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ASSESSING OPPONENS ENTHESES MORPHOLOGY IN MODERN HUMANS: IMPLICATIONS FOR PALEOLITHIC STONE TOOL BEHAVIOR INFERENCE

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ABSTRACT

Inferring soft tissue anatomy and reconstructing extinct behaviors from muscle attachment sites (entheses) on dry bones is a common practice among paleontologists. Paleolithic stone tool behaviors are assessed using this method on fossil hominin hand bones. Little is known, however, about how or even whether the morphologies of the entheses of muscles are affected by their morphology or activity regimes, particularly in the hand. The size and shape of the opponens entheses of modern humans were evaluated using opponens muscles from a sample of modern humans. In terms of enthesal morphology and behaviorally-influenced muscle architecture, we found no consistent relationship. Fossil hominins cannot be inferred to have exhibited patterns of behavior, such as stone tool making, based on these entheses.

Key words: human, Muscle, Hand, Architecture.

INTRODUCTION

Paleontologists and biologists often lack sufficient data from which to reconstruct past populations' anatomy, physiology, and behavior. The fossils and artifacts left behind by previous generations are searched for information about their lives. An osteological feature called an enthesis is a site where soft tissues attach to each other, and those entheses provide insights into the behavior of past populations by reconstructing soft tissue anatomy. Indications of muscle anatomy and physiology are thought to be reflected in entheses, since they are visible on bone [1–6].

Due to their physical connections to muscles and tendons, and their large variability in size and shape between individuals, entheses are often used as a direct inferential basis for reconstructing muscle anatomy of extinct individuals, past behaviors, and, at times, even the degree to which these behaviors were carried out [7–13]. Human evolution is thought to have been influenced by the

advent of stone tool usage by our ancestors as a cultural shift and an impetus for other influential changes [14–17].

It is difficult to pinpoint the exact origins of hominin stone tool behaviors and the taxa that produced and used them because of a sparse fossil record. Muscle architecture of stone tool behaviors is routinely estimated using the hypothesis that enthesal morphology and muscle anatomy are directly related [18–23].

Some fossil hominins have then been analyzed based on their muscle reconstructions to suggest how they used tools. Individuals or species simultaneously acquire cognitive and motor abilities based on these assumptions (indirectly). Entheses, as direct behavioral indicators, fail to consider the multifactorial influences on their morphologies due to their complex anatomy, physiology, and mechanical properties. Numerous extrinsic variables can affect both enthesal morphology specifically as well as bone and muscle growth, including muscle function,

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entheses type, biomechanics, and various extrinsic variables (e.g., age, sex, genetics, health variables) [24–29]. In analyzing enthesal gross surface morphology, reconstructions of anatomy and behavior tend to simplify the relationship between them. It is also reasonable to assume that enthesal morphology will differ even within the same species due to the variety of variables that influence tendons and bones [30]. Thus, muscle architecture and stone tool behavior may not be directly correlated with specific entheses, even across various fossil hominins.

Using enthesal morphology and muscle anatomy in order to infer levels of participation in stone tool behaviors among fossil hominins, we conducted the first direct assessment of the assumed relationships between these two structures: opponens pollicis (OP) and opponens digiti minimi (ODM) on the first metacarpal (MC). The opponens muscles work together with the other thenar and hypothenar muscles to oppose the pads of the first and fifth digits distal phalanges. Stone tool behaviors are heavily influenced by opposition, which is why the OP and ODM entheses are widely used to reconstruct muscle anatomy and to infer tool behavior [31–34].

