Chapter Two

Inferring ancient human activities through skeletal study: An example from Archaic Greece

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Abstract

This paper critically evaluates the range of skeletal attributes available for identifying activity patterns in the past. Our investigation is contextualized in the study of Phaleron, an Archaic Greek site where non-elite individuals were buried. We consider the following skeletal attributes: fractures, osteoarthritis, entheseal remodeling, bone cross-sectional diameters, bone density, and trabecular patterning as possible sources of information, finding that entheseal remodeling and long bone shape and density imaging hold the greatest potential. Studies of fracture patterning will also be employed to explore the risk of interpersonal violence and accidental bone breaks.

" Then let thy forest-feller cut thee all
Thy chamber fuel, and the numerous parts
Of naval timber apt for shipwrights' arts."
Hesiod [~700 BCE] in Chapman (1875: 234)

INTRODUCTION

Contextualized in an archaeological case study, this paper addresses the challenges of interpreting ancient behavior from human remains. Our ancient subject is the vast Phaleron cemetery (ca. 700-480 BCE), which contained over 1600 remains of people who lived during a socially, politically, and economically transformative period, just as Greek democracy was emerging along with the consolidation of the Greek State (Chryssoulaki 2019a, 2019b). This Archaic period (ca. 800-480 BCE) has largely been characterized in terms of elites—archaeologically, historically, and epigraphically. By contrast, the burials at Phaleron appar-

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ently represent those whose lives and identities at death had been marginalized from the elite core and are as yet unknown.

Characterizing the people of Phaleron depends upon analyses of the archaeological remains, primarily the skeletons themselves, their burial contexts, and associated material culture. One important aspect of this bioarchaeological research is the interpretation of ancient activities, including those that reflect occupational specializations. Following brief discussions of the Phaleron archaeological context and historical sources that consider occupations from this period, the paper engages in a review of the current status of skeletal methods appropriate for inferring activity at Phaleron, including antemortem and perimortem fractures, entheseal changes, bone cross-sectional diameters, and joint degeneration. Among the methods based upon entheses, the "Validated Entheses-based Reconstruction of Activity" (VERA) method (Karakostis and Lorenzo 2016; see dedicated review by Karakostis and Harvati 2021) receives special emphasis due to the rigor of this approach. We conclude with recommendations for best practices in the study of activity and occupation at Phaleron.

Occupations during the 1st Millennium BCE.

Attica's immediate post Palatial periods (1050+ BCE) are commonly characterized by historians and archaeologists in terms of myriad agricultural communities arrayed across a variegated landscape. We, therefore, assume that most activities were agrarian or in support of peasant lifeways. By the early decades of Archaic times, however, there is written evidence of non-agrarian occupational specialization. Extracted from Hesiod's *Works and Days*, the above epigram reflects the poet's experience in his agricultural community of Ascra in ancient Boetia, near the base of Mt. Helicon. As he advocated for diligence at the dawn of the Archaic period, Hesiod identified several non-agrarian occupational specialties, including bard, beggar, "maker," potter, blacksmith, and carpenter (Davies 2018: 59). Specialists in arboriculture and shipbuilding, as well as those who sailed the ships, are also implied.

Shifting our perspective forward to the Classical period (500-250 BCE), immediately postdating Archaic times, Harris (2001) recorded a surprising (to Harris) count of 170 occupations, ranging across specialties in food production, retail sales, various services, finances, the plastic and performing arts, and education. Harris (2001) emphasized marked horizontal differentiation in social organization, without significant vertical, administrative specializations. Important for bioarchaeological efforts to reconstruct occupational diversity, these activities range from heavy laborers, such as stone-cutters, miners, and butchers, to those with lighter physical demands, such as barbers, speechwriters, or harp players. This listing does not include the military, athletes, and avocations of the elite classes. Similarly, it does not speak to the proportions of people engaged in specific tasks. The development of professions has thus been identified during the Classical period, hinting at earlier origins (Stewart et al. 2020).

Hesiod's short list and Harris's extensive catalog bracket the Archaic period (ca. 800-480 BCE), the subject of this essay. Here we explore methods for identifying the activities associated with our ancient people; the written record has largely passed the Archaic period by. Both authors identify occupations requiring heavy labor, Hesiod's blacksmiths and Harris's miners, which contrast with their bards and harp players. We may therefore surmise that a wide range of physical demands faced the ancient Archaic communities from which our Phaleron burials were drawn.

Our analytical question now becomes how to characterize the people of Phaleron in relationship to the range of occupational specialization defined in the centuries bracketing the Archaic period. What **can** we say, and how accurate can we be? Are we able to distinguish fractures attributable to interpersonal violence from those that result from nonviolent activities? What attributes accurately identify perimortem trauma, as opposed to postmortem bone alterations? Can we identify those engaged in heavy labor, compared to those in less demanding daily behaviors? Can we proceed further, with at least a few occupations associated with distinctive suites of behaviors? Which skeletal attributes are the most reliable for characterizing bone-altering behaviors, having been tested in other, documented contexts? Are we able to identify (groups of) adolescent-young adult individuals whose daily lives suggest that occupations are being defined through apprenticeship at an early age? The goal of this paper is to evaluate methods commonly used by bioarchaeologists for identifying either severe episodic or repetitive behaviors that assist in characterizing the daily lives of the people of Phaleron. Let us first turn briefly to the archaeological record and the site of Phaleron itself.

Phaleron

Overviews of the Phaleron site and its excavation have been provided by Dr. Stella Chryssoulaki, the excavator (2019a, 2019b). Under excavation between 2012 and 2020, the site has produced approximately 1960 human remains, thus far including the highly visible "Esplanada Mass Graves" (Ingvarsson and Bäckström 2019), which were left *in situ* for display. These *biaiothanatoi*, considered to have suffered violent deaths, have been grouped with other mass and non-normative graves to form a distinctive *desmotes* burial form or "D-Group." A minority of adults were buried in cist tombs or were incinerated in pyres; juveniles were generally interred within jars. Most of the adult individuals were interred in simple pit graves, without associated material culture. The Phaleron Bioarchaeological Project, centered at the Wiener Laboratory of the American School of Classical Studies in Athens, focuses upon the approximately 1200 interments from the 2012-2013 season and serves as the inspiration for this essay.

