CONSEQUENCES OF OTTOMAN EXPANSION ON DAILY ACTIVITY IN CROATIA: AN EXAMINATION OF ENTHESEAL REMODELING AND OSTEOARTHRITIS

by

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To

My husband, for your support & patience

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ABSTRACT

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Title: Consequences of Ottoman Expansion on Daily Activity in Croatia: An Examination of Entheseal Remodeling and Osteoarthritis.
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The purpose of this dissertation research was to use markers of activity change to explore the effects of imperial expansion and sociopolitical upset on a population. This study focused on markers such as entheseal remodeling and the development and progression of osteoarthritis that are commonly used in bioarchaeological literature to assess changes in activity over time. Three populations were used, comprised of seven different sites, which are divided into the Late Medieval (pre-Ottoman), Early Modern (post-Ottoman), and Vlach populations. These sites come from both the Adriatic and continental region of Croatia and are curated at the Croatian Academy of Sciences and Arts – Anthropology Center. The skeleton is highly plastic, which allows it to serve as an archive for the lived experiences of the individual. Because of this plasticity, embodiment theory was employed as a lens through which to examine the changing activity of people under Ottoman rule. Historical narratives paint this time period as being rife with conflict, with a large proportion of the Croatian population being displaced, subsumed by the Ottoman threat, or killed. This is reported to have caused drastic changes in the daily lives of all Croatians across the country as they were forced to adapt to new rulers or leave their homes. This was tested by examining entheseal remodeling and osteoarthritis within the different populations. The data indicate that although there were some differences found between the time periods, the changes were not as drastic as what may have been expected from the historical data. This is perhaps due to most Croatian people at the time being serfs, living a rugged lifestyle on the lands of feudal lords. Although the Ottomans may have been relentless rulers, they may not have worked common Croatians more so than their Croatian lords. Most people probably remained in their roles as craftsmen or food producers, which would not have left dramatic changes in the form of activity markers on the skeleton.

CHAPTER 1. INTRODUCTION

The purpose of this dissertation is to use bioarchaeological methods to analyze the effect of imperial conquest on the everyday activity of the people of Croatia before and after the invasion of the Ottoman Empire in the mid-15th century C.E. Empires are a significant area of study in anthropological literature; they exert their influence upon the populations that they invade and dominate, making the examination of invasions and other life-altering events an important path of inquiry. The chaos encompassing periods of imperial conquest are due largely to the fluctuating relationship between centralized power and peripheral communities; between negotiation of local identities and enforcement of foreign rules. Empires have been defined myriad ways in academic and historical literature. Most authors agree that an empire is a type of expansive state in which a dominant or elite core exerts political, economic, and moral inequalities over other sociopolitical groups (de L'Estoile et al., 2005; Morrison, 2001; Pitts, 2010; Sinopoli, 1994). Empires are ubiquitous, both temporally and geographically; ancient examples include the Roman Empire, the Mongol Empire, the Wari Empire, the various Chinese dynasties, and the Assyrian Empire (Arnason & Raaflaub, 2011; Honeychurch, 2015; Isbell, 2008; Wilkinson et al., 2005). Imperial growth is motivated by different reasons, including economic needs (Blanton, 1994) and religious crusades (Geraci & Khodarkovsky, 2001). Imperial growth opens trade routes, increases global contacts, and brings foreign goods and tribute back to the imperial core, establishing and increasing prestige. This is sometimes achieved by affecting community, political structures, and economic production in the invaded land. In addition to the influence of foreign invaders, these different facets of sociocultural and political life are ultimately affected by the dynamic daily activities that are carried out by members of communities.

The period of interest for this dissertation is the 11th century C.E. through the 18th century C.E. in Croatia, which features the transition from the Late Medieval period (11th - 15th centuries C.E.) through the conquests of the Ottoman Empire in the Early Modern period (15th – 18th centuries C.E.). The Medieval period in Croatia was a time of little conflict, economic development and prosperity. This era featured the appearance and evolution of the Croatian written language, an increase in literacy, a surplus of wealth and a rejuvenation of fortifications following their earlier destruction. This stable period was followed by the invasion of Ottoman Turks, whose violent raids disrupted every aspect of daily life for the people of Croatia, in addition to modern-day Bosnia and Herzegovina, Serbia, Hungary, Austria, and many other Southeastern European countries. The purpose of this dissertation is to use bioarchaeological methods to examine entheseal remodeling and osteoarthritis on individuals excavated from seven sites in Croatia. This data is used to undertake a discussion about possible activity and lifestyle changes experienced by the people subjugated by the Ottoman Empire during the 15^{th} – 18^{th} centuries C.E. in Croatia.

Historical Context

The country of Croatia sits at a crossroads. Its location in the Balkans allows influence from both the East and the West. It is bordered by Hungary to the northeast, Slovenia to the northwest, Bosnia and Herzegovina and Montenegro to the southeast, and Serbia to the east. The history of Croatia, much like that of other European countries, is rife with conflict. Because of its position, Croatia has been treated as both a strategic point of military conquest and a corridor for travelers; the Romans, Byzantine Empire, Crusaders, Mongols, Nazis, and Serbs have all either occupied Croatia or crossed its lands (Tanner, 1997). Its history is one of relatively constant warfare with small windows of peace and prosperity from which the Croatian identity emerged and the people began their recovery once more. In the subsequent sections, the time periods for this study will be presented to set the context for this project.

The Late Medieval Period (11^{th} – 15^{th} Centuries C.E.)

The Late Medieval period was a time of relative prosperity. With the earlier unification of the Croatian territories by King Tomislav in the 10^{th} century C.E., the people of the Late Medieval period experienced short disruptions from the Mongols and the Bubonic Plague (1348) (Font, 2005; Goldstein 1999). Nobles in southern Croatia grew powerful by acquiring land, which was then organized into estates with judicial and administrative power. With newly acquired wealth, fortifications were built around cities (Font, 2005; Goldstein, 1999), and previously unprecedented autonomy was granted to many of the larger, richer town centers, including Zagreb. Literacy increased, which led to a proliferation of books. Many of these benefits did not reach the common people of Croatia, except in the form of occupation on the land of local lords.

The majority of people in Croatia during this time period were serfs, working as farmers or livestock caretakers on the estates of the nobility, (Rothenberg, 1960) although some individuals practiced pastoralism along the Dalmatian coast (Šarić, 2008).

The Rise of the Ottoman Empire

Ottoman rule stretched from Croatia and Hungary in the west and across Anatolia to the east. This Empire, called the Ottoman Empire in the West, and known as "The divinely protected well-flourishing absolute domain of the House of Osman" (Sugar, 1977:3) in the East, would last relatively unchallenged, with varying degrees of power and influence, for the next four hundred years. There are numerous explanations for why the Ottomans were inclined to invade their neighbors (Sugar, 1977). The most frequently mentioned are the need for money and land (Özoğlu, 2004). Military service was compulsory, and most members of the military were unpaid; however, they were given gifts of land, or *timar*, for good work in war. Keeping this large, unpaid military occupied was of exceptional importance so that their idleness did not lead to conflict in their home cities. As Mehmed II, the conquering ruler of Constantinople, stated, an "imperialist mentality" was also necessary to conquest simply for the sake of conquest; the extension of the realm of *dar al-Islam*, or the domain of Islam, was of primary importance (Sugar, 1977). Finally, slavery was a large motivator for the invasion of neighboring countries, and slaves were taken at every chance. Slavery was the fuel for the Ottoman war machine, and they were used ubiquitously in Ottoman society (Sugar, 1977). Islamic jurisprudence was very specific about what class of individual could become a slave (Inalcik, 2002). By law, individuals captured in war or those born to slave parents were the only people who could be forced into servitude, although this did not necessarily doom these individuals to slavery. Additionally, they were not always treated poorly. Learned slaves could become important in administration (Sugar, 1977) and slaves that performed well in battle were given land alongside free military members. This led to a constant need for invasion of neighboring territories to subsidize the relatively precarious slave market that much of the military and economy relied upon.

Croatia and the Ottoman Empire: The Early Modern Period (15th – 18th Century C.E.)

Instability in the Balkans was exacerbated in 1386 when the Ottoman Empire invaded Bosnia, heralding a conflict that would plague Europe for several hundred years. The Ottoman war machine operated via several mechanisms; standing (*janissary*) and locally raised (*tamir*) armies moved in the wake of the *akinji*, named after "*akinti*," the Turkish word for "flood" (Goodwin, 2006; Magaš, 2007; Šlaus et al., 2010). The *akinji* were the Turkish light cavalry and worked exclusively on the frontier (Sugar, 1977). *Akinji* were paid from spoils of war and were tasked with the plunder of enemy territory to disrupt the native population by destroying natural, material, and human resources. This served to make the country an easy target for later invasion by the Turkish army proper via decentralization (Kruhek, 1995). This army would occupy the landscape and settle it with Turkish subjects and army officers. The Ottoman light cavalry typically carried sabers, war knives, hammers, maces, spears, and reflex bows. Firearms were not commonly used by the *akinji* because they were unpractical and unwieldy on horseback (Olesnicki, 1938), although they were utilized by Turkish foot soldiers.

Although the primary goal was to create turmoil and confusion in invaded territories, the *akinji* were also tasked with the subversion and obtainment of slaves. Slaves were captured and returned primarily to the cities of Skopje, Edirne, Bursa, and Istanbul. Silk production, agriculture, and long-distance, large-scale trade organizations depended heavily on slave labor. Fifteenth century Croatian writers attempted to estimate the number of slaves taken by the *akinji* during the many raids into Croatian territory (Mijatović, 2005). Estimates of individuals taken during the raids in 1415 and 1471 hover somewhere between 20,000 and 30,000 during each of those two raiding events. Although these numbers likely overestimate the damage, the regularity of raiding and slave-taking events highlights the *akinji* in capturing slaves (Šlaus et al., 2010).

A lack of support from the ruling class created a precarious situation in Croatia during the 14th and 15th centuries, due to inadequate funding for fortifications (Raukar, 2008). Additionally, Western Europe turned a blind eye to the Ottoman threat. As Croatians worked to buttress themselves against the looming Ottoman threat, emissaries to the West attempted desperately to convince Western courts and the Vatican that they, too, were in danger of succumbing to the Ottoman war machine if Croatia were to fall (Raukar, 2008). They were met largely by indifference to their pleas, and although they were promised support by several Popes over the decades of invasion, this was only verbal, and no material or military support ever materialized (Kurelac, 2008; Raukar, 2008).

The Croatian army likely faced the Ottomans for the first time in 1389, while fighting on the Serbian side of a conflict over Kosovo (Goldstein, 1999). The Ottoman army invaded Croatia itself in 1391 (Mažuran, 1991; Šlaus et al., 2010). Incursions were noted in the historical record in the years 1391, 1396, 1400, 1422, 1423, 1441, 1450, 1494, 1501, and 1512 (Mažuran, 1991). It is likely that they occurred more frequently, as these dates do not include incidences of permanent occupation. In the 1420's the Ottoman army reached Dalmatia, and the Bosnian state officially fell in 1463 (Goldstein, 1999; Magaš, 2007). Conditions in Croatia deteriorated even further. Peasants and nobles alike fled to the northwestern part of the country and farther to Austria, Slovenia, Slovakia, and Hungary in response to continuing raids. Some of the nobility attempted to hold out but a decisive battle in Krbava Valley in 1493 led to the holdouts fleeing their land. Those that remained in occupied areas who did not resist, or who were no longer able to resist, were assimilated into the domain of the Sultan. In 1526, the Ottomans finally dominated Croatia in a victory over both the Croatian and Hungarian armies at Mohács (Kurelac, 2008). This led to gradual economic stagnation in continental Croatia and the Dalmatian hinterlands and shifted the cultural and ethnic demographics of the region as people fled the Ottoman threat (Kurelac, 2008).

The Croatian nobility and common people alike were surrounded by hostile forces on both sides; the Ottoman Turks could be relatively lenient to those already practicing a monotheistic religion who surrendered without resistance (Sugar, 1977). However, the Austrian rulers of these lands were less understanding to those who surrendered out of self-preservation. One example of the perilous position of village and city administrators comes from the city of Belgrade in Serbia. Nicolas Doxat de Morez (1682-1738) was the Austrian army colonel and arms engineer that managed construction in the city (Leben des Herren Baron Doxat von Morez, 1757; Popović, 2006). He made the difficult decision to surrender the fortress of Niš to the Ottomans to spare the lives of its occupants. As a reward for saving so many lives, Austrian rulers sentenced to death by beheading and he executed in Belgrade in 1738 (Leben des Herren Baron Doxat von Morez, 1757; Miladinović-Radmilović & Bikić, 2015).

The Croatian Military Frontier & the Austrian Habsburgs

The Austrian Habsburgs established a military frontier along the south of Croatia and into Hungary to provide protection to these very vulnerable areas. The administrative center for this border was in Graz, Austria, and thus was geographically and culturally removed from the area (Grgin, 2012; Kurelac, 2008; Raukar, 2008). Finances for this new endeavor were lacking, and in 1521 the Ottomans exploited this lack of investment and captured Belgrade, which made Germany and Austria susceptible to invasion. The Croatian parliament voted Ferdinand of Austria as the official ruler of Croatia, to reaffirm the relationship and bolster local security. This occurred under the conditions that the ownership Croatian land would be transferred back to Croatian jurisdiction in times of peace, and that their political rights would remain respected and unchanged (Rothenberg, 1960).

Despite the vulnerability of Germany and Austria, the Ottomans never progressed far enough north to successfully capture Vienna, although it was subject to several multi-month sieges over the next 200 years (Shaw & Shaw, 1976). However, the Ottoman army still took ample opportunity to cross through Croatia and into the southern regions of Austria (Rothenberg, 1960). In 1522, to alleviate some of the stress associated with the invasions, the Austrian Habsburgs established an administrative and jurisdictional military border along the south of Croatia (Figure 1). Croatians could live and work within the border, and were encouraged to do so; however, the border was primarily staffed by foreign foot soldiers called *grenzer* (Rothenberg, 1960). The *grenzer* were refugees, primarily Serbian, who had fled their home countries after the invasion of Ottoman forces. The *grenzer* were given special privileges unavailable to the everyday Croatian, including being free subjects who did not need to work as serfs despite being non-noble, paying minimal taxes, and being able to elect their own captains. Although these rights were given to incentivize individuals to move to the border and the harsh reality of life there, they would become a point of contention in later years when the Ottoman threat had waned and Croatians outside of the border were incensed about the discrepancy in rights.

