Bioarcheology Has a “Health” Problem: Conceptualizing “Stress” and “Health” in Bioarcheological Research

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KEY WORDS bioarcheology; stress; critical history; skeletal indicators of stress; health

ABSTRACT This article provides a critical historical overview of the stress concept in bioarcheological research and critically evaluates the term “health” in reference to skeletal samples. Stress has a considerable history in 20th century physiological research, and the term has reached a critical capacity of meaning. Stress was operationalized around a series of generalized physiological responses that were associated with a deviation from homeostasis. The term was incorporated into anthropological research during the mid-20th century, and further defined in bioarcheological context around a series of skeletal indicators of physiological disruption and disease. Emphases on stress became a predominate area of research in bioarcheology, and eventually, many studies utilized the terms “health” and “stress” interchangeably as part of a broader, problem-oriented approach to evaluating prehistoric population dynamics. Use of the term “health” in relation to skeletal samples is associated with the intellectual history of bioarcheological research, specifically influences from cultural ecology and processualist archeology and remains problematic for two reasons. First, health represents a comprehensive state of well-being that includes physiological status and individual perception, factors that cannot be readily observed in skeletal samples. Second, the categorization of populations into relative levels of health represents a typological approach, however unintentional. This article advocates for the integration of methodological and theoretical advances from human biology and primatology, while simultaneously incorporating the theoretical constructs associated with social epidemiology into bioarcheological research. Such an approach will significantly increase the applicability of bioarcheological findings to anthropological and evolutionary research, and help realize the goal of a truly relevant bioarcheological paradigm. Am J Phys Anthropol 155:186–191, 2014. © 2014 Wiley Periodicals, Inc.

One probably does not need to say that “stress” is now a well-accepted noun and verb, state and process, in the English language. A recent Google search (6.26.2014) yielded 154 million hits on the search term “stress.” Not all of these hits refer to physiological or psychological dimensions of stress, for example, some hits refer to the use of stress in a mechanical sense. Yet, “stress” is an undeniably common notion in our health and nutrition conscious times; as a search term it yields more hits than “disease” and “nutrition” and has over three times the number of hits than the term “illness.” The broadening, everyday adoption of this term has lead to a widening and diffusion of its meaning. Now, many contexts for the use of stress move drastically beyond its intended purpose in the study of human physiological well-being. While a useful term, the vagueness of “stress” permeates bioarcheological uses.

The current situation is new. In the 1950s and 1960s, stress was a concept with a more restricted circulation and precise definitions. Stress and strain were used in mechanics and physics and then morphed into the biological sciences. At about the same time, notions of stress, coping, and maladaptation began to circulate in psychology. The experimental work of Selye (1936, 1956) showed that a diverse range of stressors, from threats and fears to heat and cold, lead to stereotypical physiological and hormonal processes, which he called “the general stress response.” Selye and others endocrinologists found that even those stressors that were perceived as positive lead to heightened alert and preparation for action: fight or flight, and specifically the activation of the sympathetic nervous system, the hypothalamus, and the release of so-called stress hormones, most importantly cortisol and adrenaline, from the adrenal cortex and adrenal medulla. The rise of a focus on stress, as measurable deviation from a homeostatic resting state, came from both the psychological and biomedical sciences and helped to reconnect the brain and body. Stress, especially if long lasting and chronic, became an accepted mechanism by which individuals might become ill. Reducing stress became an important mantra of self-help programs and biomedicine. Moreover, variation in stress by groups might explain variations in health.

The study of the general stress response gained traction in biological anthropology in the 1970s. A focus on signs of stress was both evidence of an adaptive challenge and evidence that adaptive mechanisms were often swamped, resulting in a perturbation to the individual (Goodman et al., 1988). This focus on stress was also a corrective to a perceived over-emphasis on the possibilities of positive and often no-cost adaptation. Not all stressors such as political subjugation or endemic famines were successfully thwarted.