That the Phaleron site falls within the Hallstatt Plateau, a term for a flat, uninformative region on the radiocarbon curve between 800-400 BCE, means that accurate chronometric resolution via radiometric dating during the Greek Archaic period is impossible to challenging, at best (Damon 1989; Davis et al. 1992; Jacobsson et al. 2017; Millard 2008; van Geel et al. 1998). A further complicating factor is the poor preservation of organic portions of bone, which further limits prospects of radiocarbon dating. Stratigraphic dating is also challenging, due to the homogeneity of the coastal beach sand and the invisibility of pit outlines and other structural details.

Fortunately, ceramic analyses provide resolution within one to two generations—a quarter to a half-century—for many of the contexts. Thus, linking those features' assigned dates through ceramic analyses to nearby located graves requires careful archaeological studies of context and assumptions about originating levels for pit excavations (Buikstra et al. n.d.).

The goals of the Phaleron Bioarchaeological Project include exploring the life histories and identities of the individuals interred in the Phaleron Cemetery (Buikstra et al. n.d.; Prevedorou and Buikstra 2019; Prevedorou et al. n.d). We, therefore, marshal osteological information about age-at-death, biological sex, stature, dental/skeletal pathology, inherited features, and activity indicators to infer social age, gender, health, kinship, and occupation (see Buikstra et al 2022). The last-mentioned includes inferences of extreme and habitual behaviors based upon bony evidence, such as fracture patterning, osteoarthritis, entheseal development, and bone-cross-sectional shape. However enticing the prospects, this is a speculative domain, subject to considerable critical review (Judd 2008; Judd and Redfern 2012; Jurmain 1999, Jurmain et al. 2012; Pearson and Buikstra 2006; Wallace et al. 2017a). With a focus on the Phaleron context, we examine the potential of these various lines of evidence through a critical, scientific lens.

ACTIVITY INDICATORS: HOW DO WE CHOSE INDICATORS AND METHODS FOR DATA COLLECTION AND ANALYSES?

Fractures

Skeletal changes commonly reflect fractures, ranging from extreme, acute events to structural failure due to repetitive events, perhaps aggravated by poor bone quality. It is important that we recognize the specificity of each, working from the bony change to the interpretative ultimate cause. Certainly, our first task is recognizing, for example, a fracture and understanding the proximate cause (Lovell 1997; Walker 2001). There are many useful guides to this process, including those drawn from bioarchaeology and forensic anthropology, including Galloway (1999), Lovell and Grauer (2018), Redfern and Roberts (2019), Symes et al. (2012), and Wedel and Galloway (2014). That accomplished, the researcher must turn to the next, more challenging step: estimating the ultimate cause, given the individual's life history. The medico-legal and biomedical sciences literatures provide many useful examples that link ultimate causes to ranges of fracture forms, e.g., lethal falls from a height (Rowbotham and Blau 2016), or spondylolysis with athletics (Syrmou et al. 2010), or the Clay Shoveler's Fracture (de Boer et al. 2016). These clinical sources should be consulted.

Sharp Force Trauma

While sharp force trauma is certainly of interest, it is quite rare in the Phaleron sample and therefore most amenable to osteobiographical approaches to interpretation. Medical knowledge during the Archaic period doubtless portended the Hippocrates' writings, with the treatise "On Head Wounds" being especially germane (Hanson 1999). The example illustrated in Figure 1, IV_554 undoubtedly reflects sophisticated and effective medical intervention. The person treating the patient apparently removed fragments or allowed the wound to suppurate and any fragments to "float" to the surface. It appears that, in this case, the edges of the bony wound were rasped and smoothed, but the bone (inner cortex) immediately adjacent to the membrane (dura mater) was left intact.

Fig. 1.
Specimen IV_554 showing two healed examples of sharp force trauma on the left aspect of the skull (photograph by Hannah Leidl).

Blunt Force Trauma

Cranial – methods in use for population approach/temporal change

Anthropologists studying ancient cranial trauma generally follow Walker (1989: 328) in assessing whether cranial trauma observed in a skeletal series resulted primarily from 1) accidents, e.g., falls; 2) intentional interpersonal violence, ranging from one on one to group interactions; and 3) self-inflicted forms. We will concentrate here on distinguishing the first two forms.

The remains of the Phaleron individuals, like those from many other parts of the world, e.g., Peru (Arkush and Tung 2013; Scaffidi and Tung 2020) and California (Walker 1989), present numerous shallow, healed, round to ellipsoid examples of blunt force trauma. Methods for distinguishing accidents from various forms of interpersonal violence include mapping locations upon the skull to establish patterns. Walker (1989), for example, while investigating ancient human remains from the California Coast and nearby islands, found concentrations of healed lesions on the frontal bone, especially frequent in males. He considered this compelling evidence for ritual encounters, rather than raids or warfare, the latter more likely being seen in the perimortem lateral (right>>left) and posterior fractures at the Crow Creek massacre site (Zimmerman et al. 1981). Tung (2007) similarly attributed the healed frontal fractures of the elite at the Wari La Real site (Majes valley, Peru), which contrasted with the anterior and posterior fractures of the Beringa community of non-elite individuals, also from the Majes valley. Tung argued that the latter pattern reflects raiding, supported by the presence of “parry fractures.” This approach has been extended temporally by Arkush and Tung (2013), who carefully presented alternative scenarios for various kinds of interpersonal violence, ranging from domestic violence to raiding and warfare. Scaffidi and Tung (2020), reporting evidence from earlier peoples (200-750 CE) from the Majes valley, argued that their elevated rate of facial and anterior vault fractures, especially prominent among males, were evidence of endemic violence. Obviously, the distribution of healed cranial fractures, their frequency and patterning, and their age/sex association will be important in interpreting the Phaleron remains.