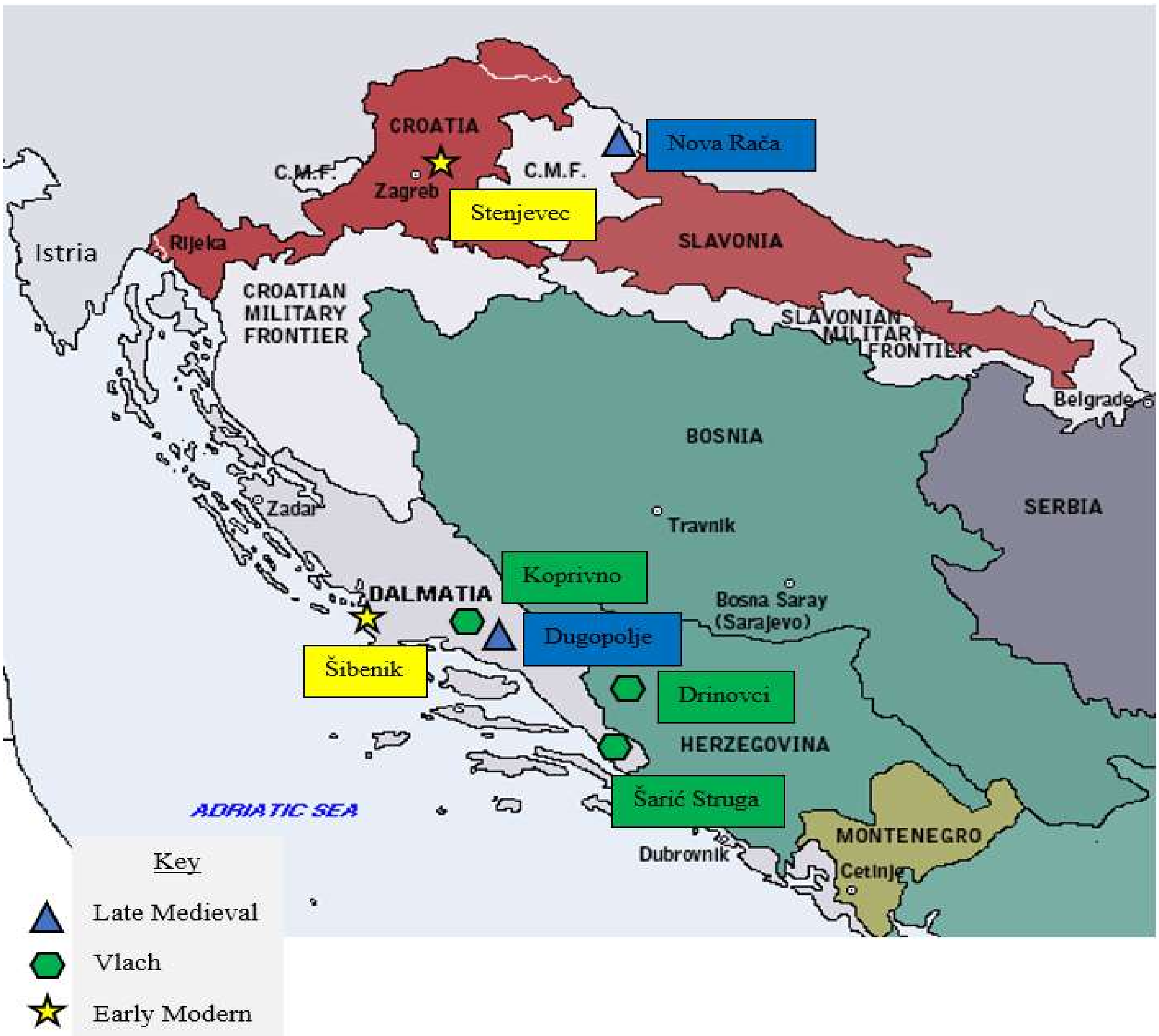

Figure 1: A map of Croatia with site locations and relevant geopolitical features (NordNordWest)

Funds for this border were lacking (Rothenberg, 1960) and Croatia was unable to bear the cost to keep it maintained (Grgin, 2012). Additionally, raiding continued into Ottoman and Croatian land despite several treaties between the Austrian Habsburgs and the Ottomans. The Turks continuously moved short distances into Croatian lands and *grenzer* repaid these transgressions by doing the same, leading to continued resource loss and death, even in what were supposed to be times of peace. When King Louis II of Hungary died during the Battle of Mohács, Ferdinand I, future Holy Roman Emperor and brother-in-law to Louis II, made a claim for the throne. He was rebuffed during an uprising by John Zápolya, who was supported by most of the Hungarian nobility and the Sultan of the Ottoman Empire, was given rule over eastern Hungary in 1532 (Spieralski, 1977). This left the Ottomans in control of all of the countries on two of Croatia's three landward sides until 1687 when the last Turkish puppet, Thököly, was cast out of Hungary and it was re-obtained by the Austrian Habsburgs (Rothenberg, 1960; Magaš, 2007).

This lack of funds and crumbing fortification within the border region led to fluctuations in its effectiveness as a defense. During time of war, a small infusion of funds helped reestablish and maintain fortifications and armaments, but during times of peace with the Ottomans, money was withdrawn, and the border once again fell into disrepair (Magaš, 2007). When strife with the Ottomans was lacking, the Austria Habsburgs were often actively involved in conflicts with other major powers in Europe and money was diverted towards defending against these other threats (Rothenberg, 1960). This cyclical neglect left the military border lacking in many aspects and damaged its effectiveness, with its power remaining relatively low but waxing and waning with time. This led to generally unsafe conditions and caused rapid depopulation of the border; particularly hard hit were the peasants, who were the backbone of Croatia's society at this time (Grgin, 2012).

The Vlachs

The Vlachs are another group worth mentioning for the sake of this research. The turmoil brought by Ottoman invasion caused numerous changes to the landscape and people of Croatia, socially, economically, and demographically. Historical records suggest that the entire Dalmatian area was depopulated due to Ottoman threat; although it is unlikely that this was the case in actuality, there is still evidence to suggest that many individuals fled, leaving many areas of

Croatia desolate (Gjurašin, 2005). The Ottoman policy of *sürgün* led to the repopulation of these areas by Orthodox Vlachs in the first half of the 16th century C.E. (Adamić and Šlaus, 2017; Gjurašin, 2005; Goldstein, 1999; Kurelac, 2008). This replaced the local elites and common people with Turkish loyalists. The Vlachs were a heterogeneous migrant population of Ottoman vassals that hailed from southern Europe (Allen, 2017). As Ottoman liegemen, they fulfilled important administrative and military tasks, filling numerous positions in Ottoman society (Kursar, 2013). They moved into more rugged areas of Croatian territories, living a semi-nomadic lifestyle and practicing transhumant pastoralism throughout a relatively rugged terrain filled with thorny vegetation and rocky soil (Muraj, 2004). Transhumant pastoralists move seasonally throughout a landscape between summer and winter pastures (Oteros-Rozas et al., 2013), moving goats, sheep, and cattle along with them (Botica, 2005; Jurin-Starčević, 2008). In addition to their different subsistence strategies, they also had different cultural practices, and were treated as a separate ethnic group than both native Croats and Ottoman citizens (Fine, 2006).

In the next section, the relevant archaeological work in Croatia will be examined. Bioarchaeological work in Croatia has been plentiful, especially regarding the influence of the Roman Empire in the area (Dzino, 2008; Novak, 2007, 2010, 2012; Rajić & Ujčić, 2003; Šlaus et al., 2004). However, the period of Ottoman occupation has not been extensively studied, especially in bioarchaeology. What little archaeological work has been done has focused primarily on large fortification sites where the *Grenzer* resided and the sites of major battles, leaving most of the record and experiences of everyday Croatians in question. Large collections of bioarchaeological materials have been excavated, but much of the material has yet to be analyzed. This phenomenon is not isolated to Croatia, however; bioarchaeological examinations of material in other Balkan countries is also lacking or inaccessible, leading to a temporal gap in the record surrounding the invasion of Eastern Europe by the Ottoman Empire. Despite this lack of information, there are a few studies that outline the effects of Ottoman raids and rule on the people of Croatia and Eastern Europe during this period.

Prior Archaeological Work

The first major work published on this period characterizes a massacre in the town of Čepin (Šlaus et al., 2010). The components of the Čepin-Turkish cemetery analyzed for this research span the Neolithic period through the Medieval period, and into the Early Modern period, from which 147 individuals were examined (Šimić, 1997, 2002, 2004, 2007). This paper highlights the extreme violence experienced by the people of Čepin during a raid that was carried out by the Ottomans in 1441; it emphasizes especially well the role of the *akinji*, the Turkish light cavalry, who were tasked with causing disarray ahead of the main army and capturing slaves. The initial osteological analyses found 82 separate instances of perimortem injuries from 22 individuals, and it is suggested that these injuries happened during one episode (Šlaus et al., 2010).

Age and sex distribution of injury incidence are skewed towards young people, specifically young females (Šlaus et al., 2010); 30% of overall adults, aged 15-29, and 53.9% of females have at least one traumatic injury, with many females having probably experienced more than one. Approximately 20% of males also featured some evidence of traumatic injury. At least four individuals with cranial trauma had evidence of between four and nine actual injuries. The shape of the wounds mean they were likely caused by a saber, which is the hallmark weapon of the *akinji*. The level of violence found in this research is extreme, but if the historical records are not exaggerations about the nature of the *akinji*, their goals, and their effectiveness, these findings could hint at the experience of Croatians during this time period.

An additional study from Croatia that analyzes this time period comes from a comparison of vertebral pathological conditions by Novak and Šlaus (2011). This research focuses on the difference between a relatively affluent population from the city of Sisak and a rural pastoralist community from Koprivno. Koprivno was subject to Ottoman laws during this period, which changed the occupation of many of the individuals in the area. This would have included forcing men to undertake more laborious work, like the maintenance of bridges and forts (Jurin-Starčević, 2008). The results of this study revealed vertebral osteophytosis, osteoarthritis, and Schmorl's Nodes to occur more regularly in the Koprivno sample. This seems to support that not individuals from these regions live different lifestyles, with the Koprivno population living a more strenuous lifestyle. Additionally, males had higher rates of these different vertebral conditions than females, supporting a division of labor within each of the populations. Ethnographic data also supports this. The men of Koprivno were involved in cutting wood, plowing, carpentry, clearing land for vineyards, and civil maintenance (Ivanišević, 1987; Voynović Traživuk, 2001). Women were regularly performing tasks such as textile processing, yard-related maintenance, and milking (Muraj, 2004; Šestan, 2008).

Research by Miladinović-Radmilović and Bikić (2015) examined beheadings in the city of Belgrade, Serbia, dating to the late 17th century. A single pit at an excavation outside the walls of the fortress in Belgrade yielded five bodiless skulls, all of which belonged to young to middle-aged males and featured cut marks indicative of decapitation. Decapitation was associated with the most severe of crimes, including treason, and was used in the domain of the Ottoman Empire (Wiltschke-Schrotta & Stadler, 2005). Although this sample is only representative of the experiences of four individuals, this material, in conjunction with the historical records regarding decapitation, paint it as a punishment used both by the Ottomans and Austrians, who each retained possession of Belgrade at different times during the 17^{th}-18^{th}centuries. These skulls are the only found in the Balkans that serve as a physical example of beheading during this conflict. Archaeological reports from the city point to a restructuring of the fortress and town around the time of Ottoman invasion and continuing into subsequent years, perhaps to bolster the area in preparation for the Turkish invasion (Miladinović-Radmilović & Bikić, 2015).

Although there are numerous pathological conditions and biological changes that could be used to analyze the effects of Ottoman invasion on the Croatian people, this research is primarily concerned with activity. Because of this focus, entheseal remodeling and the analysis of osteoarthritis were deemed the most informative. The methods used to analyze these conditions have been used extensively in bioarchaeological literature to elucidate past activity (Angel, 1966; Angel et al., 1987; Austin, 2017; Block & Shakoor, 2010; Couoh, 2015; Godde et al., 2018; Havelková et al., 2013; Hough, 2001; Jordan et al., 2007; Jurmain, 1977, 2013; Kennedy, 1989; Lieverse et al., 2013; Merbs, 1983; Nagy, 1998; Palmer, 2019; Palmer et al., 2016; Palmer & Waters-Rist, 2019; Radin, 1982, 1983; Radin et al., 1972, 1991; Schrader, 2012; Schrader & Buzon, 2017; Takigawa, 2014; Thomas, 2014; Wagner, 2018; Weiss & Jurmain, 2007). Although clarifying the etiologies of these conditions can be difficult, they are a useful tool for understanding the ways in which the body is affected by activity. In the next section, a thorough discussion of the development and progression of these two conditions will be undertaken.

Entheseal Remodeling and Osteoarthritis

What is Entheseal Remodeling?

An enthesis is the area at which a muscle, ligament, or joint capsule adheres to a bone. Its purpose is thought to balance the differing elastic moduli of bone and muscle (Biermann, 1957; Knese & Biermann, 1958), and helps transmit force created by the muscle to the bone to facilitate movement (Benjamin et al., 2002). Despite their purpose, entheses are still subject to significant wear and tear. Entheseal remodeling, also known as musculoskeletal stress markers (MSM) in some bioarchaeological literature, is characterized by distinct bone growth at the point of muscle attachment; ossification and hypertrophy of tendons and ligaments are credited with this change (Dutour, 1986; Kennedy, 1989). As the muscle or ligament exerts more force on the bone, the cortex of the bone responds by remodeling and this presents initially as bony spicules or pitting at the attachment site. These changes can expand if strenuous activities are continued. This reaction is a biological response to long-term, repetitive, arduous activities that stimulate an increase in muscle mass, which requires a more stable and stronger connection to the bone. Entheseal remodeling can continue to such an extent that eventually bone growth ceases and the developed bone slowly obliterates into lesion-like hollows (Hawkey & Merbs, 1995).

Types of Entheses

There are two kinds of entheses that have been documented in both biomechanical and clinical literature: fibrocartilaginous and fibrous entheses. Fibrocartilaginous entheses occur with fibrocartilage and fibrous entheses are marked by dense fibrous connective tissue (Benjamin & McGonagle, 2001; Benjamin & Ralphs, 1997, 1998, 2000; Benjamin et al., 2002). Fibrous entheses have been largely ignored in biomechanical, clinical, and even bioarchaeological literature, suggesting a bias against this type of enthesis. This partiality may be due to the increased tendency for fibrocartilaginous entheses to exhibit overwork injuries (Benjamin et al., 2002). Fibrocartilaginous entheses are characterized by four histological zones, listed here in order layer from muscle to bone: (i) dense fibrous connective tissue, (ii) uncalcified fibrocartilage, (iii) calcified fibrocartilage, and (iv) bone (Benjamin & Ralphs, 1997, 1998). Zones 2 and 3 are separated by the tidemark, which is the calcification front. It has been suggested that these zones create a gradient that allow for balancing of the elastic moduli between bone and tendon (Kneses & Biermann, 1958) by gradually moving from soft tissue to fully ossified bone.

An unmodified fibrocartilaginous enthesis is defined as an enthesis where: "…the tidemark is relatively straight and the fibrocartilage zones avascular, the site of attachment in a healthy enthesis is smooth, well circumscribed, and devoid of vascular foramina' (Benjamin et al., 2002:939). This description fits relatively well with what is seen on the skeleton. A typical enthesis on dry bone exhibits no soft tissue and is characterized by a regular margin, no vascular foramina, and a well-defined imprint (Villotte, 2006, 2009; Villotte et al., 2010a). A modified enthesis will exhibit erosion of calcified fibrocartilage and subchondral bone, tidemark modification, vascularization of the fibrocartilage (pitting and porosity), calcification and ossification of soft tissues (enthesopathies), and avulsions (Villotte, 2006, 2009; Villotte et al., 2010a, 2010b).