MATERIALS AND METHODS

Muscle dissection and variables. As part of the study, the opponens pollicis (OP) and the opponens digiti minimi (ODM), both located on the right hand's first and fifth metacarpals, were collected. Forearm, hand, and first and fifth fingers skin and fascia were removed prior to dissection. A digital caliper was used to measure in situ the muscles, tendons, and other structures of interest before the muscle was removed. Each muscle-tendon unit (MTU) was measured to the nearest 0.1 millimeter, including the muscle belly length (Lb), the total tendon length (LT) and the full muscle-tendon unit (LV). Myotendinous junctions were defined as the joints between the proximal and distal ends of the muscle fasciculus (Lb). Intra- and interindividual differences were observed in the presence of proximal and distal tendons. To calculate the total tendon length (LT), the proximal and/or distal lengths of the muscles were added together. It was also determined that the muscle-tendon unit (MTU) could be defined as the sum of Lb plus LT. After measurement of the muscles and their associated tendon(s), they were removed in an effort to preserve as much muscle and tendon tissue as possible, and excess tissues were removed. It was maintained and fixed in a 10% formalin solution by storing each muscle in a separate storage container. A 10% formalin solution was used to store the first and fifth digits after all superficial soft tissues and fibers had been removed.

A portion of the liquid from the muscles was removed before further analysis. Measurements of muscle mass were made with a digital scale to 0.1 grams accuracy. After pinning the muscle to a vinyl dissecting pad, the muscle was incised longitudinally three times (on the superficial

side, the deep side, and the reverse side on the cleanest surface possible). A determination of the fiber length (Lf) was carried out on each incision in two ways: (a) perpendicular distance between the central tendon and the distal tendon for a specific muscle fiber; and (b) fiber length (Lf) from the central tendon to the distal tendon. In contrast, PCSA has been found to be proportional to muscle force, whereas fiber length has been found to be proportional to muscle excursion and contraction velocity.

RESULTS

By analyzing 23 cadaveric modern humans (46 metacarpals), functionally-influenced architectural variables were examined for the opponens muscles (muscle mass, muscle-tendon length [MTU] and fiber length [Lf]). The length, area, and radial breadth of these variables were considered in relation to their associated entheses. Correlations between architectural variables of the opponens muscles and their associations with enthesal surface morphology did not reach statistical significance ($P > 0.05$), regardless of metacarpal and gender. Except for the correlation between radial breadth and PCSA, which was statistically significant but noticeably stronger than the rest, most correlation coefficients were extremely small.

DISCUSSION

Scientists studying osteological remains have reconstructed muscle anatomy and behavior patterns from enthesal morphology on dry bones to reconstruct muscle anatomy of past populations. Because of the complexity of osteotendinous interfaces as well as the numerous variables that can influence bone and muscle, this method has always been questioned. Based on this history, we examined two entheses (along with their associated muscles) commonly used to infer tool behaviors in fossil humans to test the hypothesized relationship between muscle anatomy and enthesal morphology. Anatomy of muscles and tendons was described by four functionally influenced variables. There were no statistically significant correlations in any of the comparisons. Based on these findings, one can infer that the enthesal morphologies of the opponens muscles do not provide a direct correlation for reconstructing the associated muscle architecture and, consequently, function. Accordingly, these data argue against the practice of interpreting fossilized enthesal morphology on first and fifth metacarpal surfaces to infer behavior, stone tool or otherwise.

An enthesis has a complex morphology that is influenced by a variety of variables. A simple classification of entheses as fibrous or fibrocartilaginous reveals their structural complexity. A tendon-bone interface can be distinguished histologically as well as grossly by its attachment location. In many fibrocartilaginous entheses, the superficial portion of the enthesis has zones of dense fibrous connective tissue (fibrous enthesis). There is a difference in mechanics between the two types of entheses

that causes such mixed entheses. Fibrocartilaginous entheses respond differently to stress and strain, as well as transferring such forces differently to the bone underneath. Even less is known about how mixed entheses interact with bone than either type of enthesis. Generally speaking, fibrocartilaginous entheses have relatively small attachment sites, which result in higher bone stress concentrations as a result of their biomechanics. Alternatively, fibrous entheses attach directly to the bone or over a larger area of the periosteum, whereas interosseous entheses attach via the periosteum.