Perimortem vs Postmortem

One of the contemporary challenges faced by bioarchaeologists and forensic anthropologists alike is distinguishing perimortem from postmortem blunt force trauma, rendered ambiguous due to taphonomic factors, especially soil pressure. As noted above, many of the individuals interred in the Esplanada mass graves are said to have been executed with clubs or similar weapons (Ingvarsson and Bäckström 2019). The methods created and applied by Sala and colleagues (Sala et al. 2015, 2016) for remains from the Middle Pleistocene site of Sima de los Huesos (Atapuerca, Spain) appear promising for resolving this significant problem. Knowledge drawn from forensic anthropology about fracture biomechanics, fracture healing rates, and the role of taphonomy in altering bone to mimic antemortem and perimortem processes is essential in bioarchaeological studies of trauma (Berryman et al. 2018; L'Abbé et al. 2021; Pokines et al. 2021; Wedel and Galloway 2014). Sala's explicit focus on fracture outline (straight, curved, depressed), angle (between the external surface and the fractured surface), surface (smooth, jagged), and cortical delamination (present, absent) appear suitable for the frontal, parietal, and occipital bones initially reported for a single individual from the Middle Pleistocene Sima de los Huesos (SH) site (Sala et al. 2015). The method was slightly modified by the researchers (Sala et al. 2016) in a more recent study of 17 SH crania in comparison to other contemporary remains. Fracture outlines were scored as either linear, depressed, stellate, or a combination of the latter two, following Wedel and Galloway (2014). Trajectory was also added as a category, distinguishing between lines that crossed sutures and those that did not.

In general, Sala and many others focus on calvaria and generally adhere to the "hat brim rule" (HBR), which as commonly applied today, asserts that injuries at the level of a hat brim are most likely resultant from a fall, and those above, from a blow to the head. This definition, as promulgated by Kremer and co-workers (Kremer et al. 2008; Kremer and Sauvageau 2009) and Guyomarc'h et al. (2010), has been criticized by Fracasso et al. (2011) and Geserick et al. (2014), who urge attention to the original definition by Kratter (1919) and Walcher (1931). The earlier workers argued that fall injuries from a standing position are unlikely to appear above the hat brim line, which connects the frontal and parietal eminences and the most superior point on the occipital squama, a location defined in a manner distinct from that of the 21st-century researchers. This does not apply to falls from a height, blows, or children's skulls. For the Phaleron analysis, we will emphasize the features discussed by Sala, without recourse to the contested HBR criteria.

Postcranial Fractures

Given the verticality of the Greek landscape, factoring the effect of accidental falls into the fracture patterns of those buried at Phaleron will be important. Lessa (2011), for example, has argued that the many fractures observed in Brazilian coastal pre-colonial groups reflected falls blocked by the lower limbs and upper limbs, common due to the rocky coastal cliffs adjacent to the shore. Trauma rates were assumed to be associated with accidental falls within these challenging locations. Differences were, therefore, interpreted as to reflect distinctive lifestyles, contrasting fishers with the shellfish-dependent *sambaquis*-builders. Postcranial fractures were interpreted biomechanically by insult type rather than by bone. Accidents associated with a vertical landscape can be assumed in this case, in the absence of apparent occupational specialization, other than perhaps gender-associated (James and Dillon 2012). This contrasts with the accident/occupation-based interpretation by Dittmar and colleagues (2021) of three Medieval cemeteries in Cambridge, which demonstrated a significantly higher risk of fractures for the poor. The clerics, however contemplative they may have been, also apparently suffered trauma during their subsistence and maintenance activities. For Phaleron, we will want to take deeper dives into the medical and epidemiological literature on the nature of fractures from falls, as distinctive from those reflecting blows while standing, for example. One might hypothesize the patterning for hoplites (foot soldiers) whose faces and limbs were exposed outside protective clothing and gear would be distinctive. Similarly, the association of equestrian activities with the elite suggests that if indeed there are elite among those subject to execution and burial at Phaleron, the impact of horseback riding would be found in their remains. Linking diagnostic trauma patterns to occupational cues from bone shape, entheseal remodeling, and other forms of pathology will undoubtedly strengthen analyses and perhaps distinguish land-based warriors from those who cultivated the land, who mined its mineral riches, and who sailed the seas, as either rowers, merchants, or pirates.

The need for care in defining postcranial fractures carefully prior to attributing cause is writ large in the fraught example of the "parry fracture," an eponym too frequently applied to forearm fractures (Judd 2008; Jurmain 1999; Lovell 1997; Smith 1996). A very careful definition and exemplary cases reported by Judd (2008) illustrate the need to distinguish between forearm fractures caused by indirect force, e.g., falling (Colles, Smith's, Galeazzi, and paired rotational fractures), and directed blows to the forearm. Defending a blow with the forearm most commonly fractures the ulna transversely; the radius may also be involved. Carefully defining fracture dynamics of direct and indirect causation, along with knowledge of contexts for likely falls, accidents, occupational stressors, or violence, is essential to interpreting fractures, individually and epidemiologically.

Repetitive Behaviors Reflecting Occupational Specialization

In the activity-related changes attributed to repetitive activities, we are faced with further challenges, as we must first consider the evidence linking the skeletal change to activity. If we are seeking evidence of occupational specialization, how likely is the dominant risk factor for osteoarthritis (OA), for example, to be repetitive behavior? What is the range of risk factors for osteoarthritis? How confident can we be that activity is the likely causal agent for OA in general and how might this vary across body regions? In the case of bone shape changes and entheseal modifications, we would like to know how long the body needs to perform the repetitive activity for it to affect bone and how long will the changes persist following cessation of the behavior. As with OA, what other factors affect bone shape and entheseal modifications and how likely is repetitive behavior to be the primary cause? Finally, is there a likely difference in the bony expression—either in form or degree—depending upon whether the activity began during adolescence rather than adulthood? Clinical knowledge must be integrated with bioarchaeological investigations of activity, as Jurmain (1999; see also Jurmain et al. 2012) has so eloquently cautioned, reacting against exuberant attempts to infer occupations, following a simple cause and effect model for relationships between bony changes and occupations, e.g., Capasso et al. (1999).