What is Osteoarthritis?

Osteoarthritis is one of the most observable and common conditions found on skeletal remains of both present and past populations, which illustrates its significance in bioarchaeology (Resnick & Niwayama, 1988; Rogers & Waldron, 1995). Osteoarthritis is characterized by degenerative changes and the breakdown of cartilaginous tissue at the joint surface (Rogers & Waldron, 1995) caused by the increasing physical activity. This increasing demand is what causes the slow breakdown of cartilaginous tissue over several stages (Hough, 2001; Larsen, 2015), characterized by lipping at the joint margins, increasing bone porosity, and eburnation and joint fusion as bone moves against bone (White et al., 2011). Osteoarthritis is a complicated condition, with multiple etiologies such as mechanical loading (Manninen et al., 2002; Sandmark et al., 2000; Thelin et al., 2004), age (Jurmain, 1999; Molnar et al., 2011), sex (Bridges, 1992; Moscowitz, 1993), and weight (Heliövaara et al., 1993; Manek et al., 2003), which have been addressed in the clinical and bioarchaeological literature.

The transition from the raw study of biological phenomena to a more holistic view of the human condition in bioarchaeology, combining both biology and socioculture, has benefited from the infusion of more rigorous social theory, taken from philosophy, cultural anthropology, sociology, and other disciplines. Recognizing the interaction between biology and culture allows bioarchaeologists to begin using human remains to access daily activities, allowing for contribution to the discussion on the ways that changes in the sociocultural sphere affect the mundane aspects of individual lives. The commonplace actions of individuals have been overlooked in some veins of bioarchaeological literature; this is problematic because those activities are considered by some social theorists to be the ways that individuals adopt, maintain, or abandon aspects of sociocultural structures and identities. These basic and prosaic aspects of our daily activities serve to reinforce our identities, both to ourselves, and to others.

Theoretical Framework: Activity & The Everyday

Activity in archaeology and anthropology can refer to a variety of behaviors carried out over the course of a long period of time, or in short bursts. Some activities are performed a specific way without thinking, such as the way someone holds a hammerstone when flint knapping, and some activities are done deliberately, such as a dance during a celebration. The focus on activity in bioarchaeology has increased dramatically in the last several years; the infusion of more robust social theories and additional methodologies have increased the utility and validity of activity studies. This has caused a proliferation of bioarchaeological literature on activity reconstruction and entheseal remodeling in the last decade (Baustian, 2015; Eng, 2015; Havelková et al., 2011; Mant, 2014; Schrader, 2010, 2012; Schuler et al., 2012; Thomas, 2014; Yonemoto, 2016; and many others).

Everyday activities have been important subjects in anthropological research; several sub-disciplines of the greater anthropological community have emphasized the importance of these seemingly mundane behaviors in the social community, as well as individually (Franklin, 2003; Gibson & Rodan, 2005; Hill, 2005; McIafferty & Preston, 2010). Seemingly unimportant or banal activities, such as food production and preparation, modes of celebration (i.e. dancing), religious practices, communication techniques, and how individuals adorn themselves, among many other personal characteristics, are important ways that people define themselves and reinforce their identities (Bourdieu, 1977; Brulotte & Giovine, 2014; Duderija, 2008, 2014; Prown, 1982; Spencer, 2008; Wilson, 2006).

Archaeology provides a unique perspective to this examination by looking at the change in cultures over time. Archaeologists are able to examine sociopolitical change over deep time, tracking alterations in quotidian activities as the sociopolitics of the groups change. Events such as colonization, imperial conquest, trade, and other form of cultural contact can alter the practices of the interacting groups, leading to changes in patterns of ordinary daily activities. These social interactions can serve as catalysts for change; agentive actions within societies in response to sociopolitical processes have the power to lead to adoption, maintenance, or abandonment of social practices, everyday behaviors, and identities. Social theories address these changes; structuration (Giddens, 1984) highlights the ways in which sociopolitical structures and norms influence certain aspects of everyday life. During times of sociopolitical upheaval, these structures can exert more influence over everyday life. This is the case for imperial rule, which alters the social, political, and jurisdictional rules and norms.

These concepts can also be effectively applied to bioarchaeology. As the sub-discipline of anthropology concerned with biological characteristics of human remains within archaeological contexts, bioarchaeologists also occupy a unique niche in the field of anthropology. Archaeologists are primarily involved with larger patterns in their work; however, because bioarchaeologists are focused on human remains, they are able to study humans on the scale of the individual (Stojanowski, 2005). Examination into sudden events leading to sociopolitical change, such as violence and forced resettlement, are common in bioarchaeological literature (Larsen and Milner, 1994; Larsen and Ruff, 1994; Torres-Rouff, 2005; Tung, 2007; Worne et al., 2012), but every day activities have not been extensively examined, and scholarship on the subject is hard to locate, but not entirely lacking (Larsen et al., 2001; McIlvaine, 2012).
Wesp (2015) analyzed a small sample of individuals from Postclassic Central Mexico to examine osteoarthritis and its association with movements associated activities, such as spinning, that may leave marks on the skeleton. Larsen and colleagues (2001) explored the pattern of missionization and the effects of this form of forced control and resettlement in Spanish Florida. They investigated exploitative labor system of the Spanish as well as the forced movement of

individuals through Spanish expansion as a way to elucidate changes on the skeleton, such as a high prevalence in osteoarthritis and upper limb robusticity (Larsen & Ruff, 1994). These studies are by no means a comprehensive list of bioarchaeological works on this subject, but they do reveal how this issue is finally being tackled in the larger bioarchaeological community.

The Body in Anthropology

Traditionally, the archaeological body has been viewed in two different ways: as a material artifact and as an aspect of the social world. As archaeologists, especially as bioarchaeologists, we endeavor to derive aspects of a social being from human remains; to "recreate a social being that is recognizable to all by describing a medical history borne by the body" (Sofaer, 2006:40). This becomes the developmental foundation of a narrative of a person's former life that is specific to the individual being examined but is fueled by experience from examination of others. Theory emphasizing the interpretation of the cultural context of the body and its place in the social sphere has been borrowed from the larger domain of anthropological scholarship, as well as sociology and philosophy (Butler, 1993; Csordas, 1990; Giddens, 1993; Shilling, 1993; Turner, 2008).

Past interpretations of human remains treated them as strictly biological phenomena that can be observed and analyzed to garner a plethora of data; this data could then be neatly categorized, and allowed for estimations of various parameters, such as demography and age-at-death, and pathological diagnoses (Sofaer, 2006). This was the impetus for developing the study of the skeleton on its own accord, as material subjected to scientific scrutiny that is treated like an artifact, such as any other. This served to highlight the potential of the skeleton as a material worth studying on its own accord, without validation from cultural artifacts. These approaches mistakenly treat the skeleton as a static artifact; as something that is fixed, restrictive, and unchangeable over time. This view confines the human body to a simple, and materialistic plane to make it trans-temporal and trans-regional, with an eventual goal of observing larger patterns in biological manifestations of activity, trauma, pathological conditions, and other bioarchaeologically-relevant markers.

An archaeological body is located in a very specific context that cannot be precluded from study (Sofaer, 2006). An archaeological body belongs to a person who is lifeless and is largely, but not exclusively, a biological phenomenon on its own. Alternatively, by focusing singularly on the living body and the experiential, emotional, and phenomenological characteristics of a person, one can overlook valuable information from the skeletal remains of the individual. This is, in some ways, just as erroneous as examining human remains while ignoring all social context. The physical properties of an object are necessary not for description of a present state, but reconstruction of a past one (Sofaer, 2006).

Contemporary views of the body in bioarchaeology have begun to examine the body in a multifaceted manner. Because the body is the physical way by which individuals experience and understand the world, it has become a more recognizable and valuable font of information for these lived experiences, including those of everyday life. The body is considered not only as an instrument by which to access lived experiences, but also as a metaphor for societal structure with a surface (and interior) upon and within which ideas, activities, and lived experiences are inscribed (Joyce, 2005). Archaeology has a lot to offer to a discussion of the body because the discipline itself is so deeply entrenched in the physicality and materiality of being. This marked shift moves the body from either exclusively a biological being, or a component of the social world, to being interpretable as a way to access the underlying individual and their lived experiences, emphasizing both biological and social contexts. In the last several years, this pursuit has allowed for the accumulation of ample data, which is then grounded in social theory, to great success (Joyce, 2005).

Embodiment Theory

Bioarchaeologists interested in the interplay between sociocultural structure and the physical manifestation of human expression of activity have searched for theoretical approaches that paint people as agentive. However, not just as thinking, feeling, acting subjects (Lesure, 2005), but also as actors within a larger societal structure that influences the body in ways that can be discerned. The primary focus of this dialogue within archaeology has been on the coaction between agency and structure – between people as independent beings and the influences that shape and affect individuals that exist within the structure. Of interest in these discussions is the physical human body, specifically the idea that the agent and the structure do not just exist out in the ether, unconnected to a physical tether, but rather embodied within the individual. Because bodies are not static, one might conclude that activity would shape them in the same manner that it affects the production and use of material culture. The ever-remodeling activity of the skeleton allows it a high degree of plasticity, which has been found to be fruitful for the inquiry into changing lifeways of past populations (Agarwal & Beauchesne, 2011; Buzon, 2011; Sofaer, 2006). Applying the same principles that allow archaeologists to examine bodily ornamentation and costume in the context of symbolic communication, bioarchaeologists can analyze human remains from an embodiment-oriented perspective to contribute to knowledge on physical manifestations of activities; these can then be interpreted and used to inform our understanding of social context.

Embodiment-oriented approaches in bioarchaeology "…aim to foreground the experience of the individual as part of a methodological and interpretive interest in the self. They represent a move towards the sensual and experiential and represent a heightened recognition and interest in the humanity of past lives" (Sofaer, 2006:22). Embodiment emphasizes the internalized actions of individuals and experiences of simply existing inside of a body, as well as how those experiences can alter the body itself. Because it deals with agentive actions that have been internalized, it is more closely aligned with the aims of archaeological, and specifically bioarchaeological, inquiry into biological manifestations such as activity or trauma. Archaeology is a discipline that is sensitive to repetition in the material record as a way to garner historically and prehistorically produced and reproduced cultural practices. Because of this, embodiment can offer a lot to the field by way of attempting to aid in bridging the gap between the material record and the actual sociocultural structure and environment, as well as various ways of life that promoted production of the record.

Embodiment theory addresses how the physical body responds to and is shaped by the social structure and individual action; specifically, how we "literally incorporate, biologically, the material and social world in which we live" (Krieger, 2001:672). Biological manifestations of well-being, disease, and general health are well suited from an embodiment-oriented theoretical perspective to elucidate the influence of social, political, and economic factors on the human body. Because the social sphere affects the biological body in which it exists, embodiment theory is appropriate for aligning with bioarchaeological goals of discerning the social nature of skeletal remains and can directly contribute to the examination of activity in the bioarchaeological record.

The primary focus on embodiment theory has come from cultural anthropological literature, and bioarchaeology has lagged slightly and only recently been using embodiment theory for the examination of skeletal material, despite its applicability (Knudson & Stojanowski, 2008). The biosocial nature of human skeletal remains facilitates the application of embodiment theory to osteological research and can expound upon the individual, social, and political bodies of the ancient past (Jones, 2002), making it a valuable tool for bioarchaeologists examining activity. The skeleton is the vestige of an individual, an archive of the biological experiences (e.g. pathologies, injuries, activity, etc.) which allow for more thorough research on wider topics (Buikstra & Scott, 2009; Knudson & Stojanowski, 2008). The skeleton is highly plastic, which allow it to embody human social activities and lived experience in a similar manner to archaeological artifacts, such as lithics and ceramic sherds, and therefore allows biological remains to represent both natural and sociocultural surroundings of the individual (Butler, 1993; Meskell & Joyce 2003).

Because of the plastic nature of the human skeleton, most bioarchaeologists utilizing embodiment theory have focused on the body as an inscriptional facade; this would imply that the body is used by the individual as an active means of personal expression, whether that be for expression of individual opinion or group identity. Archaeologists have used other items of personal adornment, such as jewelry and individual attire (Bayman, 2002; Fisher & DiPaolo Loren, 2003; Gilchrist, 1997; Joyce, 1999, 2002) to explore individual's representation of himself or herself. In this same manner, bioarchaeologists have used body ornamentation and modification (Blom, 2005; Robb, 1997; Torres-Rouff, 2002, 2003) in an attempt to discern the ways that these biological/skeletal modifications can represent the individual. When planted within identity theory, these characteristics are public and exterior; they serve as an outward expression of group identity in the same way that material culture does, and are viewable by members and non-members, and interpretable (Joyce, 2005). By characterizing the exterior, an interior is also created (Rautman & Talalay, 2000), which applies to the embodiment of different osteological developments, such as those of activity, like osteoarthritis and entheseal remodeling.

The Use of Embodiment Theory in Bioarchaeology

Studies that utilize embodiment theory, while generally not explicit about their choice of social theory, are relatively ubiquitous in bioarchaeological literature. The goal of the bioarchaeologist is not only to examine the physical body for markers of trauma, activity, dietary stress, or disease. This discipline also emphasizes the social sphere in which individuals lived and how biology and sociocultural constructs form a feedback loop upon one another. Bioarchaeologists examine the physical body within an archaeological context, recognizing the importance of cultural materials and systems in the shaping of biological bodies. Combining archaeologically collected material culture and bioarchaeologically examined skeletal remains allows for a united front in confronting questions about activities of past populations and how these actions are presented on the skeleton.

The main pursuit of bioarchaeologists is to examine not only the physical body, but also how this body interacts with the larger society around it. The traditional bioarchaeological methodologies are used to make sense of larger patterns, such as the sexual division of labor (Havelková et al., 2011; Eshed et al., 2004). Bioarchaeologists have been criticized by their treatment of the skeleton as simply a specimen instead of the representation of the embodied experience of an individual (Sofaer, 2006). A vast portion of current literature authored by bioarchaeologists have attempted to incorporate contemporary social theories into the overall paradigm (Grauer & Stuart-Macadam, 1998; Robb, 2002). Theories of religion, ethnicity, culture, gender, age, and disability (Agarwal & Glencross, 2011; Diaz-Andreu et al., 2005; Knudson & Stojanowski, 2008; Martin et al. 2013; Tilley, 2015) continue to lend valuable insight to bioarchaeological research. However, the attempted integration of bioarchaeology with social theory has allowed anthropologists to address some previous criticisms of the field, thus promoting advancement past these conceptual issues and reaffirming the aim of encouraging articulation of the more multifaceted nature of humans and a connection between mind and body.