Even more problematic for the practice of reconstructing soft tissue from hard tissue remains, regardless of the type of enthesal, is the fact that tendons exhibit non-uniform strain patterns near their insertion site and that the primary and initial sites of force transfer for enthesopathies and tendinopathies are not the same. This suggests that the associated diseases may be caused by underuse rather than overuse of the osteotendinous interface, as well as highlighting its complex nature. Muscle contractions, whether strong or weak, may not affect enthesal morphology until a pathological condition has developed. In other words, enthesopathies or exaggerated entheses cannot always be attributed to excessive muscle recruitment. Qualitative enthesis analysis also has the practical problem of insertion of several soft tissues at the same location. In this way, a particular enthesis may be affected by more than one structure and may reflect multiple forces. Several paleontological and bioarchaeological studies have shown that species modify

their entheses at the same pace and in the same way. As a species morphologically transforms its entheses faster than another, it is likely that the first species will show wide variations in morphology, whereas the latter will be more homogeneous. Using entheses to compare behavior between species presents further challenges.

The relationship between enthesis morphology and muscle anatomy or behavior has been characterized by a consistent trend across mammalian species, although caution should be exercised when extrapolating our findings beyond our study. There is no evidence that muscle anatomy or behavior can be correlated with enthesis morphology, location, or even muscle presence.

CONCLUSION

A presumed enthesis can be found in areas where no corresponding muscle attaches, or in areas where a presumed enthesis exists despite the absence of an entis. In mice and sheep, experiments found no discernible difference between groups exercising regularly and those exercising only occasionally. We challenge the method of reconstructing anatomy or daily behavior based only on surface entheses in fossil taxa. Similar discoveries have been made elsewhere in the literature as well. When interpreting the significance of enthesis morphology in evolutionary and behavioral contexts, caution should be exercised until concrete experimental evidence can be provided to support such relationships.

REFERENCE

1. Rabey, K. N. Locomotor activity influences muscle architecture and bone growth but not muscle attachment site morphology. *J. Hum. Evol.* 78, 2015, 91–102.
2. Benjamin, M. The skeletal attachment of tendons-tendon ‘entheses’. *Comp. Bioche. Phys.* Pt. A 133, 2002, 931–945.
3. Cardoso, F. A. & Henderson, C. Y. Enthesopathy formation in the humerus: data from known age-at-death and known occupation skeletal collections. *Am. J. Phys. Anthropol.* 141, 2010, 550–560.
4. Milella, M., Belcastro, M. G., Zollikofer, C. P. E. & Mariotti, V, *et al.* The effect of age, sex, and physical activity on enthesal morphology in a contemporary Italian skeletal collection. *Am. J. Phys. Anthropol.* 148, 2012, 379–388.
5. Trinkaus, E. The evolution of the hominid femoral diaphysis during the Upper Pleistocene in Europe and the Near East. *Zeitschrift für Morphologie und Anthropologie* 67, 1976, 291–319.
6. Jurmain, R., Cardoso, F. A., Henderson, C. & Villotte, S, *et al.* In A companion to paleopathology (ed. Grauer, A. L.), 2012, 531–552.
7. Hawkey, D. E. Disability compassion and the skeletal record: using musculoskeletal stress markers (MSM) to construct an osteobiography from early New Mexico. *Int. J. Osteoarchaeol.* 8, 1998, 326–340.
8. Hawkey, D. E. & Merbs, C. F. Activity induced musculoskeletal stress markers (MSM) and subsistence strategy changes among ancient Hudson Bay Eskimos. *Int. J. Osteoarchaeol.* 5, 1995, 324–338.
9. Lieverse, A. R., Bazaliiskii, V. I., Goriunova, O. I. & Weber, A. W, *et al.* Upper limb musculoskeletal stress markers among middle holocene foragers of Siberia’s Cis-Baikal region. *Am. J. Phys. Anthropol.* 138, 2009, 458–472.
10. Villotte, S. Enthesopathies as occupational stress markers: evidence from the upper limb. *Am. J. Phys. Anthropol.* 142, 2010, 224–234.
11. Eshed, V., Gopher, A., Galili, E. & Israel, H, *et al.* Musculoskeletal stress markers in Natufian hunter gathers and Neolithic farmers in the Levant: the upper limb. *Am. J. Phys. Anthropol.* 123, 2004, 303–315.
12. Churchill, S. E. & Morris, A. G. Muscle marking morphology and labour intensity in prehistoric Khoisan foragers. *J. Osteoarchaeol.* 8, 1998, 390–411.
13. Niinimäki, S. What do muscle marker ruggedness scores actually tell us? *Int. J. Osteoarchaeol.* 21, 2011, 292–299.

