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Patterns of infectious disease in ancient Brazilian groups: the role of different environments and demographic parameters

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Abstract. In the last 200ka, humans have explored and adapted to a changing world. Environmental challenges faced by humans today, like emergent pathogens and overpopulation, are not that different from the ones in the past. This article aims to discuss the patterns of disease observed in ancient human populations from southeastern and southern Brazil (hunter-gatherer groups associated to riverine and coastal shellmounds and agriculturalists associated to the Tupiguarani archaeological Tradition). The role of new pathogens and high demographic density will be discussed, as well as the interpretations regarding the frequencies of chronic infectious diseases that affect bones. We will also present the importance of understanding patterns of health and disease in past human populations in order to address present day scenarios related to climate change, vulnerable populations, and disease. Warning: This article discusses and presents images of ancient human remains. While we acknowledge that this can be a sensitive topic, we would like to stress the importance of studying and generating knowledge about past human populations which otherwise would be completely unknown and forgotten.

1 Introduction

In the last 200 kyr, populations of *Homo sapiens* have colonized, explored, and adapted to a changing environment. Such adaptive strategies can be observed in the myriad of different and innovative ways of adaptation and natural resources management observed in hunter-gatherer groups, as well as in the anthropogenic constructed niches (mostly) related to the advent of plant and animal domestication. The challenges faced by humans today (global warming, emergent pathogens, overpopulation, among others), which apparently seem so distant from the Pleistocene and most of the Holocene period, are actually not that different. In the past, human populations also grappled with the stresses of climate change, exposure to new pathogens, as well as population growth.
This article aims to discuss the interplay between infectious diseases and demographic parameters inferred from past human skeletal remains using hunter-gatherers and agriculturalists from southeastern Brazil as a case study. The study of the patterns of health and disease in past human groups can also illuminate contemporary issues related to climate change, population growth and the role of diseases.

1.1 Paleopathology, the study of skeletal human remains and the Osteological Paradox

Paleopathology can be defined as the study of diseases in past populations, though the analyses of art, literature, and human remains. Most paleopathological studies are based on human remains, especially skeletons. There are many approaches to paleopathological analyses, ranging from individual case studies (that can be also known as osteobiographies) to a populational approach. Populational approaches allow researchers to better understand how subsistence strategies, settlement modes, and environmental settings can influence the patterns of health and disease of a given population in the past [1].
The study of bones in order to reveal diseases in the past presents quite a few difficulties when looking at the bones on their own, because there are few diseases which leave marks in them. The few diseases which are likely to cause marks in the bones are those bacterial infections which do not kill the host very quickly, leading to a chronic state of infection which causes damage in the bones. Once there are lesions found in the bone, differential diagnosis of these conditions can be very difficult. This is due to the fact that many conditions may cause a similar pathological response [2]. In the case of infectious diseases, two manifestations have been traditionally associated with the presence of bone infections: periostitis and osteomyelitis. Periostitis consists of an inflammation within the periosteum in response to local or systemic infection [2, 3]. Osteomyelitis is the result of the introduction of bacteria into the bone marrow by direct infection after a trauma, by extension from an adjacent infection process or by hematogeneous spread [2,4].
Demography plays a significant role in the presence, frequency and nature (acute or chronic) of infectious diseases. The cause of such relation is the amount of naïve hosts that are present in a given population, which are pivotal for the support and spreading of pathogens. In the hypothetical and very simplistic case (that does not take into account the possibility of reinfection), in a small hunter-gatherer group, a pathogen will infect all the individuals and after some time, these individuals

will be either dead or resistant to the infection. This means that unless there are new (naïve) individuals in the population (through birth or migration), the infection will die out. Therefore, most hunter-gatherer groups will not present good conditions to sustain for a long time acute infectious diseases. In groups that present higher demographic densities, like most agriculturalists, there will be more (new) individuals to support the spreading of such infection [5]. Moreover, the increase in the sedentarism in past populations have been pointed out as an important factor that contributes positively to the spread of some parasites and pathogens [6].

According to Wood et al. [7], researchers have been too hasty in making inferences about the health of prehistoric populations on the basis of indicators of morbidity and mortality derived from skeletal samples. Factors like the number of lesions in a skeletal sample have often been assumed to be negatively correlated with the health of the population from which the sample is derived [8]. However, Wood et al. [7] have suggested that paradoxically the reverse of such assumptions may more accurately reflect the true situation. As a result of factors like "selective mortality" and "hidden heterogeneity of risks", the commonsense view that skeletons presenting many bone lesions derived from chronic infections confer poor quality of health may be misleading. Since skeletal samples comprise only the individuals who were selected to die at a given point in time, they may or may not be representative of the population as a whole. Also, individuals within populations are heterogeneous in frailty or susceptibility to disease, making it near impossible to conclusively identify the context in which particular members were selected to enter the skeletal sample. As a means of support for their "osteological paradox", the authors [7] have identified various instances in which skeletal samples that at face value might be taken to be indicative of a sickly population could in fact be just the opposite [9].