Those who undertake this research first examine the physical state of the body. Different sub-disciplines within bioarchaeology, such as paleopathology (Anderson, 2003; Buzhilova, 1999; Grauer, 2012; Mays et al., 2001; Mitchell, 2003; Weston, 2011), paleoepidemiology (Roberts & Buikstra, 2003), paleodemography (Hoppa & Vaupel, 2002; Sullivan, 2004) are aimed at answering different questions, so analyze different aspects of the skeleton. Bioarchaeologists are particularly concerned with activity (Eng, 2015; Larsen, 2002; Schrader, 2012; Thomas, 2014), analysis of diet and nutrition (Chamberlain & Witkin, 2003; Katzenberg, 2000; Pate, 1994; Sanford & Weaver, 2000; Schoeninger & Moore, 1992), body modification (Robb, 1997; Tiesler, 2012), human variation (Howells, 1973, 1989; Schillaci & Stojanowski, 2002; Zakrzewski, 2003), or molecular studies (Kaestle & Horsburgh, 2002; O'Rourke et al., 2000), research the skeleton with the ultimate goal of elucidating the effect of human activity on biological bodies; this allows examination of the social realm and other sociopolitical factors that may have influenced the emergence of these various conditions or pathologies.

Two of the most common subjects of research in this regard are the transition from hunter-gathering to agriculture (Bridges, 1989; Cohen & Armelagos, 1984; Larsen, 1995; Peterson, 2000) and the effects of colonialism and imperialism on societies, both pre-contact and post-contact (Larsen & Milner, 1994; Morris, 1992). These studies elucidate the manner in which colonial and imperial situations affect daily lives, if at all, using the skeleton; for example, McIlvaine (2012) examines the increase in osteoarthritis of the upper limb and a reduction in the lower limb during colonialization by the Greeks, suggesting a decrease in mobility and an increase in physical activities that preferentially required use of the upper limb. These studies use embodiment theory, whether it is explicitly stated or not, to examine the ways that sociocultural influences can be collected from skeletal remains. Embodiment theory promotes more thorough scrutiny of the ways in which humans accommodate different circumstances, such as interpersonal violence (Boylston, 2000; Brothwell, 1999; Robb, 1998; Walker, 2001; Williamson et al., 2003) and disability (Hawkey, 1998; Tilley, 2015). Studies on personal adornment are also used effectively to examine sociopolitical structure, especially those dealing with cranial modification typically associated with a specific class or ethnic group (Duncan, 2009; Torres-Rouff & Yablonsky, 2005).

In the same way that personal adornment and skeletal modification can embody someone's life choices, entheseal remodeling and osteoarthritis are appropriate and promising measures of the activities that a person performed throughout their lifetime, allowing for discernment of changes in those patterns of activity. Entheseal remodeling has received a lot of attention in the last couple of decades within bioarchaeological research. A substantial body of bioarchaeological research has focused on examining useful methods to clarify entheses and entheseal remodeling (Hawkey & Merbs, 1995; Henderson et al., 2013, 2016, 2017; Mariotti et al., 2007; Villotte & Knüsel, 2013). As methodologies have become more accepted and well-tested, bioarchaeologists have begun attempting to elucidate the social significance of the appearance of morphological differences at entheses (Havelková et al., 2013; Lopreno et al., 2013; Santana-Cabrera et al., 2015; Schrader, 2012). Embodiment theory has been a popular theoretical framework for use in this research because it assumes a visible connection between activity and skeleton, though not a one-to-one correlation between skeletal materials and activity.

Embodiment theory, as a framework that examines the juncture between sociocultural practices and biological remains, can play a special role in this discussion. Embodiment theory is able to contribute to studies on the construction and maintenance of identities by emphasizing the way that the body responds to repetitive activities. As individuals, consciously or unconsciously, conform their everyday actions to the sociocultural structure in which they live, either as benevolent acts of acceptance or antagonistic reactions to excessive power, an embodiment-oriented perspective allows bioarchaeologists to access these behaviors by looking at skeletal remain. In this study, historiographic sources indicate that Croatians were farming during the Late Medieval period. A deviation from this found in the Early Modern sample would indicate that perhaps people were no longer farming and had adopted another activity; alternatively, no change in the entheses, and thus the muscles, being used would indicate that the people had not adopted a new activity and therefore had continued their original traditions in the face of imperial invasion. Using those entheses, the movements associated with the particular muscles can be analyzed, speculated upon, and subsequently applied to discussions of activity and social change in the event of imperial invasion.

Research Questions and Hypotheses

This research will examine the physical manifestation of changes in or intensification of activity via the bioarchaeological examination of entheseal remodeling and osteoarthritis between the Late Medieval and Early Modern period, and frame this change in the context of the larger sociopolitical environment, as well as expound upon the effects of imperial expansion on the sociocultural status of past groups. The historical records during this time period paints a grim picture for the people of Croatia during the invasion of the Ottoman Empire; widespread chaos, intense violence, expulsion of people from their land, and destruction of their daily lives and practices are just some what Croatians experienced during those several centuries. Does the bioarchaeological support these ideas? Can we see evidence of these life-altering experiences? The goal of this project is to explore these ideas through analysis of the human skeleton. This research utilizes a combination of bioarchaeological methodologies in conjunction with embodiment theory to investigate these ideas. Stemming from these goals, I have developed two primary research questions for this dissertation:

1. Did the Ottoman Empire severely affect the people of Croatia, as historical records indicate?
2. Is there evidence of these effects in the bioarchaeological record via changes in patterns or intensity of activities?

From these questions, I have formulated two research hypotheses that are examined in this study.

H_0: *Patterns and severity of entheseal remodeling and osteoarthritis between the Late Medieval and the Early Modern Period will not be statistically significantly different.* This would suggest that although the invasion of the Ottoman Empire would probably have been an intense and stressful time for the Croatian people, the influence of the Ottoman Turks did not cause changes in activity/an intensification of activity (entheseal remodeling or osteoarthritis) that is detectable in the skeleton. Alternatively, the Ottoman Empire could have caused dramatic changes, but these may not have dramatically affected the lives of the common Croatian. This could be because life for serfs was already rife with hardship, so although things deteriorated for the nobility, they may not have changed dramatically for serfs or other peasant farmers.

H_A: *Patterns and severity of entheseal remodeling and osteoarthritis between the Late Medieval and the Early Modern Period will be statistically significantly different; the sample examined from the Early Modern Period will show a more severe presentation of entheseal remodeling and osteoarthritis.* Failing to reject this alternative hypothesis suggests that the influence of the Ottoman Empire and the forced changes in life ways were so significant that some increase in physical activity or a change in the basic pattern of activity occurred, as evidenced by entheseal remodeling and osteoarthritis.

Materials

Seven skeletal collections from Croatia were used to explore the questions posed in this dissertation (Figure 1). These sites represent two time periods; the first, known as the Late Medieval period (11th century C.E. – 15th century C.E.), is the pre-Ottoman period. The second time period is known as the Early Modern period (15th century C.E. – 18th century C.E.) and is the time period subsequent to the Ottoman invasion. The sites also range geographically from the Adriatic region and the continental region, where the extent of Ottoman influence was higher due to this region being used as a corridor to the Habsburgs in Vienna. These materials can be found curated at the Croatian Academy of Sciences and Arts in Zagreb, Croatia.

The Pre-Ottoman sites, Šibenik – Sv. Lovre and Stenjevec, all date from between the 10th century and the 15th century C.E. Šibenik – Sv. Lovre is a Late Medieval/Pre-Ottoman rural cemetery associated with the church of Sv. Lovre (St. Lawrence) and is located in the Adriatic region. This is a multicomponent site with dates ranging from the 9th to the 15th centuries C.E (Krnčević, 1995). The graves were typical Christian graves for this region (Krnčević, 1995). Stenjevec is located within the continental region of Croatia. It dates to between the 11th – 13th century C.E. (Bedić & Šlaus, 2010).

The Post-Ottoman sites are Dugopolje and Nova Rača and date to between the 15th century and 18th century C.E. Dugopolje dates to between the 14th and 16th century C.E (Jurin-Starčević, 2008; Sarić, 2008) and is located in the Adriatic region of the country. Nova Rača is located in the continental region of the country, approximately 75 km east of the capital of Zagreb. It is a parish cemetery and is dated to between the 14th and 18th century C.E.

The Vlach sites are Koprivno-Križ, Šarić Struga, Drinovci-Greblje, and are technically Post-Ottoman, but are considered as a separate category because of their different sociocultural context. These sites are all located in the Adriatic region of the country. Koprivno-Križ is a multicomponent site; the second phase of this site dates to between the 15th and 18th century C.E (Gjurašin, 2002; Gjurašin, 2006). Šarić Struga dates to the 15th through 17th century C.E. (Milošević & Šućur, 2008). Finally, Drinovci-Greblje is a partially excavated site that is dated to the 16th century C.E (Bedić et al., 2013). The Vlachs were a heterogeneous group of people who settled the regions that were cleared by the Ottoman Empire (Adamić and Šlaus, 2017). They were cattle-breeders and practiced transhumance pastoralism (Jurin-Starčević, 2008); they were largely considered mountain dwellers and were at conflict with the lowland agriculturalists. Their way of life was different than their neighbors, and quite rugged. Transhumance pastoralism involves the seasonal movement of livestock between summer and winter locations, allowing for the maximum use of the most productive pastures at different time periods (Oteros-Rozas et al., 2013). Additionally, the Vlachs practiced a form of agriculture that required more energy investment as the soil was filled with large rocks and thorny vegetation (Muraj, 2004).

Structure of The Dissertation

This dissertation is formatted as three separate articles that are meant to stand independently of one another. Chapter 1 served to introduce general information about relevant historical and archaeological information about Croatia. Additionally, the theoretical framework and methodological approaches were introduced in this chapter. In chapter 2, entheseal remodeling is discussed in the context of social change brought about by the Ottoman Empire in the mid-15th century C.E. In Chapter 3, osteoarthritis is discussed within the same context, with an emphasis on the contribution of clinical medicine to the study of osteoarthritis in bioarchaeology. Chapter 4 is a statistical article that focuses on comparing two different bioarchaeological methods for the examination of entheseal remodeling: the more common and older Hawkey and Merbs (1995) method and the newer and more clinically relevant Coimbra method (Henderson et al., 2013, 2016, 2017).

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CHAPTER 2. THE EFFECT OF OTTOMAN INVASION ON ENTHESEAL CHANGE

Introduction

Empires are a significant arena of study in anthropological literature; they exert influential forces upon the populations that they invade and dominate, making the examination of these life alterations an important path of inquiry. The chaotic and intense environment surrounding periods of imperial conquest are due largely to the evolving relationship between centralized power and the peripheral communities, between negotiation of local identities and enforcement of foreign ideals. Empires have been defined in a number of a different ways in the literature; however, most authors agree that an empire is an expansive state in which a dominant or elite core exerts political, economic, and moral inequalities over other sociopolitical entities (L'Estoile et al., 2005; Morrison, 2001; Pitts, 2010; Sinopoli, 1994). Empires have been ubiquitous, both temporally and geographically, and examples include the Roman Empire, the Mongol Empire, the Wari Empire, the various Chinese dynasties, and the Assyrian Empire (Arnason & Raaflaub, 2011; Honeychurch, 2015; Isbell, 2008; Wilkinson et al., 2005). The growth of empires can be due to a myriad of different reasons, including economic (Blanton, 1994) and religious crusades (Geraci & Khodarkovsky, 2001). Imperial growth opens trade routes, increases global contacts, and brings foreign goods and tribute back to the imperial core, establishing and increasing prestige. As empires endeavor to grow, they dramatically affect community, political structures, and economic production. These facets of sociocultural and political life are ultimately affected by the commonplace daily activities that are carried out by members of communities; as these communities are forced to change, their habits and patterns of activities are also altered.

The infusion of more rigorous social theory has benefited the field of bioarchaeology. The commonplace actions of individuals have been overlooked in some veins of bioarchaeological literature; this is problematic because those activities are considered by some social theorists to be the ways that individuals adopt, maintain, or abandon aspects of sociocultural structures and identities (Bourdieu, 1977; Brulotte & Giovine, 2014; Duderija, 2008; Ness, 1992; Prown, 1982;

Spencer, 2008; Wilson, 2006). Apparently unimportant or banal activities, such as food production and preparation, modes of celebration (i.e. dancing), religious practices, communication techniques, and how we adorn ourselves, among many other personal characteristics, are important ways that we define ourselves and reinforce our identities (Bourdieu, 1977; Brulotte & Giovine, 2014; Duderija, 2008; Ness, 1992; Prown, 1982; Spencer, 2008; Wilson, 2006). In recent decades, the study of everyday life has made an appearance in bioarchaeology, within the context of imperial conquest and colonialism, as well as in other contexts (Larsen et al., 2001; McIlvaine, 2012; Schrader, 2012; Sofaer, 2006; Wesp, 2015). Specifically, the ways that everyday life could be used to examine the ways in which individuals change under the pressure of sociopolitical changes, and how those sociopolitical changes can be influenced by small acts of defiance in every day practice (Lefebvre, 2008), have been under tighter scrutiny in bioarchaeology. As the sub-discipline of anthropology concerned with biological characteristics of human remains within archaeological contexts, bioarchaeologists can study humans on an individual scale (Stojanowski, 2005). The study of sudden events leading to sociopolitical change, such as violence and forced resettlement, are common in bioarchaeological literature (Larsen & Milner, 1994; Larsen & Ruff, 1994; Torres-Rouff, 2005; Tung, 2007; Worne et al., 2012), but every day activities have not been extensively examined, and scholarship on the subject is hard to locate, but not entirely lacking (Larsen et al., 2001; McIlvaine, 2012).

Bioarchaeologists are uniquely positioned to study everyday life from an alternative perspective. Instead of examining materiality, bioarchaeologists can examine embodied activity on the skeleton. Human remains are tangible biological remnants of a once living individual. These remains are biologically modified to contend with externally imposed forces over the course of an individual's lifetime (Krieger, 2001). They serve not only as an instrument by which to access lived experiences, but also as a metaphor for societal structure with a surface (and interior) upon and within which ideas, activities, and lived experiences are inscribed (Joyce, 2005). This biological transformation of living materials grants the body the ability to grapple with physical stresses in a way that promotes alteration of various tissues, like bones, to continuously accommodate infusion of outside pressures (Agarwal & Beauchesne, 2011; Buzon, 2011; Sofaer, 2006). The nature of this cyclical modification allows for not only the bioarchaeological investigation of the physical well-being of the individual, but also deeper scrutiny into the social structure in which they lived. This has caused an explosion of bioarchaeological literature on activity reconstruction and entheseal remodeling in the last decade (Baustian, 2015; Eng, 2015; Havelková et al., 2011; Lopreno et al., 2013; Mant, 2014; Santana-Cabrera et al., 2015; Schrader, 2010; Schuler et al., 2012; Thomas, 2014; Yonemoto, 2016; and many others), as well as literature focusing on developing methods for this analysis (Hawkey & Merbs, 1995; Henderson et al., 2013, 2016, 2017; Mariotti et al., 2007; Villotte & Knüsel, 2013).