> *"Activity is rarely rigorously defined in the anthropological literature. Firstly, is it habitual or exceptional? Although most studies tacitly assume that the relevant bone changes result from habitual activity, the influence of exceptional, acute behavioral episodes, as reflected in traumatic lesions, has occasionally been discussed under the broad topic of activity reconstruction (e.g., Jurmain 1999; Walker et al. 2009; see Chapter 20 by Judd and Redfern in this volume [2012]). In addition, activity needs to be more fully and more clearly characterized in terms of duration (total exposure time), frequency (number of repetitions per unit time) and mechanical overloading (Luttmann et al. 2003). Other factors such as intensity, age of onset, and postural demands need to be considered. Ideally, this broadened understanding should be concordant with clinical definitions."* (Jurmain et al. 2012: 532)

We, therefore, proceed to consider critically (but optimistically) osteoarthritis (OA), entheseal modifications (EM), and bone shape/density/cross-sectional diameters.

Osteoarthritis (OA)

The need for conservative approaches to the interpretation of OA has been cautioned by Bridges (1992), Jurmain (1999), Jurmain et al. (2012), Waldron (1995, 2012, 2019), and Wallace et al. (2017b), among others. Tony Waldron, for example, has persistently argued, based upon clinical and epidemiological data, for an appreciation of the multiple genetic, activity-related, and individualizing features, such as age, sex, obesity, and joint shape that may stimulate the breakdown of joints, ensuing bony OA. This multifactorial etiology continues to be represented in the recent clinical literature. Genetic risk factors for joint breakdown have been identified—with weight-bearing being considered separately (Boer et al. 2021)—in an article that also defined risks specific to females, individual joints, and age groups. Risk factors have been considered separately for different individuals and across joints.

> *"Person-level risk factors with strong evidence regarding osteoarthritis incidence and/or progression include age, sex, socioeconomic status, family history, and obesity. Joint-level risk factors with strong evidence for incident osteoarthritis risk include injury and occupational joint loading; the associations of injury and joint alignment*

with osteoarthritis progression are compelling. Moderate levels of physical activity have not been linked to increased osteoarthritis risk. Some topics of high recent interest or emerging evidence for association with osteoarthritis include metabolic pathways, vitamins, joint shape, bone density, limb length inequality, muscle strength and mass, and early structural damage." (Allen et al. 2015: 276)

Also of interest are studies from sports medicine, as we shall review more extensively below in reference to cross-sectional diameters. This literature provides case studies related to specific sports and surveys, such as a recent review and meta-analysis by Bestwick-Stevenson et al. (2021) that considered the following activities: American football, bobsleigh, handball, ice hockey, shooting, and wrestling. The hip, knee and ankle were considered, and a statistical review in relationship to controls for all sports found more OA at all three joints. Ice hockey athletes and wrestlers were at risk for hip and knee OA, while handball players developed hip arthritis.

Turning to bioarchaeological reviews of occupational associations, we also emphasize that while risk factors for joint degeneration are higher in certain groups, there is no simple relationship:

"There have been a great many studies of OA in modern occupational groups, usually with results that are entirely unsurprising; that is to say, miners tend to have a greater than normal prevalence of OA of the spine, carpet layers of the knee, ballet dancers of the foot, and so on. There are, in addition, some results that are not so obvious, the most convincing being that farmers have a much greater frequency of OA of the hip than the general population . . . and it has to be remembered that by no means all those who engage in hard physical work get OA and, conversely, that those who lead entirely sedentary lives may do so.
The most important features of all this endeavor, however, are that there is absolutely no form of OA that is unique to one occupational group, and secondly, that even in those occupations in which there is a greatly increased risk of developed OA of a particular site, there are many more individuals outside that occupation with the condition than inside it. Thus, although there seems little doubt that farmers are greatly at risk of developing OA of the hip, the majority of those with the condition are not farmers." (Waldron 2012: 519-520)

One of the most compelling arguments for the multitude of currently risk factors for OA appears in Wallace et. al.'s (2017b) longitudinal study of prehistoric and historic (pre vs. post mid-20th century, characterized as early industrial vs. postindustrial) skeletal remains. This study illustrates that age is insufficient to explain the current marked increase in knee OA since 1976. The authors suggest that OA may be due to modifiable factors such as BMI and activity levels, thus joining type 2 diabetes, atherosclerosis, and hypertension as possible "evolutionary mismatches," biological results of human bodies being imperfectly adapted to contemporary lifestyles.

Jurmain et al.'s (2012: 534) persistent caution that there is no support for assuming a simplistic relationship between habitual activity and OA, including both joint degeneration and bony changes, therefore, continues to be compelling, especially in the face of recent experimental and clinical evidence.

This ambiguous relationship between observable bony changes and repetitive activity, along with the variable preservation of joint surfaces at Phaleron, leads us to only consider joint degeneration when it has been noted to be associated with a particular behavior or type of behavior we are modeling and in concert with other forms of bony change in individuals. We emphasize that such evidence is compelling in reference to specific activities only when carefully contextualized (e.g., Merbs 1983).

