bone is sheared when the bone repairs itself, then it mostly likely will have a different cross-sectional shape. It also straddles the next category of markers, which is about fractures.

Another marker oftentimes used in order to reconstruct activity patterns, yet is more difficult to attribute to physical activity is the analysis of fractures (Buikstra and Beck, 2006). Fractures, which come in different forms such as healed, unhealed, partially healed and infected, can be used to determine activity patterns (Jurmain et al., 2011). An example of this is the presence of multiple fractures in the same place that have re-healed over time. This is mostly interpreted as evidence for frequent use and/or stress of that particular bone in a repetitive and constant manner (Larsen, 1997). While this variable seems like a plausible way in which to determine activity patterns, in reality, it is oftentimes more difficult. Depending on the quality of healing i.e., how long ago it healed as well as other factors such as frailty etc., specific fractures might not be the result of activity patterns at all but rather other influences such as pathology, accidental injury or violence (Larsen, 1997).

This uncertainty is also oftentimes seen in the next category of osteological markers, which is articular joint wear and tear (Buikstra and Beck, 2006). It is mostly attributed to either a particular general motion such as walking long distances or a collection of motions such as those seen in the development of agriculture (Larsen, 1997). The most common example of this wear and tear is the development of osteoarthritis, which is the degradation of joint cartilage (Buikstra and Beck, 2006). In severe cases, the cartilage will wear away until

all that is left are the bones, which then rub against each other when the joint is used, causing severe pain (Buikstra and Beck, 2006). If the joint is used often enough after the destruction of cartilage, friction occurs between the bones which makes the bone surfaces shiny, a process called eburnation. Similar to fractures, this particular method is oftentimes faulty in regards to activity pattern reconstruction and is a machination of other factors such as pathology, predisposition, and age (Knusel, 2000).

The final osteological marker considered in the reconstruction of activity patterns is musculoskeletal stress markers (will also be referred hereto as MSM), also called enthesal changes (Villotte and Knusel, 2003). These markers refer to the changes in specific sites of bones where muscles attach to them (Villotte and Knusel, 2003). Research has demonstrated that these areas oftentimes change in regards to the stress and activity placed on the body (Stefanovic and Porcic, 2013). These are oftentimes scored based on degree of robustness and demonstrate the build-up of bone in order to accommodate the growing muscle. This particular type of marker has increased in popularity recently in regards to these studies as it has looked at areas in which pathology and age have a lesser effect than other such as fractures or osteoarthritis (Villotte and Knusel, 2003). That being said, there is still much debate amount the types and levels of activities that can be determined from such markers (Stefanovic & Procic, 2013).

-Pathological Markers-

The second approach to evaluating activity consists of pathological conditions and trauma. This particular group has not been as common as osteological indicators in regards to activity pattern reconstruction because of the various outside influences and uncertainty (Jurmain et al., 2011). The two major aspects of this group is osteoarthritis, which has been explained above and osteophytosis, which the accumulation of bone spurs, and the creation of bony projections as a result (Buikstra and Beck, 2006). Similar to the discussion about osteoarthritis in the previous section, both of these conditions rely on other factors such as age, health, diet etc. which could affect the amount of osteoarthritis or the development of osteophytosis rather than just activity patterns (Jurmain et al., 2011). Past research, which has looked at these types of pathological conditions oftentimes, does not discuss much about these other factors, which therefore has created much skepticism and controversy within the biological anthropological community. On the other hand, biological anthropologists have recognized the need for the evaluation of these other variables in relation to these pathological conditions and new research is coming out currently but as of yet is still inconclusive (Jurmain et al., 2011).

-Previous and Current Literature-

In order to fully understand why there is so much controversy specifically surrounding the issue of reconstructing activity patterns from human skeletal material, it is necessary to address the historic and current literature regarding this topic. Much, if not all, of the research on the reconstruction of activity patterns from human skeletal material is the result of only a few decades worth of work. As mentioned in the section on types of activity patterns that can be reconstructed, historic and current literature can be divided into two different sections, one that looks at more generalized patterns and those that are more specific. In order to cement the importance of the literature, some of the previous points will be reiterated and elaborated further. Studies about activity reconstruction from skeletal material began to gain popularity in the early 1980s with works like Ruff et al's, (1984) research regarding structural changes in the femur with the transition to agriculture on the Georgian coast. As mentioned earlier, this work is one of the first ones that recognized that there were patterns within the skeletal record that could be used to reconstruct patterns of physical activity among individuals (Ruff et al., 1984). It is also more recognizable in looking at cross-sectional analysis and attempts to

standardize its methodology and decrease margin of error by looking at two different human population lifestyles, pre-agricultural, and post-agricultural (Ruff et al., 1984). Since these beginning steps, the evolution of this topic has taken a drastic step towards trying to reconstruct specific activity patterns and subsequent occupations.