One example is of a fictitious population containing three sub-groups that differ in terms of both the level of exposure to and the likelihood of death from a disease [7]. In this scenario, a skeletal sample would be of little use in determining the overall health of such a population because it would not be possible to distinguish healthy people that never came into contact with the disease from very frail people who succumbed to the disease before skeletal lesions had a chance to form. While both these groups would be represented by individuals completely lacking in lesions, a third group of people who suffered from the disease, but were strong enough to survive at least for a period of time would be characterized by skeletons that did present lesions. Thus, skeletal lesions may not always be indicative of relatively unhealthy groups in which individuals have a higher chance of being subjected to disease. Rather, despite being a manifestation of disease, skeletal lesions could in fact be a sign of comparative health.

Regardless of such difficulties involving the interpretation of the patterns of chronic infectious diseases affecting bones, there is a very important question when aiming to use patterns of health and disease in the past as models to better understand the present: what can such patterns tell us about the human past and present? To answer such a question, the so-called Applied Paleopathology can be an important tool to discuss how the study of ancient human populations can help us to better understand our current situation. Many present-day scenarios can be tentatively addressed using Applied Paleopathology, including the importance of reemergent infectious diseases like tuberculosis in specific vulnerable groups, as well as other diseases associated to migrants, refugees, and homeless population. Moreover, climate change also plays a relevant role by creating climatic refugees and associated diseases and other unhealthy events, including increased violence [10].

2 A case study from South and Southeastern Brazil

In order to better explore the possibilities of using paleopathology as tool to unravel patterns of infectious diseases in the past under the light of the Osteological Paradox and the demographic parameters of human populations, we will present data from three human groups from southern and southeastern Brazil: published data from many archaeological sites associated to two hunter-gather groups (coastal shellmounds and riverine shellmounds) and preliminary data from agricultural groups associated to the Tupiguarani Tradition. These groups are fit for the case study because they represent different subsistence patterns (hunter-gatherers and agriculturalist), and they present different chronologies (Early, Middle, and Late Holocene), as well as distinct environmental/regional settings (coastal and inland region). Moreover, there are hypotheses regarding the demographic parameters of such groups based on different criteria (site size and number of burials in the case of hunter-gatherers and site size and historical accounts in the case of the agriculturalist groups).

The riverine shellmounds that will be presented in this case study (Figure 1) refer to small mounds found in the region of Ribeira do Iguape Valley, in the boundary between Sao Paulo and Parana state, in southern Brazil. Such mounds are smaller in size when compared to some of the huge coastal shellmounds and their distribution occurs along the Ribeira de Iguape river and its affluents. These sites are dated from the Early to the Late Holocene [11]. There is evidence of contact between these sites and the coastal environment, given that shark teeth were found in some of these sites, and such evidence is supported partially by craniometrics [12]. However, isotopic analyses [13] show that a terrestrial diet was prevalent among the riverine shellmound groups. There is no strong evidence that such groups were very different from the classical model accepted for most hunter-gatherer populations, therefore it is assumed a fairly low population density and some mobility in the landscape.

Fig. 1. Riverine shellmound from Adrianopolis county, Parana state, Brazil. Photo: Aline Lima.

Coastal shellmounds (Figure 2), also known as "sambaqui", are sites found in the coast of Brazil mostly from the current states of Rio de Janeiro, Sao Paulo, Parana, and Santa Catarina. Most of these shellmounds date to 6,500 and 800 BP, with a peak between 5,000 and 3,000 BP [14]. Although the percentage of shells and the size of the mounds can present variations, they are all related to hunter-gatherers that heavily occupied the coast in the past. In fact, data from zooarchaeological studies, as well as isotopic analyses point to a diet based on fish and other marine resources (for a review, see [15]). Sambaqui groups have been interpreted as fairly sedentary populations, given the huge size of some of such mounds (in some places, many mounds were built at the same time [16] and the great number of human burials that are found in such structures.

Fig. 2. Coastal shellmound from Jaguaruna county, Santa Catarina state, Brazil. Photo: Mercedes Okumura.

Discussions about the origin and expansion routes of the Tupiguarani archaeological Tradition are among the hottest in the Brazilian archaeology. First, because archaeological sites presenting this pottery tradition associated to sedentary groups that domesticated plants abound in almost the entire national territory and second because, unlike what happens with other archaeological traditions already identified in Brazil, the debate on the Tupiguarani have been putting together information from archaeology, ethnology and historical linguistics.