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Received 19 July 2014; revised 10 August 2014; accepted 10 August 2014

DOI: 10.1002/ajpa.22602
Published online 19 August 2014 in Wiley Online Library (wileyonlinelibrary.com).
An important pioneering example of this use of stress is Brown's (1981) anthropological study of catecholamine responses of Filipino migrants to Oahu, Hawaii. Brown was the first individual to collect urine samples and assay adrenaline and noradrenaline from the samples collected in the field. His study suggested that different coping mechanisms and lifestyles seemed to vary in their ability to successfully reduce stress, as evidenced by variation in adrenal medullary activation. Prior to Brown, nearly all studies of catecholamine responses were performed on experimental animals and/or in laboratory settings. Whereas studies of human adaptation focused on successful responses (either genetic of developmental) to environmental constraints and stressors, a focus on the stress response, in a sense, focused more on the constraints, contradictions, and limits of adaptation.

Since the pioneering work of Brown, field studies of stress in humans have become far more common. Many researchers, anthropologists and others, have restricted themselves to the original indicators of stress, catecholamine, and corticosteroid levels (see for examples the reviews by James and Brown, 1997; Ice and James, 2012). Recent work has been made more efficient by the development of techniques for the rapid assessment of salivary hormone levels (Ice and James, 2012).

As well, as we see with bioarchaeological studies, the meaning of stress has broadened. In recent years, stress has come to mean more than a hormonal response or even a sign or residue of a hormonal activation. In all of the human sciences it is common to hear of different stresses faced by humans, such as emotional stress, climatic stress, disease stress, and nutritional stress. All of these have become object of analysis for human ecologists and biologists who are interested in adaptation and in the present.

STRESS RESEARCH IN BIOARCHEOLOGICAL CONTEXT

The intersection of health, stress, and biocultural approaches in bioarchaeology and skeletal biology has a lengthy history, and there is great historical agency within the discipline that has acted to promulgate these studies over the last 40 years. Specifically, bioarchaeological emphases on “stress” and “health” have grown out of a broader, problem-based approach that is tied to the resistance of early 20th century skeletal biology. One of the earliest and most influential attempts at a biocultural approach to stress and disease in bioarchaeological research is found in the monograph, Indians of Pecos Pueblo (Hooton, 1930). The work documents and interprets skeletal indicators of disease at the protohistoric site, and attempts to contextualize these indicators within the lives and lifestyles of the Pueblo Indians. However, the work has been critiqued for references to racial categories and population origins of the skeletal sample (Armelagos et al., 1982; Armelagos, 2003; Armelagos and Van Gerven, 2003; Martin et al., 2013). This racialized approach to anthropology, and skeletal biology in general, remained a common theme throughout the mid to latter 20th Century, particularly because of the popularity of forensic anthropology (Armelagos and Van Gerven, 2003).

Later contributions, including Armelagos (1969, p. 225), explicitly define and operationalize the idea of stress in bioarchaeological research. Armelagos (1969) twice uses the term stress as an “index of biological response” that may be the result of cultural variation and change. The theme of stress is subsequently applied more explicitly by Jerome Rose (a student of Armelagos) in a study of “histological enamel indicators of childhood stress” at Dickson Mounds, Illinois (Rose et al., 1978). Rose et al. (1978) consider Wilson bands, accentuated stria of Retzius, to be indicators of early life stress (rather than disease or under-nutrition, for example) and links their frequency to population differences in adaptation to economic changes. The equating of Wilson bands as a sign of stress is sensible given the wide array of potential causes of enamel growth disruption (Goodman and Rose, 1990). By the late 1970s, stress had entered the vocabulary of skeletal biology.

Health, disease, and stress were soon solidified as key concepts in the emerging field of bioarcheology, defined at about the same time in the North American literature by Buikstra (1977) as the study of human skeletal remains in the context of their associated mortuary artifacts, and by extension their culture. This early work to incorporate skeletal indicators of stress and disease into bioarchaeological research by Armelagos, Rose, and Buikstra established human remains as dynamic products that represent the lived experiences of past people, social, and ecological. In particular, Buikstra (1977) notes that the rise of prehistoric cultural ecology and processualist archeology provided opportunities for anthropologists working with skeletal remains to test actionable hypotheses about human/environmental interactions. This research provided new perspectives on social organization, diet, and stress during the Late Woodland period, and it ushered in a phase of bioarchaeological research focused on transcending descriptive or typological (see below) approaches, with indicators of stress at the forefront of many endeavors.