MSMs and Entheseal changes

As Kennedy (1998: 305) notes, studies of activity-related stress began during the Middle Ages, with medical diagnoses related to military service and trade assuming prominence, followed by discussions of industrial medicine in 1700 (Kennedy 1989). Within bioarchaeology histories of the "musculo-skeletal markers" (MSMs) – more recently termed "entheseal changes" (ECs) – relate enthusiasm for the use of these alterations of areas of tendinous attachments as attributes associated with activities or specific occupations started during the 1960s (Henderson and Alves Cardoso 2013; Jurmain 1999, 2012; Kennedy 1989; Pearson and Buikstra 2006; Sick 2020). Influenced initially by the work of Angel (1966, 1971) and subsequent twentieth century scholarship (e.g., Bridges 1989; Capasso et al. 1999; Kennedy 1989; Kennedy et al. 1986; Merbs 1983), enthusiasm for "Bioarchaeology's Holy Grail" (Jurmain et al. 2012) led to a 1997 symposium at the annual meeting of the American Association of Physical Anthropologists (AAPA) in St. Louis and a subsequent symposium volume in the *International Journal of Osteoarchaeology* (IJO) (Peterson and Hawkey 1998). In the preface, the editors emphasized that much remains to be learned about MSMs:

> *"A number of factors still need to be addressed in this relatively new approach, including an understanding of the role and rate of bone remodeling, the effect of hormonal differences and pathological agents on bone growth, and how biomechanical variables (including the role of individual variation in muscle attachment, muscle fiber arrangement, and origin/insertion type) may affect musculoskeletal stress markers." (Peterson and Hawkey 1998:303)*

The organizers also argued that the "next logical step in this field of enquiry is to generate predictive models against which to test the data, focusing on the use of all joint complexes in an individual (Peterson and Hawkey 1998:303). While most of the papers in the symposium volume were case studies, these were linked to critiques (e.g., Stirland 1998) and explicit statements about how far to take interpretations. Robb (1998) argued for patterning differences that emerged through cluster analyses of Iron Age samples from Italy. Hawkey and Merbs (1995) illustrated a detailed case study of "care" that anticipated 21st century excitement over osteobiographies and the bioarchaeology of care. Another promising direction was illustrated by Churchill and Morris's (1998) use of the Optimal Foraging Dietary Breadth model to make predictions about muscle scar rugosity and size for muscles of the upper and lower limbs across ecozones for pre-contact foragers from South Africa. The authors concluded that food foraged by males differed more across the ecozones than that foraged by females, based upon significant differences across male upper limbs. That sex-based activities other than explicit food acquisition could be implicated does not detract from the elegance of a study grounded in theoretical expectations, based on detailed contextual knowledge.

During the first decade of the 21st century, methodological concerns mounted. Bioarchaeologists did learn a great deal more from anatomists about the anatomical structure of entheses (Benjamin et al. 2002, 2006; Benjamin and McGonagle 2009; Villotte and Knüsel 2013), and decisions about collecting data reflecting changes in the spectrum of attachment sites that ranged from fibrous to fibro-cartilaginous required attention, with the latter being preferred due to lack of knowledge about the relationship between the former and activity (Villotte and Knüsel 2013). Concern about the unknowns affecting the unrealized potential of MSMs for the reconstruction of activity led to a Workshop in Musculoskeletal Stress Markers on July 2-3, 2009, sponsored by the Research Centre for Anthropology and Health at the University of Coimbra, Portugal (http://cias.uc.pt/workshop-musculoskeletal-stress-markers-msm/). The outcomes of this conference were many and productive. Given the need for in-depth consideration of terminology, scoring protocols, and the relationship between activity and the form taken by MSMS, including tests in skeletons of documented occupations, three working groups were formed on each of these topics. Papers from the Workshop were posted online (http://www.uc.pt/en/www.uc.pt/en/cia/msm/MSM_Occupation-cia/msm/msm_after) and a summary was presented (Santos et al. 2011). A further review of progress (Jurmain et al. 2012) was followed by a poster symposium at the 2012 annual meeting of the AAPA in Portland, Oregon. Results that the symposium largely reflected progress achieved by the Coimbra Workshop Working Groups were published the following year in the IJO (http://www.uc.pt/en/cia/msm _after) (Henderson and Alves Cardoso 2013). Some outcomes have been readily implemented, for example, using the term "entheseal changes" or "EC" to reference the attachment sites, rather than "MSMs" or "MOS" (markers of occupations stress). EC was viewed as being a neutral term for describing the changes being recorded (Jurmain and Villotte 2010). While no universally accepted visual scoring system has become the consensus method (cf. Havelková et al. 2013, Wesp 2014; 2021), the Coimbra method's relatively high repeatability and relative ease of training (Wilczak et al. 2016) presents decided advantages (Henderson et al. 2013a, 2016, 2017). Other desirable features include its assimilation of the strengths of the Villotte et al.'s (2010) anatomical and clinically informed approach, integrated with Marriotti's clearly identifiable attributes, scored along specified dimensions of variability (Mariotti et al. 2004, 2007; Milella et al. 2012), which appears to be the most rigorous method for EC to date (Henderson et al. 2013a; Henderson et al. 2016). Imaging methods continue to be explored (Karakostis and Lorenzo 2016; Karakostis et al. 2018; Nikita et al. 2019; Nolte and Wilczak 2013).

A persistent problem in EC studies is how best to address activity levels in relationship to occupation. One of the Coimbra Workshop task forces faced that issue directly in their studies of EC in skeletal collections wherein occupation was documented (Perréard Lopreno et al. 2013). They concluded that previous studies have focused primarily upon biomechanical (manual/nonmanual) categories—which seem relatively consistent across researchers—and sociocultural categories—which do not (Alves Cardoso and Henderson 2013). Alves Cardoso and Henderson's (2013: 1194) advice, that "research should not blindly rely on occupation at death to test the relationship between EC and occupation", is an important outcome of these deliberations. Related, constraining issues include the fact that many women's occupations in these 19th and early 20th century circumstances are not differentiated beyond "housewife" (Milella et al. 2015; Villotte 2009). Age-at-death and body mass have also emerged as important variables associated with EC patterning in documented collections (Alves Cardoso and Henderson 2013; Godde et al. 2018; Jurmain et al. 2012). Other ambiguities develop from distinctive cultural differences in defining occupations and failure to record time depth for occupations (Henderson et al. 2013b). The Basel Spitalfriedhof Collection is an exception to the latter limitation, as discussed below (Hotz and Steinke 2012; Karakostis et al. 2017). In general, those working with documented collections approach consensus in terms of "biomechanical" categories—e.g., manual vs. nonmanual workers (www.uc.pt/en/cia/msm/MSM _Occupation) – or similar distinctions based upon muscle groups—e.g., Wesp 2014, 2021. Milella et al. (2015), for example, in an inductive approach using merged Italian and Portuguese collections, report distinctions between three main groups, with the first and third providing the clearest contrasts: 1) occupations related to farming, 2) physically demanding occupations not related to farming, and 3) physically undemanding occupations. The authors argue for methods "not constrained by a priori assumptions in testing biocultural hypotheses" (Milella et al. 2015: 222). While this is excellent advice for exploratory efforts at Phaleron, seeking evidence relating to specific professions is also desirable, e.g., rowers (discussed in the closing sections).