Brochado [17] was a pioneer in this debate, suggesting the existence of two archaeological subtraditions: Guarani and Tupinambá. Also, according to the author, the Central Amazon would have been the location of origin of these cultures. From that point of origin in the Central Amazon, two axes of population expansion would have occurred: one (called Proto Tupinambá) towards the mouth of the Amazon river, then extending to the east, populating the entire coast Brazilian Atlantic to, approximately, the limits between São Paulo and Paraná sates; another in a southern direction, via Uruguay, Paraná and Plata river basins, which would have populated all of southern Brazil, Uruguay and northern Argentina. In terms of linguistics, the present-day state of Rondonia is considered as a good candidate for the early migrations and diversification of the speakers of Proto-Tupian languages, given the presence of five of the ten Tupían (western) linguistic families and part of those of the Tupí-Guaraní family [18].

Noelli [19], reviewing the available dates for the Tupiguarani Tradition in the Brazilian territory, came to the conclusion that the expansion of that tradition must have occurred by at least two millennia before the 500 AD hypothesis by Brochado-Lathrap in Central Amazonia, converging with the chronology suggested by Rodrigues [20], which was based on historical linguistics. An Amazon origin for these populations is far from settled [21] and more recent research, discussing the differences between archaeological data and historical linguistics, has pointed to alternative models to Brochado's ideas [19, 22, 23]. The fact is that around 2000 BP there are numerous archaeological sites in northeastern, southeastern (São Paulo and Rio de Janeiro states), as well as in the southernmost part of Brazil (including Rio Grande do Sul state) presenting pottery and other features associated to Tupiguarani groups [24]. It is proposed that these populations introduced the called "polyculture agroforestry" [25], which includes cultivation of domesticated plants, marked the transition to more permanent settlements, and diffused practices of landscape modification including the formation of anthropogenic dark earths [24]. Pottery vessels were used not only for cooking and storing food, but also as burial urns (an example of secondary use of such vessels), in the case of the Guarani, another vessel could be used as a lid). The burial of individuals on the ground, without any vessels is also proposed for both Guarani and Tupinambá [26]. Tupi historical groups could also practice endocannibalism. Being populations that domesticated more than a hundred plants (including manioc and maize), it is expected that such groups lived in great demographic densities, which is supported by the size of the archaeological sites [27].

3 Results and Discussion

The oldest site included in this study is Capelinha, a riverine shellmound, which yielded an individual dated from the Early Holocene (8,860±60 years BP, Beta 153988, Cal BP 10,180 to 9,710 [28]). The site is located in Cajati county, Sao Paulo state. A single individual (Burial II) was analyzed given the highly fragmentary state of other human remains found on the site. Burial II individual presents a very slight bone infection (periosteal reaction, Figure 3), which can be indicative of a chronic infectious disease. However, given the small sample size, no population parameters can be inferred from this site.

Fig. 3. Periostitis observed in a fibula from Burial II Capelinha site. Photo: Sabine Eggers.

More data about infectious diseases from riverine shellmounds from the Ribeira de Iguape Valley are available for Moraes site [29]. The authors divided the results between subadults and adults. The frequency of periostitis observed by type of bone ranged from 18% to 48% in juvenile individuals and from zero to 28% in the adult population. The authors do not report osteomyelitis using the range parameter, which hampers any comparison between the two bone responses to infection. The greater frequency of osteomyelitis in juveniles was 24% (tibia) and in adults, 7% (femur). Frequencies of periostitis in the tibia were reported as 35% in subadults and 28% in adults.

The lack of more complete skeletons (especially post cranial bones) found in riverine shellmounds prevents a more comprehensive analysis of the presence and frequency of bone infections in these populations. This is certainly not the case with the coastal shellmounds, which presented huge numbers of human skeletons.

Frequencies of periostitis and/or osteomyelitis (Figure 4) in the tibiae of human skeletons found in coastal shellmounds range from 90% to 30%, depending on the site [30, 31].

Fig. 4. Osteomyelitis observed in a long bone found in a coastal shellmound site from Rio de Janeiro state. Photo: Jose Filippini.

It is interesting to call attention to the presence of morphological changes associated to chronic infectious diseases observed in some individuals buried in coastal shellmounds that were very similar to the changes associated to treponemal diseases in the literature, as shown in Figure 5 [31, 32].