Complementary work on the history of skeletal biology through the 1980s critiqued bioarcheology, and skeletal biology in particular, as one mired in typological thought (Armelagos et al., 1982). Here, the term typological references research that fails to test hypotheses and focuses on description or categorization in the absence of broader anthropological theory. This critique argued that skeletal tissue expresses some degree of plasticity and anthropological explorations in skeletal biology should be focused on morphological variation related to diet and mechanics. These arguments followed the lead of Buikstra (1977) by suggesting that skeletal biology has a unique opportunity to test hypotheses associated with processual archeology, cultural ecology, and functional adaptation.

Simultaneously, one of the authors (Goodman) worked at the Laboratory for Clinical Stress Research in Stockholm, directed by Levi (1975), a leading synthesizer and proselytizer of stress. Goodman helped to expand the meaning of stress in bioarcheology and developed what was first called “an ecological model of general stress” (Huss-Ashmore et al., 1982). This model was then

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1There, the application of a biocultural approach in bioarchaeology follows Stinson et al. (2012), where human biology interacts with culture and human biological variation must be evaluated within this context. Because humans are highly encephalized and socialized mammals, culture also influences the surrounding environment and how humans react to challenges associated with local ecologies. Therefore, a biocultural approach in bioarchaeology evaluates variation in human skeletal remains in terms of culture, environment, and the influence of culture on environment.
modified slightly and renamed as a “model for interpretation of stress indicators in paleoepidemiological research” (Goodman et al., 1984, p. 14) in the groundbreaking volume “Paleopathology at the Origins of Agriculture” (Cohen and Armelagos, 1984).

Charged with providing an overview of indicators of health, disease and nutrition available through bones and teeth, Goodman et al. (1984) decided to organize their comments, and in some sense orient the field, around what came to be called the stress perspective. Whereas one could not directly measure adrenal activation as Brown (1981) had done, Goodman et al. argued that hard tissues were limited in the ways they could respond to stressors. Sometimes, signs of stress remained on bones as evidence of growth disruption, disease, and premature death. Of course, many fundamental questions remain, such as understanding how to evaluate circumstances when stress is so rapid that there is no osteological response (Wood et al., 1992).

The full model (Fig. 1) depicts a linear process flowing from left to right. On the left, the start of the stress process, environmental constraints (including limiting resources such as nutrients and stressors such as excess heat and cold) interact with cultural buffering systems. Culture could be both a reducer or buffer of environmental constraints/stressors and a system to induce new stressors. For example, food production systems provide nutrients that combat stress but political systems might limit food distribution. The biophysical and cultural environment interacted with an individual and due to different biological factors (sometimes related to age and sex) might vary in their ability to further resist stress.

Importantly, if these systems (environmental, cultural, host) are not able to remain in homeostasis, then physiological disruption (or stress) would result. The paleoepidemiologist can assess “stress” by analysis of residues or signs on bones and teeth. The goal for bioarcheologists was to collect information on a diverse array of these signs of stress or stress indicators to gain a fuller picture of the adaptation within a group. Goodman et al. (1984) divided their review of stress indicators into general stress indicators such as mortality, growth, and enamel developmental defects, and specific disease stress indicators (such as traumatic lesions and periosteal reactions).

One of the interesting observations about the first version of the stress model (Goodman et al., 1984) is that the term health is never used. In fact, the term “health” is not found in the index to the seminal volume “Paleopathology at the Origins of Agriculture.” The focus is clearly on the bad news: stress, disease, and death. This omission of health from the model is intentional in the realization that health is so difficult to operationally measure, even in living populations.