14. Aiello, L. C. & Wheeler, P. The expensive-tissue hypothesis: the brain and the digestive system in human and primate evolution. *Curr. Anthropol.* 36, 1995, 199–221.
15. Navarrete, A., van Schaik, C. P. & Isler, K., *et al.* Energetics and the evolution of human brain size. *Nature*, 480, 2011, 91–93.
16. Stiner, M. C. & Kuhn, S. L. Subsistence, technology, and adaptative variation in middle paleolithic Italy. *Am. Archaeol., New Ser.* 94, 1992, 306–339.
17. Wood, B. & Strait, D. S. Patterns of resource use in early Homo and Paranthropus. *J. Hum. Evol.* 46, 2004, 119–162.
18. Kivell, T. L., Kibii, J. M., Churchill, S. E., Schmid, P. & Berger, L. R., *et al.* Australopithecus sediba hand demonstrates mosaic evolution of locomotor and manipulative abilities. *Science* 333, 2011, 1411–1417.
19. Susman, R. L. Fossil evidence for early hominid tool use. *Science* 265, 1994, 1570–1573.
20. Ricklan, D. In *From Apes to Angels: Essays in Honor of Philip V. Tobias* (ed. Sperber, G. H.) 171–183 (Wiley-Liss, 1990).
21. Ricklan, D. Functional anatomy of the hand of Australopithecus africanus. *J. Hum. Evol.* 16, 1987, 643–664.
22. Susman, R. L. Hand function and tool behavior in early hominids. *J. Hum. Evol.* 35, 1998, 23–46.
23. Kivell, T. L. Evidence in hand: recent discoveries and the early evolution of human manual manipulation. *Phil. Trans. R. Soc. B* 370(1682), 2015.
24. Williams, S. B., Wilson, A. M., Rhodes, L., Andrews, J. & Payne, R. C., *et al.* Functional anatomy and muscle moment arms of the pelvic limb of an elite athlete: the racing greyhound (*Canis familiaris*). *J. Anat.* 213, 2008, 361–372.
25. Hamrick, M. W., McNeil, P. L. & Patterson, S. L., *et al.* Role of muscle-derived growth factors in bone formation. *J. Musculoskelet. Neuro. Interact.* 10, 2010, 64–70.
26. Mathewson, M. A., Chapman, M. A., Hentzen, E. R., Fridén, J. & Lieber, R. L., *et al.* Anatomical, architectural, and biomechanical diversity of the murine forelimb muscles. *J. Anat.* 221, 2010, 443–451.
27. Wilczak, C. A. Consideration of sexual dimorphism, age, and asymmetry in quantitative measurements of muscle insertion sites. *Int. J. Osteoarchaeol.* 8, 1998, 311–325.
28. Schlecht, S. H. Understanding entheses: bridging the gap between clinical and anthropological perspectives. *Anat. Rec.* 295, 2012, 1239–1251.
29. Pearson, O. M. & Lieberman, D. E. The aging of Wolff’s “law”: ontogeny and responses to mechanical loading in cortical bone. *Yearb. Phys. Anthropol.* 47, 2004, 63–99.
30. Cashmore, L. A. & Zakrzewski, R. S. Assessment of musculoskeletal stress marker development in the hand. *Int. J. Osteoarchaeol.* 23, 2011, 334–347.
31. Marzke, M. W. EMG study of hand muscle recruitment during hard hammer percussion manufacture of Oldowan tools. *Am. J. Phys. Anthropol.* 105, 1998, 315–332.
32. Marzke, M. W. & Shackley, M. S. Hominid hand use in the Pliocene and Pleistocene: evidence from experimental archaeology and comparative morphology. *J. Hum. Evol.* 15, 1986, 439–460.
33. Vlek, E. Morphology of the first metacarpal of neandertal individuals from the Crimea. *Bull. Mém. Soc. Anthrol. Paris*, XIII 2, 1975, 257–276.
34. Marzke, M. W. Precision grips, hand morphology, and tools. *Am. J. Phys. Anthropol.* 102, 1997, 91–110.