The period of interest for this study is the 11th century C.E. through the 18th century C.E., which features the transition from the Late Medieval period (11th - 15th centuries C.E.) through the conquests of the Ottoman Empire (15th – 18th centuries C.E.) in the Early Modern period. The Medieval period in Croatia was a time of little conflict and prosperous development; it featured the appearance and evolution of the Croatian written language, an increase in literacy, and a surplus of wealth and town security. This stretch of relatively stable time was followed by the invasion by the Ottoman Turks, who brought violent raids and disruption of daily activities to the Croatians, as well as the people of modern-day Bosnia and Herzegovina, Serbia, Hungary, Austria, and many other Southeastern European countries. The purpose of this study was to examine the ways in which the imperial conquest of the Ottoman empire may have affected the daily lives of the Croatian people. Did the invasion and conquest of the Ottoman Empire cause dramatic lifestyle changes that are detectable on the skeleton? If the Ottoman Empire exerted enough influence to change the daily lives of the Croatians they subjugated, it may be possible to see this influence on the skeleton in the form of changes at entheseal points between the different skeletal series.

Activity Studies Through Entheseal Remodeling

Validity of Study

Entheseal remodeling has been extensively studied in bioarchaeological literature (Angel, 1966; Angel et al., 1987; Couoh, 2013; Godde et al., 2018; Havelková et al. 2013; Jurmain, 1977, 2013; Kennedy, 1989; Lieverse et al., 2013; Merbs, 1983; Nagy, 1998; Palmer & Waters-Rist, 2019; Palmer et al., 2016; Schrader & Buzon, 2017; Takigawa, 2014; Thomas, 2014; Wagner, 2018). The etiology remains uncertain, but previous work has indicated that entheseal remodeling is influenced by age (Chapman, 1997; Hawkey, 1998; Jurmain, 2013; Mariotti et al., 2007; Robb, 1998; Wilczak, 1998), sex (Molnar, 2006; Peterson, 1998; Steen & Lane, 1998), genetics, environmental influences, and pathological conditions (Jurmain, 2013; Resnick & Niwayama, 1983; Wilczak, 1998). Despite the complicated etiology, entheseal remodeling is still a significant avenue of inquiry in bioarchaeological literature and methods for analysis of the changes at entheses continue to be refined (Cardoso & Henderson, 2010; Henderson et al. 2013, 2016, 2017; Molnar et al., 2011; Watkins, 2012). Additionally, there are several methodological and statistical approaches that can be used to alleviate some issues surrounding conflating factors in analyses of entheseal remodeling (Robb, 1998; Weiss, 2007). In addition to statistical approaches, analyses of skeletal collections where age, sex, and occupation are already known have found correlations between remodeling at entheses and activity (Cardoso & Henderson, 2010; Mariotti et al., 2007; Villotte, 2006; Villotte et al., 2010b; Watkins, 2012), suggesting that the analysis of entheseal remodeling can still be informative and should be pursued. In fact, in the past, specific activities or occupations have been associated with distinct changes at entheses (Dutour, 1986; Lai & Lovell, 1992; Merbs & Euler, 1985; Steen & Lane, 1998), although more recently this route of direct correlation has been discouraged by researchers (Churchill & Morris, 1998; Jurmain, 2013; Robb, 1998; Weiss, 2007). Employing caution while making conclusions and using statistical techniques to alleviate for confounding variables (e.g. body size, age, and sex) can allow for the thoughtful use of entheseal remodeling in studies of activities.

Types of Entheses

There are two kinds of entheses that have been documented in both biomechanical and clinical literature: fibrocartilaginous and fibrous entheses. Fibrocartilaginous entheses occur with fibrocartilage and fibrous entheses are marked by dense fibrous connective tissue (Benjamin & McGonagle, 2001; Benjamin & Ralphs, 1997, 1998, 2000; Benjamin et al., 2002). Fibrous entheses have been largely ignored in biomechanical, clinical, and even bioarchaeological literature, suggesting a bias against this type of enthesis. This partiality may be due to the increased tendency for fibrocartilaginous entheses to exhibit overwork injuries (Benjamin et al., 2002). Fibrocartilaginous entheses are characterized by four histological zones, listed here in order layer from muscle to bone: (i) dense fibrous connective tissue, (ii) uncalcified fibrocartilage, (iii) calcified fibrocartilage, and (iv) bone (Benjamin & Ralphs, 1997, 1998). Zones 2 and 3 are separated by the tidemark, which is the calcification front. It has been suggested that these zones create a gradient that allow for balancing of the elastic moduli between bone and tendon (Kneses & Biermann, 1958) by gradually moving from soft tissue to fully ossified bone.

An unmodified fibrocartilaginous enthesis is defined as an enthesis where: "…the tidemark is relatively straight and the fibrocartilage zones avascular, the site of attachment in a healthy enthesis is smooth, well circumscribed, and devoid of vascular foramina' (Benjamin et al., 2002:939). This description fits relatively well with what is seen on the skeleton. A typical enthesis on dry bone exhibits no soft tissue and is characterized by a regular margin, no vascular foramina, and a well-defined imprint (Villotte, 2006, 2009; Villotte et al., 2010a). A modified enthesis will exhibit erosion of calcified fibrocartilage and subchondral bone, tidemark modification, vascularization of the fibrocartilage (pitting and porosity), calcification and ossification of soft tissues (enthesopathies), and avulsions (Villotte, 2006, 2009; Villotte et al., 2010a; 2010b).

Materials

A total of 7 skeletal collections (n = 330) from Croatia were used in this study (Table 1). These materials are curated at the Croatian Academy of Sciences and Arts in Zagreb, Croatia. The sites of choice straddle the invasion of the Ottoman Empire and fall within the Late Medieval Period (11^{th} century C.E. – 15^{th} century C.E.) and the Early Modern Period (15^{th} century C.E. – 18^{th} century C.E.), also known as the Pre-Ottoman period and the Post-Ottoman period. Additionally, they range geographically from the continental region of Croatia, which was used as a corridor for the Ottomans to reach the Habsburgs in Vienna, and the Adriatic coast, which was not as dramatically affected by the invasions (Figure 1). There are 178 males and 152 females included in this study. Individuals are organized into young adult (18-29 years, n=56), middle-aged adult (30-45 years, n=184), and older adults (46+ years, n=90). Finally, individuals were divided into three body size categories based on methods outlined in subsequent sections. The categories and number of individuals included in each are listed in Table 2.

Table 1: Collections Used in Entheseal Remodeling Analysis (Coimbra Method)

Site Name	**Period**	**Date (C.E.)**	**Region**	**Number of Individuals**
Stenjevec	Pre-Ottoman	11th - 13th	Continental	75
Šibenik-Sv.Lovre	Pre-Ottoman	10th - 13th	Adriatic	49
			Pre-Ottoman Total = 124	
Dugopolje	Post-Ottoman	13th - 16th	Adriatic	108
Nova Rača	Post-Ottoman	14th - 16th	Continental	17
			Post-Ottoman Total = 125	
Koprivno-Križ	Vlach	16th - 18th	Adriatic	60
Šarić Struga	Vlach	16th - 17th	Adriatic	7
Drinovci-Greblje	Vlach	16th	Adriatic	14
			Vlach = 81	
			Total = 330	

Table 2: Body Size Distribution for Entheseal Remodeling (Coimbra) Materials

Relative Limb Length	**Lower Limb Frequency**	**Upper Limb Frequency**
Small	62	75
Medium	176	189
Large	92	66

Methods

Sample Selection

Individuals were excluded from study if they were subadult. Subadults feature constant remodeling of the periosteum during growth (Ruff et al., 2006) and little is known about the effects of activity on the growing skeleton; thus, it was decided that subadults should be excluded from this study. Additionally, individuals were removed from the study if sex, age, and/or body size estimates were unable to be obtained. This is because controlling for complicating factors is essential in an analysis using entheseal remodeling as a proxy for activity, and all three of these factors have been found to be associated with differential development of entheseal remodeling. Additionally, individuals were excluded if they were missing greater than 50% of their entheses variables.

Recording Entheseal Remodeling

Ten fibrocartilaginous entheses in the upper limb were used for this analysis (Table 3). The method of choice is the newly published Coimbra method, which was developed during a workshop held in Coimbra, Portugal, in 2009 (Santos et al., 2011). In this method, the enthesis is divided into two zones. Zone 1 is the "margin of the enthesis at which fibers attach most obliquely to the bone" (Henderson et al., 2013, 2016, 2017). Zone 2 includes the footprint of the enthesis. From there, different features are analyzed in each of the zones. Because zone 1 is the enthesis margin, bone formation and erosion are recorded. Zone 2 features are textural change, bone formation, erosion, fine and macro porosity, and cavitation. This method was chosen not only because it is new, but also because the developers have taken great care to incorporate new findings on the anatomy and physiology of entheses, as well as biomechanical and clinical research. Additionally, after publication of the initial method (Henderson et al., 2013), a revision followed in which the authors addressed some initial weaknesses of method, such as high interobserver error and repeatability, and more clearly defined the different features of note (Henderson et al., 2016, 2017). The method is outlined in Table 4; for specific definitions see Henderson et al. (2016).

Table 3: Entheses and Associated Bones Involved in this Study

Enthesis	**Origin**	**Insertion**	**Joint**	**Movement**
Subscapularis	Subscapular fossa of scapula	Lesser tubercle of the humerus	Shoulder	Internally rotates and adducts humerus; part of the rotator cuff that stabilizes the shoulder
Supraspinatus	Supraspinous fossa of scapula	Superior facet of the greater tubercle of humerus		Abduction of the arm; part of the rotator cuff that stabilizes the shoulder
Infraspinatus	Infraspinous fossa of scapula	Middle facet of the greater tubercle of the humerus		Lateral rotation of the arm; part of the rotator cuff that stabilizes the shoulder
Teres Minor	Lateral border of the scapula	Inferior facet of the greater tubercle of the humerus		Laterally rotates the arm; part of the rotator cuff that stabilizes the shoulder
Extensors	Various	Numerous	Wrist	Extends the wrist
Flexors	Various	Numerous		Flexes the wrist
Biceps Brachii	Short head: coracoid process of the scapula Long head: supraglenoid tubercle	Radial tuberosity of the radius	Elbow	Flexes elbow, shoulder, and supinates radioulnar joint in the forearm
Triceps Brachii	Long head: infraglenoid tubercle of the scapula Lateral & medial heads: around the radial groove of the humerus	Olecranon process of the ulna		Extends forearm and shoulder
Brachialis	Antero-distal surface of the humerus	Coronoid process and tuberosity of the ulna		Flexes the elbow
Brachioradialis	Lateral supracondylar ridge of the humerus	Radial styloid process		Flexion of the elbow, supination and pronation of the radioulnar joint

Table 4: Details of the Coimbra Method (Henderson et al., 2013, 2016)

Zone	Feature	Degrees of Expression
Zone 1	Bone Formation	1=distinct, sharp new bone formation that does not meet requirements of stage 2 2 = distinct, sharp new bone formation that is both ≥1 mm high and affects >50% of the bone margin
	Erosion	1 = <25% of the bone margin 2 = ≥25% of the bone margin
Zone 2	Textural Change	1 = covering >50% of surface
	Bone Formation	1 = bone formation >1 mm in size, <50% of surface 2 = bone formation >1 mm in size, ≥50% of surface
	Erosion	1 = <25% of surface 2 = >25% of surface
	Fine Porosity	1 = <50% of surface 2 = ≥50% of surface
	Macro Porosity	1 = 1 or 2 pores 2 = >2 pores
	Cavitation	1 = 1 cavitation 2 = >1 cavitations

Sex and Age

Sex and age data were collected using methods defined in Buikstra and Ubelaker (1994). Age was assessed using changes at the auricular surface (Bedford et al., 1989; Lovejoy et al., 1985; Meindl & Lovejoy, 1985), pubic symphysis (Brooks & Suchey, 1990; Katz & Suchey, 1986), and if necessary, dental wear patterns and cranial suture closures (using a method compiled by Buikstra and Ubelaker (1994), from Baker (1984), Mann et al., (1987), Meindl et al., (1985), and Todd & Lyon (1924; 1925a; 1925b; 1925c)) because only adults were included in this study. Individuals were grouped into young adult (18-29 years), middle adult (30-45 years), and old adult (46+ years) categories. No commingled remains were utilized. Because there are strong associations between entheseal remodeling and age (Cardoso & Henderson, 2010; Hawkey & Merbs, 1995; Weiss, 2003; Zumwalt, 2006), sex (Villotte et al., 2010b; Weiss et al., 2012), and body size (Hamrick et al., 2000; Montgomery et al., 2005), it was important for the individuals used within this study to have estimable measures for age, sex, and body size.

Body Size

Males have been found to have higher entheseal remodeling scores than females in previous work (Elkasrawy & Hamrick, 2010). This is typically attributed to a higher level of activity in males (Chapman, 1997; Peterson, 1998), although this explanation seems to ignore the sexual dimorphism seen between males and females in regard to strength, overall size, and muscle mass. Elkasrawy and Hamrick (2010) suggest that this may be due to tendon fiber volume rather than actual repetitive stress. Whatever the cause, statistical analysis can be used to mitigate the issues with body size and entheseal remodeling. Weiss (2003, 2004, 2007) outlined methods to standardize body size by using z scores based on humeral and femoral measurements. Maximum length, maximum head diameter, and epicondylar breadth were collected from all burials used in this analysis per Buikstra and Ubelaker (1994). Z scores were summed to form an aggregate upper body and lower body score, and the scores for the left and ride side were compared via Pearson's correlation. These scores were binned into small, medium, and large categories for ease of analysis. The bin limits were calculated differently for males and females to contend with differences in body size ranges (Table 5).

Table 5: Bin Limits for Analysis Including Body Size

Limb Limits & Associated Sexes	Small	Medium	Large
Lower Limb Limits: Females	<-0.913	>-0.913, <0.093	>0.093
Upper Limb Limits: Females	<-0.816	>-0.816, <0.266	>0.266
Lower Limb Limits: Males	<-0.419	>-0.419, <0.809	>0.809
Upper Limb Limits: Females	<-0.196	>-0.196, <0.961	>0.961

Statistical Analysis

Bioarchaeological data is frequently zero-inflated, which means that the data is zero-heavy because what is defined as normal is not usually a distinct condition, but a range of conditions. This can make statistical analysis difficult. Thus, a zero-inflated gamma model was chosen as the appropriate test for this data set, which was predictably zero-heavy. This is a type of multiple linear regression that can accommodate a dataset where the probability distribution is skewed by excessive zeroes (Lambert, 1992). The multiple linear regression (gamma) was chosen to analyze the relationship between a dependent variable and one or more independent variables (Nathans et al., 2012). This model is valuable when trying to assess the relationships between a response and explanatory variable, and to detect when there is no linear relationship between dependent and independent variables. In the case of this study, the independent variables will be sex, age, region, time period, and body size, with the response variable, or the recorded entheseal remodeling value, as being the dependent variable. Relationships between the right and left side were analyzed using a Pearson correlation. If this test is found to be statistically significant, this means that there is a significant relationship between the two different groups of values. Pearson's R then estimates the direction of the correlation (i.e. whether it is positive or negative), and the magnitude of this correlation. SAS 9.4 statistical software was used to analyze this data and the α was set at 0.05.

Results

Summary statistics for the results can be found in the Appendix (Table 15). The first step was to use the Pearson Correlation test to compare the right and left sides. The results of these test are found in Table 16 – Table 25. The metrics for left and right were found to be correlated with one another, thus the sides were averaged to create a composite variable for each metric, and this was used in the analysis.