Three significant revisions were later made to the model (Fig. 2; Goodman and Armelagos, 1989, p. 226). The last box of the former model, skeletal indicators of stress, is moved under physiological disruption (stress) to signify that the skeletal indicators are manifestations of stress but not the cause of functional impairment. The last box of the linear model is new and labeled “impact of stress on population.” These are so-called functional capacities, including decreased reproduction, work capacity, and health. Finally, these functional impacts feed back to the environment and cultural systems.

This theoretical framework moved bioarcheological research beyond a descriptive approach and toward one that embraced anthropological themes, including population stress and culture change (Cohen and Armelagos, 1984; Armelagos and Swedlund, 1990; Cohen and Crane-Kramer, 2006), the biological consequences of contact (Larsen, 1994, Larsen and Milner, 1994), stress in marginal environments (Merbs and Miller, 1984), broad comparisons of “health indexes” within hemispheres (Steckel and Rose, 2002), and differences in stress and disease related to socioeconomic structure (Powell, 1988).

The important publication of The Osteological Paradox (Wood et al., 1992) pointed out that skeletal indicators of stress may not form a straightforward relationship with “health” and urged researchers to adopt several epidemiological methods to reevaluate these relationships. Skeletal lesions should, for example, be problematized in terms of their impact on survivorship, rather than simply compared in prevalence. Framing skeletal indicators of stress within a demographic context would help support the possibility that those individuals with skeletal evidence for systemic perturbation did not represent an advantaged segment of the population relative to those who died without lesions.

Wood et al. (1992) helped reinforce at least two trends that had already begun but, perhaps, had not been as widespread as they ought to be. First, as noted above, they questioned whether a stress indicator had any consequence on future morbidity and mortality. Indeed, this epidemiological relationship has frequently been considered for dental enamel hypoplasia (see review of Armelagos et al., 2009). The vast majority of the studies reviewed show some inverse relationship between enamel defects and longevity. However, the strength of this relationship is highly variable. Second, Wood et al., remind us of the importance of evaluating the meaning of skeletal indicators of stress in comparative context.

The operationalization of the stress model in bioarchaeological research has not, however, been free from problems of a formulaic and typological approach. Paralleling the use of stress and health in general use today, one finds nebulous conceptualizations of “health” versus “stress” in bioarchaeological studies, and the categorization of populations as “healthy” or “not healthy” based on skeletal indicators of stress render many studies
typological, however unintentional. By extension, those studies interested in reconstructing the consequences of social-cultural complexity frequently experience what might be referenced as meta-typological dilemmas, labeling members of a sample as “high status” or “low status” based on the presence/absence of grave goods, then further categorizing those individuals as “healthy” or “not healthy.” The reality of stress and social organization are far more complex than these categorical treatments, and significant progress in theoretical development is needed for the continued growth of bioarchaeological research.

MOVING FORWARD: CONTEXTUALIZING STRESS IN (POST) MODERN BIOARCHEOLOGICAL AND HUMAN BIOLOGICAL RESEARCH

Despite the pervasive threat of typological research, bioarchaeology is now embracing themes that delve into broader social conceptualizations of stress and life history; it is drawing on principles and insights from diverse fields such as social epidemiology and embodiment theory (Agarwal and Glencross, 2011). In fact, one could argue that bioarchaeological research has significantly broadened the use of anthropological and evolutionary theory: for example, the number of bioarchaeological publications in the American Journal of Physical Anthropology that test hypotheses and incorporate questions of anthropological/evolutionary relevance increased in relation to typological research between 2000 and 2003 (Larsen, 2003). Even studies of biodistance focus on expressions of ethnicity, identity, and population interaction as opposed to origins and categorization (Buikstra et al., 1990; Stojanowski and Buikstra, 2003; Stojanowski, 2010).

Recent theoretical contributions in human biology have also appealed to evolutionary conceptualizations of these problems, specifically focusing on the concepts of life history and trade-offs within the human physiological system (Worthman and Kuzara, 2005). These studies argue that there is great plasticity in development; for example, humans differentially allocate energy budgets to essential tissue growth and maintenance during periods of stress. However, the process is not without consequence as these energetic allocations reduce investment in future growth and maintenance as well as other functions such as reproduction and disease resistance.