In the present era i.e., from 2010 onward, there has been a push to really understand and develop the argument for sexual dimorphism within population as shown by Havelkova et al.'s (2011) article. As a result, the idea that sexual division of labor can be indicated from skeletal markings on the bones has become a popular research topic. This article also demonstrates how in the past few years, the reconstruction of activity patterns based on human skeletal remains has been called into question. At the same time, this topic has become increasingly important to other fields outside of anthropology such as the medical or forensic fields. Godde and Taylor's (2011) article looks at the question of obesity and what kind of stress that puts on the skeletal material. This article among others similar to it, have been used in current population studies in order to combat what are seen as huge issues within society such as the obesity epidemic. Yet, like other research of its time, it too is being called into question in regards to similar issues, such as lack of consideration for specific variables, which are oftentimes mentioned in the research that looks at past populations. In regards to that specific examples, anthropologists such as Villotte and Knusel reviewed and critiqued Godde and Taylor's (2011) research arguing that they did not consider important variables such as age at death and also that their conclusions are too far-reaching for the science that is currently developed on this issue.

-Issue for Anthropologists-

There are many different reasons why the reconstruction of activity patterns based on osteological and pathological markers is controversial in the biological anthropological community. While many of them span different topics, the majority of the major critiques can be narrowed down into two different sections; one, the issue with samples and two, incomplete or dysfunctional methodology (Meyer et al., 2011). In regards to the issues with samples, most of the critiques revolve around the lack of strong sample sizes within a population. Since the majority of sample sizes with the skeletal biology research and especially bioarchaeology research are small to begin with because of preservation, legal issues etc., this critique is present in almost every methodology on the analysis of human skeletal material (Buikstra and Beck, 2006). What is somewhat unique to activity patterns is the use of these sample sizes to make broad assumptions not only about that particular population, but also across a multitude of different populations (Meyer et al., 2011). It is oftentimes coined as the individual versus population debate and has had a constant presence in anthropology since early anthropologists like Franz Boas. Can researchers make broad conclusions about one individual's activity pattern reconstruction to other individuals in that population? Can even that population be used as a comparison against other populations that show similar markers? These are questions that are constantly being considered and in accordance, the methodology is being reevaluated.

The other major topic is the problem with incomplete or dysfunctional methodology. In some ways, this topic connects to the previous one as oftentimes sample sizes are to blame for some of the reasons why the methodology is lacking (Meyer et al., 2011). In regards to the specific methodology used for the reconstruction of activity patterns, the major critique demonstrated by the writings of Meyer et al.'s (2011) work on "Tracing patterns of activity in the human skeleton: an overview of methods, problems and limits of interpretation" argues that the majority of methods created in reconstructing activity patterns do not 'truly conform' to the standards of the field. Specific examples of this non-conformist approach include the neglect of other possible explanations for data results such as disregarding other variables that essentially could impact data or are even the cause of data results (Meyer et al., 2011). An

illustration of this critique as pointed out by Meyer et al. is the issue of sexual dimorphism in regards to reconstructing physical activity. The authors argue that in some instances the differences seen in bone markers between the sexes could in fact be sexual dimorphism within the *Homo sapiens* species rather than between cultural populations (Meyer et al., 2011). As a result, many authors like Meyer et al. argue that much of the methodology that has been created needs to be evaluated and standardized before this topic should be developed further.

-Why Is It Still Useful?-

Despite the controversy and issues surrounding this topic, it remains a useful one within biological anthropological research. As current research demonstrates, many of the issues with past reconstruction of activity lies in the inadequate or nonexistent accounting of various variables that in fact affect the development of stress on the skeletal system (Knusel, 2000). The following is my critical analysis of many of the variables that can affect the amount of stress put on the skeletal system and therefore is crucial in regards to any type of research on this topic. I also include recommendations when analyzing of some of the variables that do not seem to have been considered by researchers, as they may help fix some of the problems surrounding this issue. The first variable is age at death. The effect that age has on the body, more specifically the skeletal system, is known in most cases as an increase in age-related effects over time. In other words, the older an individual is, the more likely their bones lose density and strength (Larsen, 1997). As a result, this has an enormous influence on activity reconstruction not only because of the types of activities that produced changes on the bone but also whether or not such activities can be attributed to a population on a wider scale. Researchers who study this topic such as Villotte and Knusel in their (2013) article, "Understanding Enthesal Changes: Definition and Life Course Changes", have understood the importance that the determination of age plays regarding the reconstruction of activity patterns. The next factor to consider is sex. As mentioned previously, sex and sexual dimorphism are commonly studied features in this topic, and some researchers have demonstrated that there are differences in stress markers between males and females.