For body size, the results were largely non-significant; this implies that there is not necessarily a relationship between the body size of individuals and entheseal changes. However, there were some results that stood out for body size estimates using upper limb measurements. For the teres minor, the small and medium individuals were found to be statistically significantly different from one another in the lower limb (p=0.0183), with the medium sized individuals having higher least squares means (μ=0.59) than the small individuals (μ=0.15). For the extensors, the small and medium individuals were found to be statistically significantly different from one another (p=0.0189), with medium individuals having a larger mean (μ=0.71) than small individuals (μ=0.27). Flexors also mirrored this trend, with small individuals having very low means (μ=0.10) and medium individuals having higher means (μ=0.42), and the two groups being statistically significant different (p=0.0482). No other muscles had statistically significant differences between body sizes for either the upper limb or the lower limb. Although there were a few exceptions, this seems to indicate that the majority of the change at entheses are not related to the body size of the individuals.

Results are summarized below, with p-values and least squares means provided in parentheses. For the subscapularis (Table 27), which internally rotates and adducts the shoulder, results between old adults (μ=2.58) and young adults (μ=0.24) (p=<0.0001) and old adults (μ=2.58) and middle adults (μ=0.73) (p=<0.0001) are statistically significantly different. The only difference found between the different groups is between the Post-Ottoman (μ=1.48) and Vlachs (μ=0.78) groups (p=0.0140). No sex difference was found (p=0.6629), although the Adriatic (μ=1.53) and continental (μ=0.83) regions were found to be statistically significantly different from one another (p=0.0102). The same age-related results were found with the supraspinatus (Table 29), which abducts the shoulder, between older adults (μ=1.33) and younger adults (μ=0.27) (p=<0.0001) and older adults (μ=1.33) and middle-aged adults (μ=0.41) (p=<0.0001) being statistically significantly different. Statistically significant differences were found between the Post-Ottoman (μ=0.58) and Vlach (μ=1.06) periods (p=0.0137) and the Vlach (μ=1.06) and Pre-

Ottoman (μ=0.38) periods (p=0.0015). No sex (p=0.3534) or regional (p=0.8823) differences were found for the supraspinatus.

For the infraspinatus (Table 31), which is the main muscle that controls the external rotation of the arm, the age pattern continued; differences between older adults (μ=2.28) and young adults (μ=0.38) (p=<0.0001) and older adults (μ=2.28) and middle-aged (μ=0.87) adults (p=<0.0001) were found. The only periods that were found to be statistically significantly different were between the Pre-Ottoman (μ=0.70) and Vlach (μ=1.67) groups (p=0.0008). A sex difference was also found (p=0.255), with females having higher least squares means (μ=1.40) than males. No regional (p=0.7432) differences were found. The teres minor (Table 33) reveals no sex (p=0.1201) difference, but a regional difference (p=0.348) was, with continental individuals having higher least squares means (μ=0.57) than Adriatic individuals (μ=0.27). Older adults (μ=0.87) and middle-aged adults (μ=0.31) (p=<0.0001) and older adults (μ=0.87) and young adults (μ=0.08) (p=<0.0001) groups were found to be statistically significantly different from one another. Post-Ottoman (μ=0.55) and Pre-Ottoman (μ=0.12) groups (p=0.0030) and Pre-Ottoman (μ=0.12) and Vlach (μ=0.59) groups (p=0.0.0037). The teres minor externally rotates the shoulder and supplies slight adduction.

Extensors (Table 35), which are responsible for extension of the wrist and digits, were found to have differences between older adults (μ=1.33) and middle-aged adults (μ=0.32) (p=<0.0001) and older adults (μ=1.33) and younger adults (μ=0.08) (p=<0.0001). No differences were found between the sexes (p=0.3478), regions (p=0.1413), or any of the periods. The flexors (Table 37) were similar, with older adults (μ=0.73) and middle-aged adults (μ=0.18) (p=<0.0001) and older adults (μ=0.73) and younger adults (μ=0.03) (p = <0.0001) being statistically significantly different. No differences between the different periods or regions, but a sex difference was found (p=0.0219), with females (μ=0.43) having higher least squares means than men (μ=0.20). The flexors are responsible for flexion of the wrist and digits.

No sex (p=0.3290) or regional (p=0.2670) were found in the triceps brachii (Table 39), which extends the elbow, although there were differences found in between the Post-Ottoman (μ=2.27) and Pre-Ottoman (μ=1.41) groups (p=0.0004) and the Post-Ottoman (μ=2.27) and Vlach (μ=1.72) periods (p=0.0394), as well as the older adult (μ=2.49) and middle-aged adult (μ=1.69) (p=<0.0001) and older adult (μ=2.49) and younger adult (μ=1.22) (p=<0.0001) groups. The biceps brachii (Table 43), which is responsible for flexion of the elbow and supination of the forearm, has statistically significant differences between all age groups, and no difference found between Post-Ottoman, Pre-Ottoman, or Vlach. Additionally, no differences were found between regions (p=0.4048), although sex differences were found (p=0.0126), with males (μ=2.20) having higher least squares means than females (μ=1.66).

The final two muscles are the brachialis (Table 41), which flexes the forearm at the elbow, and the brachioradialis (Table 45), which also flexes the elbow, and can pronate or supinate. Older adults (μ=1.14) and young adults (μ=0.73) groups (p=0.0174). No sex (p=0.7205) differences were found, although Adriatic (μ=0.66) and continental (μ=1.18) groups were found to be statistically significantly different (p=<0.0001). Additionally, the three periods were all found to be different from one another; Pre-Ottoman (μ=0.47) and Post-Ottoman (μ=0.94) (p=0.0006), Post-Ottoman (μ=0.94) and Vlach (μ=1.35) (p=0.0032), and Pre-Ottoman (μ=0.47) and Vlach (μ=1.35) (p=<0.0001) were all statistically significantly different. No age differences were found amongst the brachioradialis. Additionally, no sex differences were found (p=0.3857). Statistically significant differences were found between the Post-Ottoman (μ=0.59) and Pre-Ottoman (μ=0.17) (p=<0.0001) and Pre-Ottoman (μ=0.17) and Vlach (μ=0.59) groups (p=0.0004) were found. Additionally, regional statistically significant differences were found (p=0.0005), with individuals from the continental (μ=0.62) region having higher least squares means than Adriatic individuals (μ=0.26).