Other studies argue that the human phenotype responds to early stress through a series of adaptive responses that help thwart stress at future stages of development (Gluckman et al., 2007). In this context, human physiology uses early environmental cues in preparing responses to future life experiences. For example, women who were small at birth have stronger estradiol output in response to intermediate labor efforts, and muscle contraction is more physiologically efficient in individuals from impoverished environments (Shetty, 1993; Ellison and Jaziehska, 2007). However, individuals who experience stress early in development also reduce energetic investment in growth, fertility, and maintenance (Kuzawa, 2007). As a result, these individuals are frequently stunted in size, reach reproductive maturity at earlier ages, and die younger (Metcalf and Monaghan, 2001; Walker et al., 2006; Kuzawa, 2007; Stock and Migliano, 2009). Bioarchaeological research has, by and large, failed to apply these experiential and evolutionary models to explorations of stress in the past, though there remain an increasing number of studies advocating for such an approach, and many even demonstrate the types of trade-offs associated with disruptions to physiological homeostasis (DeWitte and Wood, 2008; Agarwal and Beauchesne, 2011; DeWitte and Morey-Hughes, 2012; Temple, 2014; Klaus, 2014).

The reasons for this deficiency are largely historical. As aforementioned, bioarchaeological research, and skeletal biology specifically, has a history that is marred by eugenics and racism. Early studies in skeletal biology used measurements of the human cranium to determine differences in similarities between racial categories, with possible cases of “unconscious” fraud found in the calculations (Gould, 1981). The results of these works have long been refuted by genetic and morphological data (Lewontin, 1972). This reliance on description was, however, highly influential in the founding of the American Journal of Physical Anthropology (Marks, 2012) and persisted through the latter 20th Century (Armelagos and Van Gerven, 2003), despite the consequences of scientific racism, particularly as depicted by public perception of human biological variability (Gravelle, 2009), and construction of dynamic research paradigms within bioarchaeology (Buikstra, 1977; Armelagos et al., 1982; Goodman et al., 1984; Armelagos, 2003).

The bioarchaeological approach that resisted typology was born out of cultural ecology and processualist archeology, and the work that resulted produced actionable hypotheses for evaluating interactions between humans and their environments. Thus, the historical agency associated with the intellectual history of bioarchaeology established these studies as paramount within the discipline. Viewed within this lens, skeletal indicators of stress were compared between samples, and researchers consistently appealed to environmental variation as an explanatory narrative. The number of edited volumes dedicated to this topic attribute to the compelling nature of this argument (see above). The obfuscation here lies in the idea that “health” is represented by skeletal lesions.

As pointed out by the introduction to this volume, skeletal indicators of stress capture an event in time, but differ significantly from evaluations of “health” in living communities. For example, individuals in this sense are not measuring health outcomes, but instead, evaluating stress within a community. For example, Reitsema and McIlvaine (2014) point out that health is a state of complete physical, mental, and social well-being and not merely the absence of disease, or infirmity (emphasis theirs). This is important because it recognizes the dichotomy between disruptions experienced at the community and individual level, how these disruptions are associated with broader perceptions of well-being, and the impact of these disruptions on evolutionarily and ecologically important factors such as survivorship and susceptibility to future stress events.

In concert with the historical agency that privileges studies of health in bioarchaeological research (see above), McIlvaine and Reitsema (2013) note that there remain a considerable number of articles published in the American Journal of Physical Anthropology and International Journal of Osteoarchaeology that misrepresent health: 17% in the American Journal of Physical Anthropology, 32% in the International Journal of Osteoarcheology. To be certain, these studies break with the intellectual history of racism in skeletal biology,
encapsulate theoretical paradigms, and test hypotheses. The problem, however, lies in the idea that health is not being evaluated. Skeletal indicators of stress and disease represent disruptions to physiological homeostasis at particular points of development, but do not necessarily act as a cumulative health index.