An especially promising approach to exploring behavior differences and muscle synergies has recently been developed by Karakostis and colleagues (Karakostis and Lorenzo 2016; Karakostis et al. 2017, 2018, 2019; Karakostis and Harvati 2021) through a careful series of empirical tests that include natural and laboratory experiments, along with geometric morphometrics (Karakostis et al. 2018). Validated in the Basel Spitalfriedhof Collection (Karakostis et al. 2017), wherein lifetime occupational information along with standard demographic information are documented (Hotz and Steinke 2012), the procedure maps multivariate patterns from hand entheses of archaeological samples upon documented long term occupational patterns. This comparative approach, termed the V.E.R.A method, has been applied to a small sample of remains from the Phaleron cemetery with promising results, which suggest distinctive life histories for individuals buried in different interment contexts (Karakostis et al. 2021).

Therefore, however enticing the identification of an unknown individual with a specific occupation via EC, this goal should be approached with caution, as the empirical support data are lacking. Osteobiographies or other studies that infer specific occupations from ECs should, therefore, be considered aspirational, rather than conclusive (e.g., Angel and Caldwell 1984; Kennedy 1983, 1989; Kennedy et al. 1986). The more conservative approach—mapping—observed differences on patterning validated through natural and laboratory experiments, however, such as the V.E.R.A. appears quite promising.

Long Bones (LB): Diaphyseal Shape, Bone Density, and Cross-sectional Diameters

As Pearson and Buikstra (2006) emphasize, studies of bone shape and adaptation to environmental and ontogenetic factors can be traced back to the late 1800s, when European pathologists and anatomists, such as Virchow, focused on plasticity. A very influential product of this tradition was Julius Wolff's "law", codifying how bone responds to external stressors (Wolff 1892; see also Frost 1993; Martin et al. 1998; Ruff et al. 2006). Following late 19th and earlier 20th century, focused observations and interpretations of platycnemia and platymeria (e.g., Matthews et al. 1893), complex biomechanical models assumed prominence in bioarchaeological studies, beginning with Ruff and Hayes (1983a, 1983b), Ruff et al. (1984), and Bridges (1985, 1989). Early studies described differences, such as a decline in femoral strength with agriculture (but see Bridges, 1989). Further comparisons focused on upper limb asymmetry and differences between the sexes.

Studies of cross-sectional geometry have been criticized on experimental grounds, with certain loading parameters not behaving in the predicted manner (Lieberman et al. 2004). Lovejoy et al. (2002) argued against simple models for explaining variation in bone shape and composition, while Jurmain (1999, Jurmain et al. 2012) emphasized the need for clinical or other controlled studies that linked cross-sectional geometry to specific activities. More recently, Wallace et al. (2017a: 234) have voiced concerns about several factors: the weak relationship between loading and bone structure, the mechanical inefficiency of bone's response to loading, the comparatively large influence of genes on bones' responsivity to loading, and age-dependency of responsiveness. The last-mentioned topic is considered below, as it may facilitate a window for addressing occupational specialization during pre-adult and early adult years.

Pearson and Lieberman (2004) have reviewed experimental evidence on the ontogeny of bone formation, which suggests that adolescent and, to a lesser extent, childhood activities may play a disproportionate influence on adult bone size and shape. Thus, studying skeletons with a sensitivity to age-at-death and including older juveniles may provide important indications concerning apprenticeship and assumption of adult identities. This point has also been emphasized by Wallace et al. (2017a).

Studies with important implications for bioarchaeological interpretations of behavior are drawn from sports medicine. As Longman et al.' (2020) review of "human sport paleobiology" underscores, studies that have emerged from the sports science fields hold excellent potential for exploring human evolutionary adaptation at the species inter-individual and intra-individual level. Enhanced by increasingly precise imaging modalities, this research has now extended over more than a quarter century and has addressed issues of significance to bioarchaeologists, seeking to explore the past of humankind.

Most investigations, both in sports science and bioarchaeology, have focused on cortical bone, especially femoral and humeral cross-sectional properties (size, strength, rigidity). Clinical and experimental results have been used to generally address mobility patterns and activity symmetry in archaeological examples. Pioneering bioarchaeological studies include those of Bridges (1989), Ruff (1987), and Ruff et al. (1984). Many such investigations compared skeletal samples across perceived adaptive thresholds (e.g., hunter-gatherers vs. agriculturalists, or Late Eneolithic vs. Early Bronze age (Sládek et al. 2007). Especially satisfying are the reports that display extensive knowledge of the archaeological record and construct testable hypotheses. A recent, impressive example of temporal and gender-based expectations for Neolithic, Bronze Age, and Iron Age groups from Central Europe is found in Macintosh and Stock (2019) and Macintosh et al. (2014, 2017). Based on a carefully designed study, this research well-illustrates our gender-based, or perhaps gender-biased, contemporary perspective on gender roles in the past: Macintosh et al. (2014:1) anticipated that:"Significant differences in upper limb asymmetry and variability will be found between the Early/Middle Neolithic and Early/Middle Bronze Age groups, associated with greater agricultural efficiency, the expansion of mining and copper and bronze metallurgy, the manufacture and production of metal objects and other crafts, and the increased task specialization that accompanied these changes. Given the considerable overlap of bronze and iron production in Central Europe, reduced temporal change in humeral asymmetry between the Early/Middle Bronze Age and Iron Age groups is expected." The authors (p. 1) discovered that "the introduction of the ard and plow, metallurgical innovation, task specialization, and socioeconomic change through 5400 years of agriculture impacted upper limb loading in Central European women to a greater extent than men." Such results importantly suggest that rethinking our perspectives on ancient daily lives and women's work will benefit from further such contextually sensitive and rigorous study.