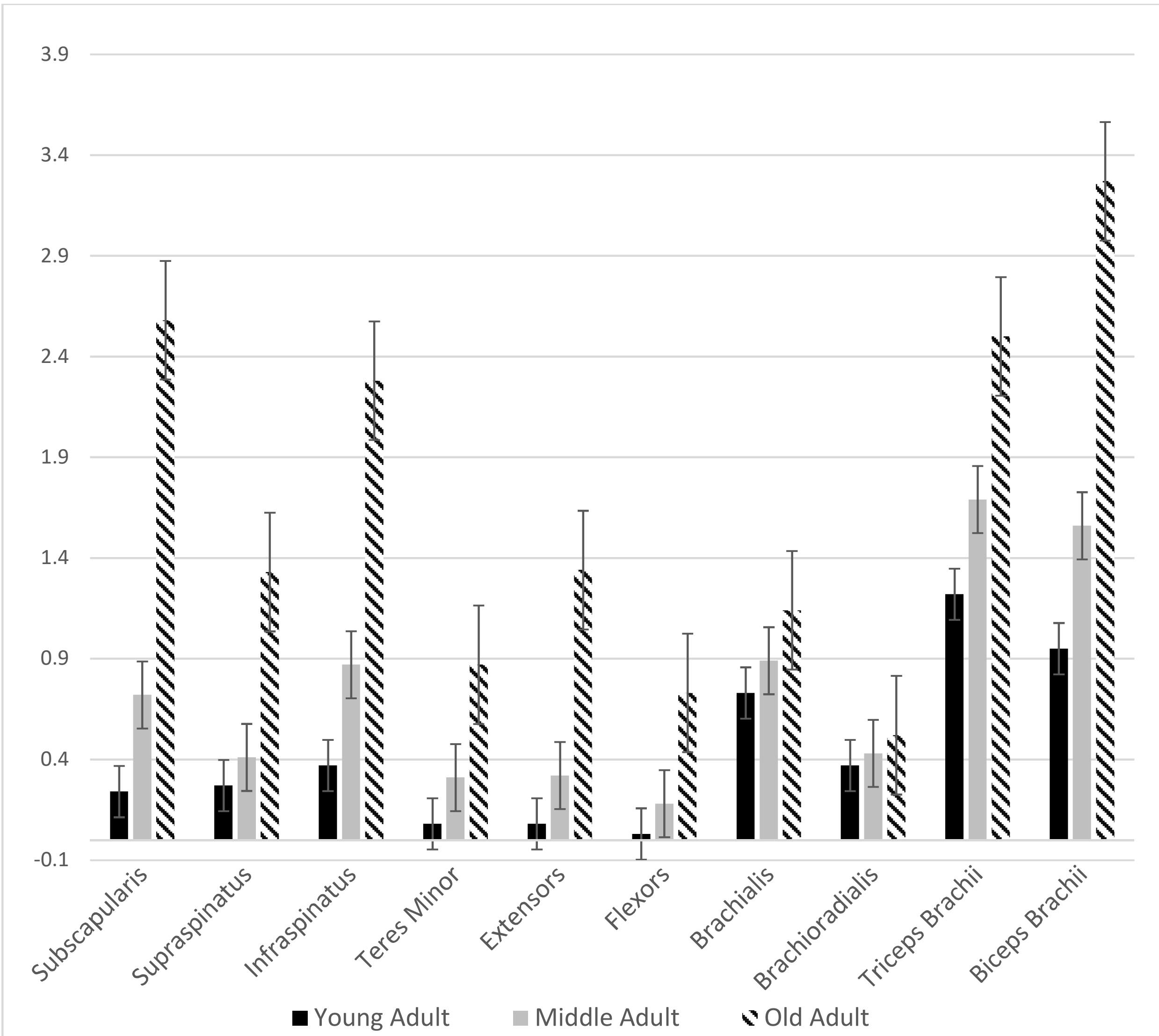

Figure 2: Least Squares Means for Age by Enthesis for the Coimbra Method

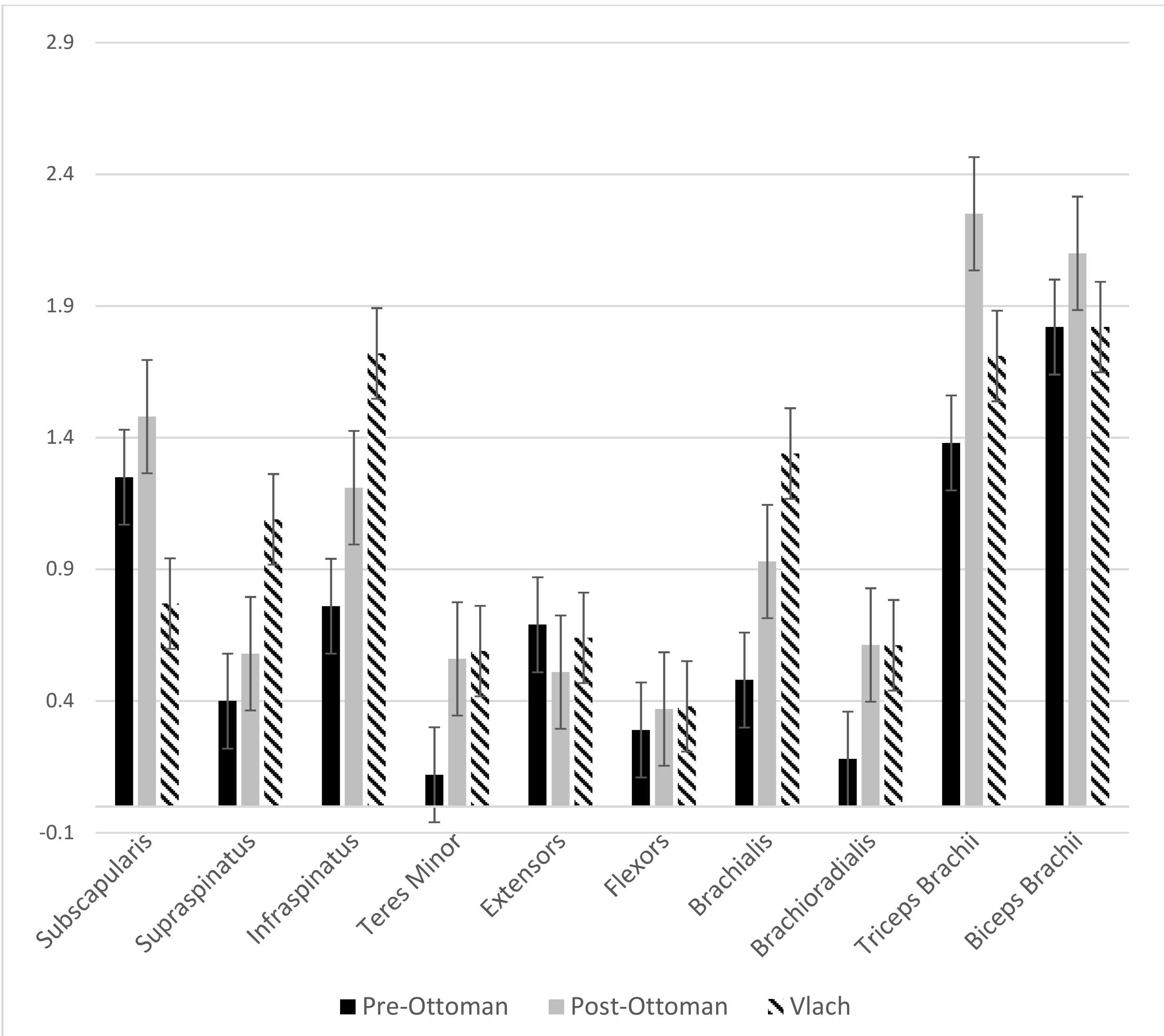

Figure 3: Least Squares Means for Group by Enthesis for the Coimbra Method

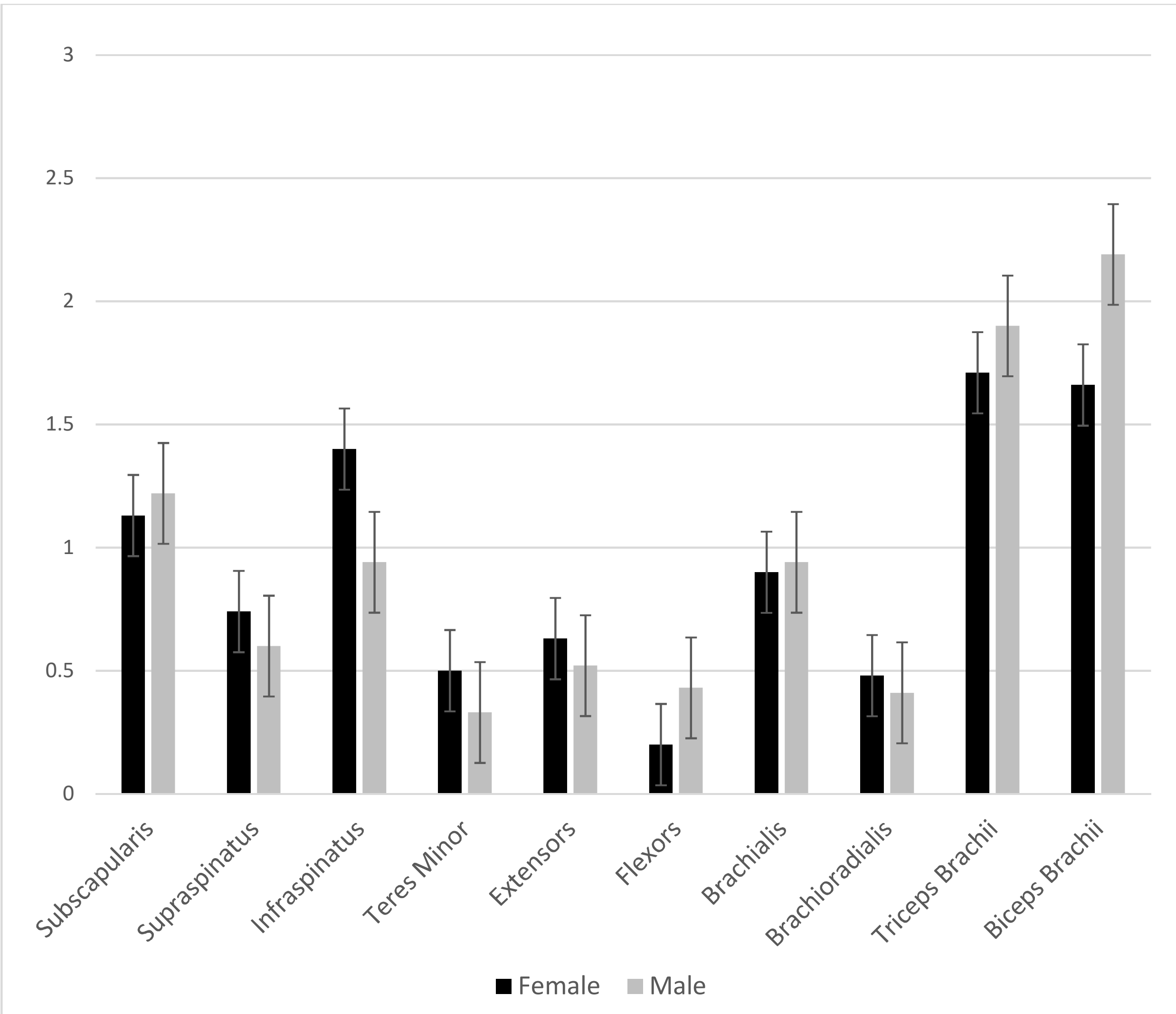

Figure 4: Least Squares Means for Sex by Enthesis for the Coimbra Method

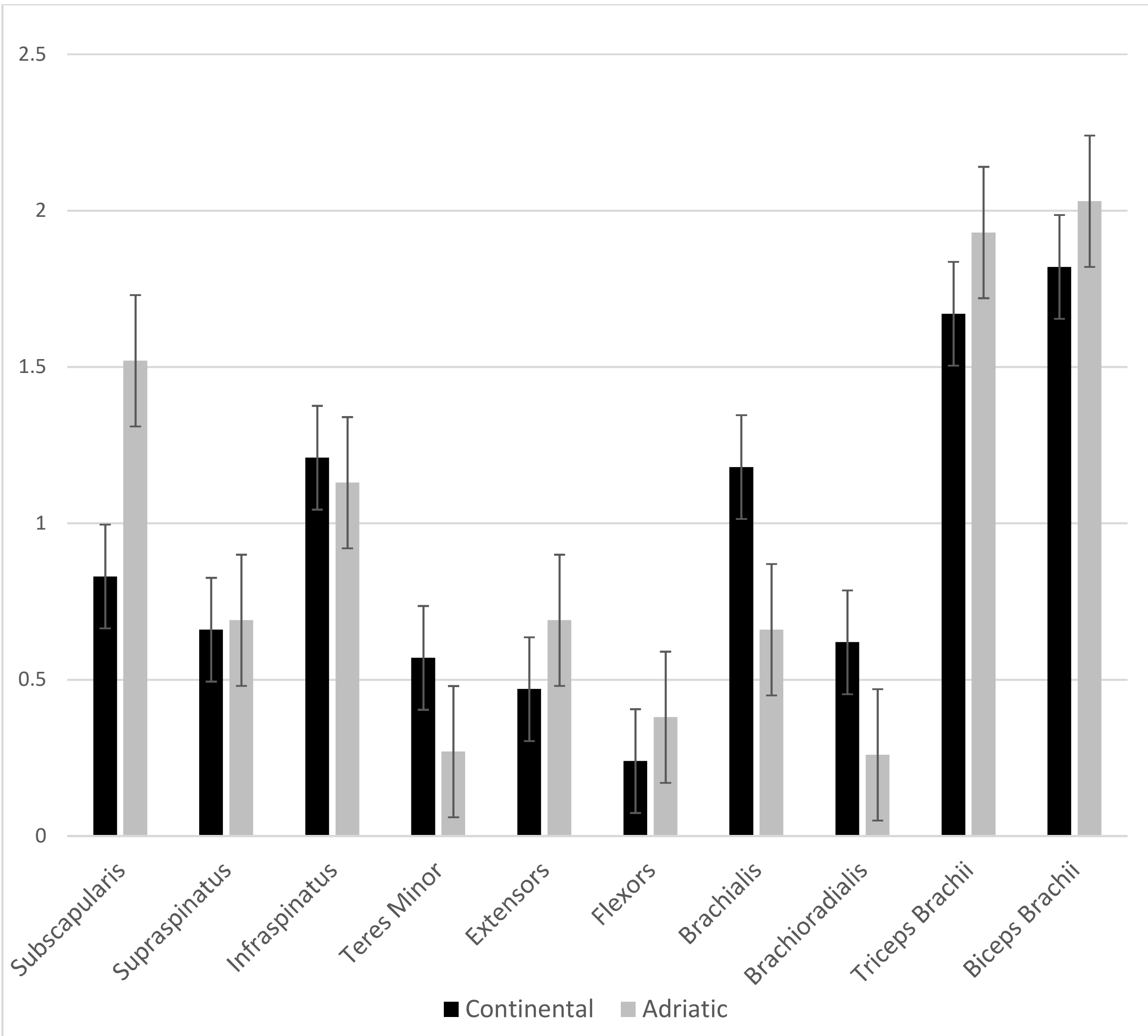

Figure 5: Least Squares Means for Region by Enthesis for the Coimbra Method

Discussion

Each enthesis seemed to show a positive linear relationship with age that was at least in some way statistically significant. Even in the absence of statistical significance, there was a positive upward trend with age and enthesis score; as an individual got older, they had higher scores for entheseal remodeling. This has been found in other bioarchaeological and clinical literature. Both fields of study have found changes at entheses to be additive over time due to the consistent use of muscles and reduced healing capacity over time (Cardoso & Henderson, 2009; Mariotti et al., 2004, 2007; Robb, 1998; Villotte, 2009; Villotte et al., 2010a).

While available historical and contemporary literature suggests that a sexual division of labor existed at these sites (Ivanišević, 1987; Muraj, 2004; Šestan, 2008; Voynović Traživuk, 2001), the data here does not seem to mirror this. Only differences between the biceps brachii, flexors, and infraspinatus had statistical significance; no other entheses showed a difference between males and females. Females had higher least squares means for both the flexors and the infraspinatus, while males had higher means for the biceps brachii. It is possible that the changes at these three entheses are related to some activity that involves heavy flexion or supination of the forearm, such as lifting or carrying, although this seems unlikely considering the other forearm flexors (brachialis and brachioradialis) being non-statistically significant. The data seem to indicate that there was no sexual division of labor, although it is possible that men and women were performing different tasks that involved the same gross muscle movements, so this cannot be ruled out. One point of note is that the appearance of similar scores between men and women could indicate that either men and women were performing at similar levels of intensity and thus had similar development of muscle, or women were doing exceptionally hard work, and thus their entheses changed more than they would on a less hard-working population. This may have involved taking over total control of a household when men were going off to war, leading them to work harder than they may have already been working.

Regional differences were found for some of the muscles. The subscapularis, teres minor, brachialis, and brachioradialis were found to have statistically significant differences between the Adriatic and continental region. For the brachialis, brachioradialis, and teres minor, the continental region showed higher values for the means. The subscapularis was found to be higher in the Adriatic region. Although slight, the differences found between Adriatic and continental populations could be attributed to different labor requirements of the Turks. Historical resources suggest that males in Koprivno, which is located in the Adriatic region, were forced to undergo public labor, or *kulluk*, while individuals in the continental region may not have been obligated to undertake this endeavor. This would have placed a higher burden on those in the Adriatic region, as they were tasked with reestablishing and maintaining important military fortresses within the region to fend off invaders (Mohorovičić, 2008).

However, the individuals from the continental region had higher least squares means for three of the four statistically significant comparisons, indicating that perhaps individuals in the continental region were performing an activity that may have involved flexion of the arm and forearm, such as carrying, at a more robust rate than those in the Adriatic region. Despite the presence of *kulluk* for the Adriatic population, the people in the continental region were subject to regular Ottoman raids as they endeavored to reach Vienna. Additionally, the continental region is the location of the Austrian military border, where individuals were encouraged to live and work to maintain a fortified border against Ottoman invasion. This border was rarely well-maintained and frequently understaffed, which could have led its occupants to work harder than those in the Adriatic to maintain this border region and the safety it provided.

More consistent is the general trend of the Vlach population having higher entheseal change values than either the Ottoman or the Pre-Ottoman populations, in most cases. This trend has the Vlachs leading with the highest values, the Post-Ottoman population in the middle, and the Pre-Ottoman population bringing up the rear. This pattern holds for the supraspinatus, infraspinatus, teres minor, and brachialis. Only one set of muscles, the extensors, have the Pre-Ottoman group leading in their means. As mentioned before, the Vlachs were cattle-breeders and practiced transhumance pastoralism (Jurin-Starčević, 2008). They were frequently at conflict with their agriculturalist neighbors due to their very different lifestyles and means. The rugged lifestyle the Vlachs practiced may have led to them having higher entheseal remodeling scores than those of their neighbors. The long distance traveled by transhumant pastoralists, in addition to agriculture during longer stays in an area, may have led to a physically demanding way of life. Especially with higher entheseal remodeling scores in three of the four rotator cuff entheses, it is possible that this is related to heavier work related to moving cattle, tilling the rockier land for farming, or carrying heavy loads over a more rugged landscape. It is interesting that Vlachs frequently have higher values than even Post-Ottoman subjects. This could indicate that perhaps the Vlach way of life was more difficult than even the physically demanding life enforced upon Croatian subjects by the Ottoman rulers.

Statistical significance between the Pre-Ottoman and Post-Ottoman populations was only found in the brachialis, brachioradialis, teres minor, and triceps brachii. However, in most cases, the Post-Ottoman population has higher rates for entheseal change than the Pre-Ottoman population. These values are higher for the biceps brachii, triceps brachii, flexors, subscapularis, and brachioradialis muscles. The brachioradialis and biceps brachii are involved in flexing the elbow, and the triceps brachii is involved in extending the elbow. This motion would have been supported by the adducting and medial rotating function of the subscapularis, which would have helped keep the arms close to the body. It is possible that this may correlate with a higher workload placed upon the Ottoman Croats in the form of carrying heavy loads, which would have required constant flexion of the elbow, kept close to the sides. Worth mentioning again, post-Ottoman populations were forced to undergo *kulluk* (Jurin-Starčević, 2008). This work involved performing civil duties such as maintaining roads, building bridges and forts, and clearing of woodland (Jurin-Starčević, 2008). The Vlach population at Koprivno was also forced to undertake this labor; if this was universally applied to Vlach populations, as they were vassals of the Ottomans, this could explain the higher entheseal remodeling values for the Vlachs and the Post-Ottomans. Documentation surrounding the rebuilding of the Požega fortress involved a team of almost 30,000 individuals (Holjevac & Moačanin, 2007). This highlights the large-scale of many of the projects undertaken by Ottoman subjects and indicates that the workload performed by individuals during times of war in this area was a heavy physical burden (Novak & Šlaus, 2011).

Conclusion

These results seem to indicate that the workload enforced upon people after the invasion of the Ottoman Empire would have led to differences in daily activity for Croatian people, although these differences may not have been dramatic between the Pre-Ottoman and Post-Ottoman periods. The trend is to higher least squares means in the Post-Ottoman group, although theses results are frequently statistically insignificant for most muscles. This could corroborate some of what is found in the historical record that indicates that the changes brought by the Ottomans were serious enough to leave lasting evidence on the skeleton, although it is possible that only the Vlachs were hard-hit, as they did feature much more statistically significant results in their comparisons, and had higher least squares means in many of those situations. However, it seems as though the deduction of specific activities, at least in these populations, is not possible. Many activities, such as cutting wood, hammering, or carrying, use similar muscle groups, and most individuals during this time were general laborers, serfs/farmers, or raised livestock. Many of the physical actions involved in these livelihoods involve the same gross movements of the body, which would not allow for the exact deduction of activities. However, it does seem possible to detect the general level of work, if not the actual activities. The addition of more laborious workloads, such as the rebuilding of fortresses or fortification of city walls, to normal daily responsibilities may have led to the higher scores found amongst the Post-Ottoman and Vlach populations. While the Post-Ottoman populations were undertaking their normal daily activities, in conjunction with added work and the production of food for a large, occupying force, the Vlachs were practicing transhumant pastoralism in addition to their extra labor responsibilities as Ottoman vassals. Both of these populations would have been greatly affected by the invasion of the Ottoman Empire culturally and socioeconomically, but it seems as though the Vlachs may have been more hard-hit biologically.

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CHAPTER 3. THE EFFECT OF OTTOMAN INVASION ON THE DEVELOPMENT AND PROGRESSION OF OSTEOARTHRITIS

Introduction

Although osteoarthritis, also called degenerative joint disease (DJD), is one of the most common conditions through which bioarchaeologists examine activity in the past (Rando & Waldron, 2012), there is still significant debate within anthropology and clinical medicine over the etiology and the implications for these patterns in daily life. The etiology of osteoarthritis is complicated by many factors such as age (Merbs, 2001; Weiss, 2005; 2006), sex (Holmberg et al., 2004), genetics (Jonsson et al., 2003; Manek et al., 2003; Min et al., 2005; Spector & MacGregor, 2004; Zhai et al., 2004), weight (Felson et al., 1988; Jordan et al., 2007; Melanson, 2007; Sharma, 2001; Sowers & Karvonen-Gutierrez, 2010; Sturmer et al., 2000), and repetitive activities (Block & Shakoor, 2010; Felson et al., 1991; Hough, 2001; Moskowitz et al., 2004; Radin, 1982, 1983; Radin et al., 1972, 1991; Weiss & Jurmain, 2007). Detecting the effects that these different factors have on the chances of developing osteoarthritis and the rate at which osteoarthritis develops has proven difficult, even with the relatively recent inclusion of clinical studies on the topic. Some of the most problematic issues include the relationship between osteoarthritis and activity in skeletal material and the evolving definition of osteoarthritis.