The work in this symposium is important because it calls for three important points to be considered. First, it calls attention to circumstances where the relationship between skeletal indicators of stress form an imperfect, and perhaps, contradictory, relationship with population health. The broader contribution argues that “health” is a complex process that includes skeletal indicators of stress, but also the impact of these processes on human life history and individual perception. Second, an integrated approach to bioarchaeological research that incorporates knowledge from human biology and primatology is necessary to understanding the physiological mechanisms of stress and disease, rather than simply focusing on the prevalence of skeletal stress indicators. Such an approach is imperative if bioarchaeological research is to forever leave behind typological approaches specifically those that use skeletal stress indicators to classify populations according to health, and assert its relevance to the broader fields of anthropology and evolutionary biology. Third, these papers show the importance of understanding the context of stress. They attest that the same frequency of stress indicators can mean very different things depending on circumstances and context. The continued integration of methodological and theoretical contributions from human biology and primatology (as advocated in this volume) will help diminish these boundaries.

CONCLUDING REMARKS

Bioarchaeological analysis of stress has a long history, and over the past 40 years this history was rooted in prehistoric cultural ecology and processualist archeology. These theoretical frameworks were granted agency through the resistance of typological research and movement towards a problem-oriented approach. The problem-oriented approach privileged questions that addressed ecological prehistory and processualist archeology. However, problem-oriented research resulted in a large number of studies exploring the consequences of cultural variation and transitions, which paradoxically and inadvertently increased studies that compared lesion frequencies between samples in an effort to understand population “health.” Unfortunately, “health” cannot be summarized according to lesion frequency. “Health” is associated with individual perception of well-being, physiological well-being, and mortality. The issue extends beyond relative population “health” and experiences meta-typological dilemmas when social structure is evaluated according to simple categories of “high versus low status” burials—a more complex framework for evaluating population stress and social structure is needed.

This symposium demonstrates that many bioarchaeological studies attempting to address “health” suffer from a dialectical failure and are actually exploring indicators of stress within skeletal samples. Here, the bioarchaeological studies misrepresent the broader, more holistic concept of health, when stress remains the focus. Skeletal indicators of stress should be evaluated in terms of mortality and survivorship. There are two rea-

sons for contextualizing stress indicators in this fashion. First, stress indicators may be associated with greater longevity. In this case, the sample with a greater prevalence of lesions experienced a reduction in stress or individuals are able to survive for longer durations following stress experiences. Second, the relationship between early-life stressors and mortality may allow bioarchaeologists to evaluate some of the more pressing questions in human biology, for example the evolution of developmental plasticity and life history trade-offs.

The articles in this volume also demonstrate that an integrated and contextual approach is essential to the ability of bioarchaeological research to thrive as a discipline. Interaction with human biology (and primatology) is crucial to providing explanatory mechanisms, particularly regarding physiological responses, for observations drawn from human skeletal remains. Human biology (and primatology) is in a unique position to provide these explanations through explorations of living human populations, thus injecting a much needed physiological perspective to bioarchaeological research that is hampered by skeletal-level data. It remains important that bioarchaeologists work within the parameters of what is known about human physiology and how this information is useful to evaluate results within bioarchaeological assemblages, and not go beyond the scope of available data (i.e., tracking intergenerational trends versus exploring the impact of early-life stress events). However, the results of this symposium demonstrate that integrating approaches with human biology (and primatology) will help bioarchaeology thrive as a discipline by providing nuanced physiological approaches that contextualize bioarchaeological results and establishing important hypotheses that can be tested on bioarchaeological assemblages.

ACKNOWLEDGMENTS

The authors are thankful to Brittany Melvaine and Laurie Reitsma for inviting us to comment on stress and health in bioarchaeology as well as for assembling a superb group of papers. They also wish to thank the contributors to the American Association of Physical Anthropology symposium and the contributed papers. As the field of bioarchaeology evolves we are aware that it does so based on the work of pioneers. It is timely to specifically acknowledge the work of George Armelagos (1936–2014) who trained many of the next generation of bioarchaeologists and whose work exemplifies the best the field has to offer.

LITERATURE CITED