Revising our visions of age and gender-based roles in the past is also advisable for our interpretations of strength in ancient bones. Sage advice on studies of bone strength and health in the past includes Agarwal's (2021) perspective on current idealized bone "norms." She (Agarwal 2021: 3) compellingly calls for researchers to "critically reflect on which measures of bone loss in the different parts of the skeleton are actually biologically and/or socially meaningful, and to call for greater consideration of the cumulative and fluid biocultural influences on the skeleton over the life course beyond sex and age." This is exceptionally good counsel as we integrate new imaging modalities and the study of bone trabeculae increasingly into our research designs.

Of importance to our research on occupation in the past is a suite of studies that demonstrate that bone mass gained during the second decade of life appears to persist for years. Such research has been stimulated by a concern for forming and maintaining bone strength into the older adult years, and relatively few longitudinal studies have been published. Useful examples include longitudinal investigations of young children who participated in high impact (jumping) exercise vs. those who stretched. Followed for eight years, the jumpers maintained elevated bone mineral content (BMC) at the hip (Gunter et al. 2008). More recent studies of impact loading (IL) suggest that IL prior to menarche is associated with postmenarche diaphysis size and strength increases in women (Murray and Erlandson 2021). Longitudinal study of pre-menarchal gymnasts, who left the sport before menarche, found that the gymnasts sustained higher forearm BMC, forearm areal bone mineral density (aBMD), and area for at least two years after menarche, compared to controls (Scerpella et al. 2010). More recent data on gymnasts of 4 to 6 years of age indicate that changes are maintained in the distal radius, but not on the tibia or on the radius diaphysis. Warden et al. (2014) argue that certain aspects of bone strength in adult baseball players are sustained life-long. Summary statistics for women emphasize that 80-90% of adult bone mass is attained by 16 years of age, with nearly half accrued during the four years surrounding menarche (Troy et al. 2018).

Studies have also suggested nuanced associations within specific bones and behaviors. The forces associated with overhand throwing in women softball players induce more than twice the dominant to non-dominant differences in midshaft humeral bone mass structure and estimated strength than in windmill (underhand) throwers, with all throwers showing more of these attributes compared to controls (Bogenschutz et al. 2011). Best and coworkers (2017) distinguished patterns of calcaneus trabecular thickness between forefoot and rearfoot striking male runners, although the small sample and intervening variables suggest calcaneus trabecular thickness was most likely explained by running distance and years of running. These, along with experimental studies (e.g., Ju and Sone 2021), reaffirm that bone mass varies across exercise regimes through different architectural patterns. Ju and Sone's rats were reported to have thicker trabecular due to jumping; while running and swimming increased trabecular numbers. Enthusiasm for studies of bone trabeculae must be tempered by a lack of empirical knowledge, explicitly linking variation in density and orientation to distinctive activity regimes and the tendency for postdepositional factors to significantly alter outcomes.

In sum, experimental laboratory studies and longitudinal research in human athletes indicate that relationships between repetitive activities, especially those of adolescents, are found in bones of those living in older years. Similarly, adult athletes present evidence of increased bone mass and strength associated with their sport. To date, such knowledge has been used by bioarchaeologists to explore longitudinal differences between groups in mobility and symmetrical, task-specific behaviors. Results have also suggested that predictions about gender roles in the past may require revisiting and refinement, based upon historical, ethnographical, and archaeological sources. It will be important to develop explicit expectations about activities and occupations prior to employing increasingly advanced imaging modalities, as these become available. Among the implications of the youthful development of bone mass, based upon activities, is that bioarchaeological studies of activity and occupational specialization should begin with remains of adolescents, contextualized in context-specific information about training, apprenticing, and assumptions of adult roles.

DISCUSSION

We now return to the questions posed at the outset of this paper.

What can we say, and how accurate can we be?

Are we able to distinguish fractures attributable to interpersonal violence from those that result from nonviolent activities?

The answer to this question is tentatively affirmative, depending upon the type and location of skeletal alterations. Sharp force trauma observed thus far in the Phaleron collection is readily attributable to inter-personal violence, as are the repetitive examples of blunt force trauma. Other cases will be interpreted on a case-by-case basis, with careful attention to environmental and cultural contexts.

What attributes accurately identify perimortem trauma, as opposed to postmortem bone alterations?

This distinction continues to pose challenges for forensic anthropologists and bioarchaeologists, alike. Especially challenging in the Phaleron example is fracture location, as many of the possible perimortem fractures occur due to blows to the lateral aspects of the cranial vault. Most models for identifying perimortem trauma are based on evidence from the dense portions of the frontal and occipital bones, along with the parietal bones. We continue to generate and interrogate experimental studies and forensic casework to resolve this issue.

Can we identify those engaged in heavy labor, compared to those in less demanding daily behaviors?

We are not optimistic about osteoarthritis (OA) in attempting to generally identify general patterns of occupational stress in the people of Phaleron. OA may be useful as supporting evidence and in individual osteobiographies. Studies of entheseal remodeling (EM) and Long Bones (LB) – Diaphyseal Shape, Bone Density, and Cross-sectional Diameters – appear to be empirically based upon data from documented collections, experimental evidence, and sports medicine. These forms of bone response to activity stress will comprise the focus of the Phaleron Bioarchaeological Project.