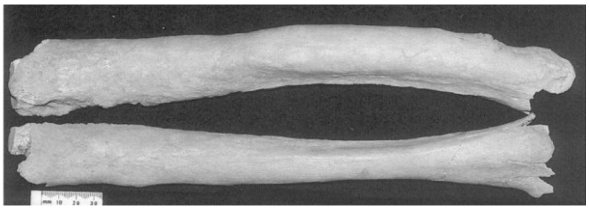

Fig. 5. Morphological changes indicative of chronic infectious disease observed in a pair of tibiae found in a coastal shellmound site. Photo: Mercedes Okumura.

Regardless of the presence or not of treponemal diseases in these populations, such patterns of infectious disease affecting bones are expected for hunter-gatherers with high demographic density, as it has been postulated for these coastal shellmound populations. It is also important to consider the role of a coastal environment in terms of exposition to potential new pathogens or pathogens different from the ones found in inland settings.

There are almost no data about infectious diseases affecting bones in the late Holocene agriculturalist Tupiguarani populations. This is the result of the bad preservation of skeletal remains found in ceramic vessels (the most frequent burial pattern recorded for these groups), meaning that these remains are not as numerous as the ones found in coastal shellmounds and, when such remains are found, usually the bones are highly fragmented, with many parts of the skeleton missing. Two fairly complete Tupiguarani skeletons were analyzed by the author, one found in Jardim Elizabeth (Salto county) and another from Putim site (SP-ST-01), Sao Jose dos Campos county, both from inland Sao Paulo state. They are, respectively, curated by Museu da Cidade de Salto "Ettore Liberalesso" and Museu de Antropologia do Vale do Paraiba. Both individuals were found in ceramic vessels that were used as funerary urns (Figure 6).

Fig. 6. Ceramic vessel from Putim site where human remains were found. Photo: Mercedes Okumura.

The former individual presented no evidence of chronic infections affecting bones (including long bones), whereas the latter individual presented some slight periosteal reaction in the right tibia and fibula (Figure 7). Given that this is a work in progress and that the sample size is small, any interpretations should be made with caution. However, given that these agriculturalists presented a much greater demographic density than the other hunter-gatherers discussed in this article, it is not far-fetched to tentatively discuss the role of acute infections in such groups and the concept challenged by the Osteological Paradox: "healthy dead individuals" [7].

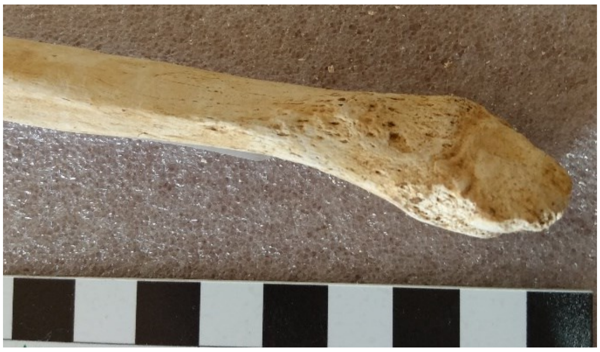

Fig. 7. Right fibula showing a slight periosteal reaction in a human skeleton from a Tupiguarani burial from Sao Paulo state. Photo: Mercedes Okumura.

Although we do not have enough data about the pathogen diversity that such Brazilian populations faced in the past, it is plausible to assume that these past human groups must have faced different infectious agents according to the migration and exploration of new environments. Novel kinds of infections might have had important impacts in the health of such populations and that, together with changes in the demographic patterns (including an increase in demographic density as proposed for both coastal shellmounds and Tupiguarani groups) could have resulted in the presence or not of chronic infectious diseases in hunter-gather and agriculturalist groups. Regardless of the small sample size analyzed for riverine shellmounds in comparison to coastal ones, it can be observed that the former groups present a much lower frequency of bone changes related to infectious diseases than the latter. More data needs to be amassed regarding the individuals found associated to the Tupiguarani Tradition, in order to test the hypothesis of a decrease in the frequency of infectious diseases affecting bones in such populations, as expected in groups presenting an important increase in both population size and sedentism. According to the expectations of such model, Tupiguarani populations might have been more frequently affected by acute infectious diseases, resulting in a low frequency of bone lesions related to infections.

4 Conclusions

The study of health and disease patterns of ancient human groups can help understanding how lifestyle, subsistence, demography, and environmental settings play an important role in the type (chronic or acute) of infectious diseases that will affect a given population. Such patterns can result in the presence of "healthy dead individuals" in the archaeological record and therefore, the interpretation of the frequency of bone lesions like periostitis and osteomyelitis needs to be done cautiously. Regardless of such obstacles, ancient human populations can give us important insights related to the current and future situation of humanity, given the impact of the changes in the environment (specially the climate driven changes) that are already resulting in the increase of vulnerable populations like refugees and migrants.

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