Another variable to consider is body size in relation to osteoarthritis. While body size is more difficult to ascertain as in past populations since all that is left is the skeleton, if other factors such as stature are taken into account along with the osteoarthritis, it is possible to get a better understanding or a more accurate idea about these activity patterns in individuals (Buikstra and Beck, 2006). Body type and stature could affect the development and growth of the bones in which people with a bigger body type and bigger bones could handle more stress than those who could not (Knusel, 2000). If so, it would be inaccurate to compare activity markers from different individuals in a one-to-one correlation and make general statements about it if perhaps one person could handle more stress than the other could. In accordance with this thinking, there are other variables of similar standing such as diet and health. The amount and types of foods that are eaten as well as the overall health, including pathology and trauma, of the individual have a huge impact on activity reconstruction and once again, it would be inadequate to make general statements about it without considering these factors. That being said, some of the current methodology acknowledges these variables yet it is not as popular as age or sex (Jurmain et al., 2011).

The final two variables, ancestry and culture can also be grouped together in most past populations; as migration of individuals was not as widespread as it is today and culture therefore was most likely linked ancestrally. These two factors really have not been considered within the literature yet could offer valuable insights into the reconstruction of activity patterns. Ancestry could be determined using genetics and studies on human variation among populations to determine whether or not individuals are more adapted or predisposed to different types of activities or pathological conditions. This is especially important for osteoarthritis as genetics and ancestral patterns can, to a certain extent,

demonstrate the predisposition of certain populations to osteoarthritis (Buikstra and Beck, 2006). The final variable that should be looked at is culture. A researcher should look at how the society or culture as a whole views levels of stress and types of activities based on these markers. It could be combined with other data such as archaeological or historical in order to get a more accurate picture such as Baker et al.'s example of the seamstress from Cyprus.

-Methodology and Recommendations-

Because of this and other critiques mentioned by the literature, a reconstruction of methodology is in order. To fully accomplish this, three major things must be taken into account. The first of which is the development of larger samples sizes. While this is more difficult in the study of archaeological specimens, I would recommend using some more recent samples such as those in the past few centuries, which oftentimes have more individuals and better preservation in order to first create a methodology which then could be applied to samples that have less individuals as a result of preservation, legal or recovery issues. The second part of this methodology would be an emphasis on a multi-variable approach using at least three of the above mentioned variables such as sex, age etc. in order to make better implications and reconstructions about activity patterns. The final part would be an emphasis, clarification and alleviation of the problem of reconstructing activity patterns based on the individual versus population debate. In other words, it would be better to separate the conclusions made about the reconstruction of activity patterns into two groups, those that look at specific individuals and those that look at the same data on a population wide scale.

In accord with this ideal methodology are my recommendations for the future development of this topic in the biological anthropological community. These two recommendations would hopefully be able to help decrease some of the controversy surrounding this topic. To reiterate, my first recommendation is the use and recognition of the fact that a multitude of outside variables that can affect the reconstruction of such activities. The second is having better communication within the community in order to establish a generalized methodology as well as pose any new research as tentative until other researchers are able to either reconstruct the results or build on such information with further research.

-The Controversy-

Even though there are smaller controversies or issues that surround this topic within the biological anthropological community such as the lack of a standard methodology or large sample sizes, the use of activity markers as reconstructions of activity also touches on two larger issues outside the field of anthropology. Many people, who study or are interested in the past, understand the concerns that frame all such studies and how problematic they can be especially within an academic setting. The underlying issue that surrounds any study concerning the past is the lack of complete objectivity and as a result, the use of researcher subjectivity. In other words, because the past is never completely clear, anyone who studies it must employ a degree of subjectivity in order to pursue their work such as using educated guesses or analytical methods. In the case of this paper's example, the use of skeletal markers to reconstruct activity, anthropologists employ a variety of techniques such as a scoring system, which they use to 'score' the amount of stress or robusticity placed on a section of a bone that has a muscle attachment. While this issue seems insurmountable, it has been proven here in anthropology as well as other fields that methods can be used to decrease the distance between what is known about the past and what has yet to be discovered. The other controversy which affects studies outside biological anthropology is the issue with comparing today's health to that of the past. In accordance with the previous concern about studying the past, studying health both in the present and in the past always poses some questions, many of which have not yet been solved. One of the more recent examples is the emergence of the so-

called popular 'Paleo Diet'. While it is an acceptable trend to the public, there are still many questions that speak to the validity of the diet as something acceptable to present human biological standards. In other words, researchers are questioning the effectiveness and healthiness of the diet, as current human biology does not match that of our human ancestors. The same thing can be said for physical activity and the comparison between the past to the present. Ultimately, both of these examples rely heavily on our understanding of past health issues, something which is still problematic and therefore presents controversy in not only in an academic sphere but also in a public one.

-Conclusion-

Overall, the reconstruction of activity patterns within the biological anthropology community, spanning disciplines such as bioarchaeology, skeletal biology, paleopathology etc., is a topic surrounded by many questions and a lot of controversy. Historic and current literature demonstrates not only the direction this topic has taken but also the problems that are the result of it. Through my recommendations, most notably the use of a multivariable analysis, I believe that the reconstruction of activity patterns based on human skeletal remains is not only still important to the anthropological community but also creates a stronger methodology in which these patterns can be reconstructed, bringing anthropologists one step closer to unlocking the murkiness of the past.

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