Can we proceed further, with at least a few occupations associated with distinctive suites of behaviors?

This goal is vastly more challenging if we attempt to move beyond general discussions of heavy labor vs. less demanding occupations. Many EM and LB changes have been proposed to link to specific behaviors, (e.g., Capasso et al. 1999; Kennedy 1989; and Kennedy et al. 1986). Even so, establishing that a condition occurred in one or a few individuals from a defined occupation group at a specific place and time does not permit the association of the unknown occupation of an individual with the presence of that condition. Similarly, a theoretically generated model for associating muscle stress with EM and LB changes requires experiment (in laboratory or in documented collections) prior to acceptance.

In a contextually grounded study, *sensu* Hawkey and Merbs (1995), Thomas (2014) has identified a suite of ECs that are statistically more common in males buried with arrowheads in the Cerny culture Neolithic sites of western Europe than in those without this burial accompaniment. Such changes are “compatible with medical data on present-day archers” (Thomas 2014: 287). This is strong circumstantial evidence for identifying hunters within these early agricultural communities.

A profession reliably linked to specific changes is that of ballet, which is not referenced in the bioarchaeological or forensic anthropological literature (Huwyler 2007; Prist et al. 2008). As Schneider et al. (1974: 628) report:

> *"Among the various abnormalities, some similar to those found in athletes, were specific patterns of stress hypertrophy of the femora, tibiae, fibulae, and the first three metatarsal bones, and multiple stress fractures of the femoral necks and tibiae. This group of findings is sufficient to identify the classical ballet dancer."*

Schneider et al. (1974) also review previous studies reporting this phenomenon, all dating to the middle of the 20th century, and many written in Russian language. More recent sources (e.g., Prisk et al. 2008) also emphasize the enormous stresses on the forefoot, and that ballet dancers are both artists and athletes.

While we are not anticipating ballet dancers among our Phaleron remains, we are inspired by Schneider et al.'s (1974) methodology that explicitly defines primary and secondary features common in ballet dancers'—including both males and females—suites of maladies. The researchers report that patterns of stress hypertrophy and stress fractures are uniquely linked to ballet dancers, while incidental findings include chip fractures, dislocations, osteochondritis dissecans, meniscus injury, mild OA in younger individuals that increased with age, calcareous peritendinitis, bunions, and calluses.

Which skeletal attributes are the most reliable for characterizing bone altering behaviors, having been tested in other documented contests?

The ability of entheseal alterations, especially the V.E.R.A. approach (Karakostis and Lorenzo 2016), and various bone shapes and densities to reflect activity is impressive. Identifying occupations thus requires a constellation of features, anchored by LB and EM, which supplemented by information from OA and fractures, holds the greatest potential for exploring occupation and activity at Phaleron.

Are we able to identify (groups of) adolescent-young adult individuals whose daily lives suggest that occupations are being defined through apprenticeship at an early age?

This approach holds potential and should be explored. It will be limited by the relatively few adolescent deaths at Phaleron, as is typical of any human group. The relatively large numbers of young adult males should be a source of relevant information, however.

Can we identify rowers at Phaleron?

Informed by this review of activity-related changes in bone shape and pathology, we hope to engage in a multivariate approach for identifying the range and frequency of physically demanding behaviors and occupations at Phaleron. We will use inductive procedures, such as cluster analyses, to identify bony alterations that seem to be uniquely associated, including fractures, EM, and LB. In addition, we will establish a priori constellations of core changes that identify certain occupations and establish whether these co-occur more commonly than one would expect by chance.

For example, a survey of the sports medicine literature and other clinical sources suggests that there is a suite of features commonly associated with rowing, including spondylolysis (Rumball et al. 2005; Soler and Calderon 2000); other lower back maladies, including disc herniation (Hosea and Hannafin 2012; Karlson 2012; Rumball et al. 2005; Wilson et al. 2010); upper back degeneration (Wilson et al. 2010); rib stress fractures (Hosea and Hannafin 2012; Karlson 2012; McDonnell et al. 2011; Rumball et al. 2005; Warden et al. 2002; Wilson 2010); sacro-iliac dysfunction (Rumball et al. 2005; Timm 1999); knee injuries, including patellofemoral and iliotibial band symptoms (Hosea and Hannafin 2012; Karlson 2012; Rumball et al. 2005); wrist conditions, such as tendinitis (Karlson 2012; Rumball et al. 2005); and shoulder pathology, such as stability issues and possible dislocation in younger athletes (Karlson 2012; Rumball et al. 2005).

In sum, rib stress fractures are the most commonly reported pathological conditions with associated skeletal changes reported in rowers. Other rib-related maladies include costochondritis, costovertebral joint subluxation, and intercostal muscle strains (Rumball et al. 2005). The full suite of pathological change reported above (2.1.1.4) will establish our comprehensive expectation range for identifying rowers on the basis of attribute clusters, with rib fractures, lower and upper back pathology, and shoulder degeneration comprising the core for a priori study.

The nature of the rowing equipment doubtless affects the frequencies of human skeletal pathologies (Karlson 2012). A comprehensive suite of additional equipment, training, and environmental factors affecting frequencies of rib fractures has been reported by Warden et al. (2002). We must be sensitive to these issues in assigning rowing or any other occupation to the people of Phaleron.

CONCLUSIONS

In conclusion, we cautiously assert that there is significant potential for identifying individuals with both general and specific activities in the past. Most useful would seem to be approaches based on 3D images analyzed according to a range of known occupations, as developed by the V.E.R.A. approach, along with the underdeveloped links between advanced imaging methods and sports medicine. Fractures hold potential as well, especially when distinctions between accidental and interpersonal, and perimortem and postmortem causes can be further established. Advancement in both methodologies and rigorous applications should be sought and eagerly embraced for all possible means for estimation of activities and occupations in the past.

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