Although older clinical work found no significant correlation between osteoarthritis and activities (Burke et al., 1977; Crosby, 1985; Konradsen et al., 1990), other modern clinical work recognizes a correlation between the development of osteoarthritis and some activities, such as farming, weight lifting, floor layers, drilling, and various sports (Jensen et al., 2000; Rossignol et al., 2003; Shepard et al., 2003; Thelin et al., 2004; for a comprehensive list see Weiss & Jurmain, 2007). However, there are factors that complicate the comparison of osteoarthritis in living groups and non-living populations. First, some clinical osteoarthritis studies are based around individuals who are symptomatic for osteoarthritis, defined as joint pain. Individuals feel pain differently, if they feel it at all, and this can affect who is included in a study about osteoarthritis. Secondly, individuals change occupations regularly throughout their lives in the modern world. This means that individuals may reveal a pattern of osteoarthritis that is inconsistent with their current occupation; they may reveal a pattern of osteoarthritis that matches best with their longest held occupation, or even one they performed at a very young age. Henderson et al., (2013) points out that this applies in the archaeological record as well, in cases where historical documentation may list the age at death of individuals. Third, studies on osteoarthritis are primarily carried out on older individuals, who have begun showing signs of osteoarthritis after a long life. In these cases, it is hard to separate osteoarthritis from occupation from age and body size (Austin, 2017).

Bioarchaeology may be able to contribute to a discussion of osteoarthritis because skeletal assemblages more often consist of individuals who participated in a specific occupation for the duration of their lives. The exact essence of this work may not be known, however, and even in cases where documentation lists known occupation, researchers may be unaware of the longevity and exact nature of this work (Henderson et al., 2013). This causes the precise nature and etiology of osteoarthritis in the archaeological record to be unclear. Additionally, the lack of ability to survey individuals based on their pain causes bioarchaeologists to rely on macroscopic views of joint surfaces to deduce osteoarthritis. This may lead to overreporting of levels of osteoarthritis in the past; in modern clinical studies, individuals may show joint narrowing upon X-ray examination, but feel no pain (Hall et al., 2014). Their osteoarthritis may go unreported. Bioarchaeologists are unable to deduce if the osteoarthritis found on the skeleton would have caused pain, thus whether it would have been experienced.

Despite these issues, osteoarthritis has been a popular way to assess activity in the past given the limited methods available for evaluating the effects of physical movements on the body. Previous work has found that osteoarthritis is a useful marker when activity-related stresses are high, and they begin early in life (Weiss & Jurmain, 2007). Some patterns have emerged with regards to specific occupations or activities; for example, Becker (2016) tied extensive arthritis in the hands, wrists, and lower arms with ceramic production. Jurmain (1991) has compiled an extensive list, that includes studies on farmers, weightlifters, drilling, and other sports. However, not every part of the body has been found to be useful in the study of activity, and some argue that there is an unclear link between osteoarthritis and physical activity (Burke et al., 1977; Crosby, 1985; Konradsen et al., 1990; Knüsel et al., 1997), in general. For example, some work suggests that the spinal column's role as the central stabilizing pillar of the body makes it a poor subject of activity studies because the arrangement of osteoarthritis in the spine reflects the stresses of an erect posture and generalized weight bearing (Bridges, 1994).

The goal of this article is to contribute to the discussion on the value of osteoarthritis studies in bioarchaeology and the complicating factors around its analysis. A collection of skeletal remains from Croatia dating to the late-Medieval period (11^{th} – 15^{th} century C.E.) and early modern periods (15^{th} – 18^{th} century C.E.) was used; these two time periods encircle the invasion of the Ottoman Empire in Croatia during the 15^{th} century. Historical documentation from the time considers the invasion of the Ottoman Empire to be extremely detrimental to daily life in Croatia. Keeping in mind the interpretive concerns, this study utilizes osteoarthritis to assess activity changes in a past population. While clarifying specific activities may not be possible, there is enough clinical and bioarchaeological evidence to support the use of this modality in the deduction of unstable activity patterns (Austin, 2017; Block & Shakoor, 2010; Hough, 2001; Jordan et al., 1995; Moskowitz et al., 2004; Radin, 1982, 1983; Radin et al., 1972, 1991; Weiss & Jurmain, 2007

Historical Context

The Late Medieval period was a time of relative prosperity. The earlier unification of Croatian territories by King Tomislav in the 10^{th} century C.E. brought stability, allowing the nobles in southern Croatia to grow more powerful by acquiring land, which was then organized into estates with judicial and administrative power. City walls lent security, and literacy increased for the nobility (Goldstein, 1999). Most common Croatian people were serfs or livestock caretakers on the lands of local lords (Rothenberg, 1960), although some individuals practiced pastoralism along the Dalmatian coast (Šarić, 2008).

The Ottoman Empire was founded in the late 13^{th} century C.E. (Finkel, 2006). The Turkish war machine was motivated to colonize their neighbors for several reasons (Sugar, 1977). The most frequently noted were the need for resources and land (Özoğlu, 2004). Military service was compulsory, and members of the military were given gifts of land, or *timar*, for their work. Keeping this large, unpaid army sated was important, which also fueled the need for conquest.

Slavery was also a large motivator and slaves were used in almost all parts of Ottoman society (Sugar, 1977). These slaves were taken to replace fallen soldiers, work the captured land, and if they were particularly learned, serve in administrative rules (Sugar, 1977). The first line of invasion for the Ottomans were the *akinji¸* or the Turkish light cavalry. They used sabers and traveled on horseback, and their primary goal was to disrupt and destroy natural, materials, and human resources, decentralizing power and priming the landscape for invasion by the Turkish army proper (Kruhek, 1995). Additionally, the *akinji* were also tasked with the capture of slaves. Literature from the 15th century attempted to estimate the number of slaves captured in the raids of 1415 and 1471 at 20,000 to 30,000 (Mijatović, 2005), although this probably overestimates the number (Šlaus et al., 2010). Other than slavery, Ottoman philosophy encouraged conquest for conquests sake (Sugar, 1977). Finally, the Austrian Habsburgs were based out of Vienna, and Croatia served as the perfect corridor through which the Ottomans could reach the nearby capital (Rothenberg, 1960).

The Late Medieval Lifestyle

Little is known about the rural home environment in Late Medieval Croatia. The number of small villages and hamlets increased at this time, according to historical literature. Along with the increase in available farmlands, the number of free peasants and serfs also increased (Kurelac, 2008; Mohorovičić, 2008). These rural locations were especially important as they were the backbone of the economy, supplying goods such as livestock, wine, and cereals (Kurelac, 2008). Individuals working in these areas were primarily farmers or worked raising livestock. Fortification was an important focus at this time; over 700 fortified buildings and towns have been identified in the continental region of Croatia alone (Mohorovičić, 2008), and these fortifications were primarily built by locals to the area. Not only were individuals engaging in work on their own home farms but were frequently called to duty helping local lords build fortifications to protect the region.

The Treatment of The Common People

There is very little literature that delves into the daily lives of average Croatians during the invasion of the Ottoman Empire. Most historical records focus primarily on the nobility and the sociopolitical changes associated with Croatia under the rule of the Austrian Habsburgs.

Although literacy had increased during the Late Medieval Period, there was a vested interest by centralized Catholic powers in preventing the common masses from obtaining literacy. This was due in part to the danger associated with Protestant literature, but largely stemmed from Catholic rulers who did not believe that the common people were capable of properly interpreting the Bible (Melton, 1988). Because of this, the records focus heavily on the lives of the nobility. However, extrapolating from the information given in these records, it is safe to conclude with some relative certainty that life as a common person on a Military Border lined by hostile superpowers on each side was probably not a positive one. Early Modern Croatia had adopted serfdom as its primary mode of agriculture and economic practice. Combine indentured servitude and lifelong debt to local noble estates with the traumas of war and the outlook is likely not beneficial for general health.

The common people who inhabited the military border and the regions just outside of Croatia were primarily serfs, although some were free peasants who occasionally owned land or worked as artisans or smiths (Rothenberg, 1960). Individuals along the coast were also performing transhumant pastoralism, or seasonal movements of people between different locations, alongside more intensive forms of agriculture (Šarić, 2008). Although serfdom was becoming less common in the West, it was developing into a fully-fledged economic system in the East during the Medieval period. The serfs resided on and farmed the land of rich lords; some serfs also worked large swaths of land that served as ranches. Information about farming implements at this time is relatively lacking in Eastern Europe compared to Western Europe. However, with the trade connection between regions, one can reasonably presume that the implements utilized between serfs and free peasant farmers would not have been significantly different. Wooden oxen plows (such as the Mouldboard Plough), sickles, and hand hoes probably would have been used (Fussell, 1952). The use of these tools may have led to specific patterns of use in the upper limb and spine.

The Vlachs

Turkish invasions into Croatia caused a massive change in the demographic of the people living in the area. Most of those native Croats who did not succumb to the violence or bend to Turkish rule were forced out, leaving empty areas (Gjurašin, 2005). The first people to repopulate the area in the first half of the 16th century C.E. were Vlachs (Adamić & Šlaus, 2017; Gjurašin, 2005). Vlachs were a heterogenous group of Ottoman vassals who were native to southern Europe (Allen, 2017). They served as important members of the Ottoman administration and auxiliary military personnel (Kursar, 2013). They were treated as a separate ethnic group, with their own burial practices involving monolithic tombstones called stećak, during the medieval period (Fine, 2006), and is still a recognized ethnic minority today. The Vlachs practiced a semi-nomadic style of transhumant pastoralism (Šarić, 2009), mainly of sheep, goats, and cattle (Botica, 2005; Jurin-Starčević, 2008), which involved seasonal migrations back and forth from summer and winter pastures (Oteros-Rozas et al., 2013). They were largely considered mountain dwellers and were frequently at conflict with their lowland agriculturalist neighbors. Their live was different, and quite rugged. The form of agriculture they practiced required more energy investment as the soil was filled with large rocks and thorny vegetation (Muraj, 2004).

Materials

A total of 7 skeletal collections curated at the Croatian Academy of Sciences and Arts in Zagreb, Croatia. (n = 295) from Croatia were used in this study (Table 6). The chosen sites temporally flank the invasion of the Ottoman Empire and fall within the Late Medieval Period (11th century C.E. – 15th century C.E.) and the Early Modern Period (15th century C.E. – 18th century C.E.). Additionally, they range geographically from the Adriatic coast, which was not as badly affected by the Ottomans, to the continental region of Croatia, which was the frequent corridor via which the Ottomans attempted to reach Austria (Figure 1). There were 159 males and 136 females used in this analysis. Individuals were divided into three age categories; young adults (18-29 years, n=51), middle-aged adults (30-45 years, n=163), and older adults (46+ years, n=81). Individuals were divided into three different body size categories based on a technique highlighted in the methods section. The body size breakdown is listed in Table 7.

Table 6: Collections Used in Osteoarthritis Analysis

Site	Period	Date (C.E.)	Region	Number of Individuals
Dugopolje	Post-Ottoman	26.78	Adriatic	79
Nova Rača	Post-Ottoman	5.76	Continental	17
			Post-Ottoman Total = 96	
Šibenik – Sv. Lovre	Pre-Ottoman	16.27	Adriatic	48
Stenjevec	Pre-Ottoman	25.76	Continental	76
			Pre-Ottoman Total = 124	
Koprivno-Križ	Vlach	18.31	Adriatic	54
Drinovci-Greblje	Vlach	4.75	Adriatic	14
Šarić Struga	Vlach	2.37	Adriatic	7
			Vlach Total = 75	
l			Total = 295	

Table 7: Body Size Distribution for Osteoarthritis Study Material

Relative Limb Length	Lower Limb Frequency	Upper Limb Frequency
Small	62	75
Medium	176	189
Large	92	66

Methods

Sample Selection

Individuals were excluded from this study if they were subadults. Although subadults can get osteoarthritis (Widhalm et al., 2014), there is compelling evidence that the majority of these cases are due to some genetic or traumatic condition. Since this study focuses on osteoarthritis that may be related to activity, subadults were deemed inappropriate for this study. Individuals were included in the study if sex, age, and body height estimates were present and complete. If one of these metrics were not present, individuals were excluded because controlling for complicating factors is essential in an analysis using osteoarthritis as a proxy for activity. Additionally, individuals were excluded if they were missing greater than 50% of their osteoarthritis data.

Methods for the Analysis of Osteoarthritis

There are several ways in which degenerative joint changes are expressed; osteoarthritis is the most commonly found degenerative condition in skeletal samples and the most commonly examined in bioarchaeological literature (Felson et al., 2000; Pritzker, 2003). Although there are myriad ways in which osteoarthritis has been interpreted, discussed, and etiologically examined, most researchers agree on a small list of essential characteristics: it is a multifaceted degenerative condition that involves the general loss of articular cartilage at the surface of joints. This eventually culminates in the formation of osteophytes and porosity as bone-on-bone contact subsequently occurs (Felson et al., 2000). Although these characteristics of osteoarthritis are detectable in the bioarchaeological record, the most commonly reported manifestation is osteophyte formation (van den Berg, 1999) at joint margins, which is likely a result of the body's attempt to bolster a destabilized joint. It is also largely agreed upon by bioarchaeologists and clinicians alike that osteoarthritis has multiple etiologies, including genetic, environmental, and/or behavioral factors (Issa & Sharma, 2006; Manek et al., 2003; Valdes & Spector, 2008; Zhang & Jordan, 2008).

In the spinal column, the joint surfaces on the articular surfaces of all vertebrae, the costal articulations of the thoracic vertebrae, and vertebral bodies were examined for evidence of osteoarthritis and osteophytosis. Additionally, the wrist (distal radius and ulna), elbow (proximal radius and ulna and distal humerus), and shoulder (proximal humerus and glenoid of the scapula) were also exampled for evidence of osteoarthritis (Table 9). Osteoarthritis is scored using the standard methodology highlighted in Buikstra and Ubelaker (1994) (Table 8); vertebral body osteophytosis is scored using only the lipping portion of this same scoring system. This method outlines how to quantify the osteophytic lipping, porosity, and eburnation found at osteoarthritic joints. Osteoarthritis occurs when the cartilage protecting a joint surface wears down over time, sometimes leading to the eventual rubbing of bone on bone. Although the exact progression of osteoarthritis on dry bone remains unclear (Rogers & Waldron, 1995), osteoarthritis is generally thought to progress from the development of bone spurs, to porosity, and finally to eburnation as the cartilage is gone and bone rubs fully against bone and forms eburnation (with a shiny appearance), which is generally thought to be the true determinant of osteoarthritis because it is the one positive sign of joint degeneration (Arcini, 1999; Jurmain, 2013; Molnar et al., 2011). However, this progression is complicated by the inclusion of clinical studies, in which osteoarthritic changes can vary widely between person to person. One individual may feel pain in their joints with minor wear of cartilage, and another may have full bone-on-bone change with no associated pain.

Table 8: Osteoarthritic Scoring Method from Buikstra and Ubelaker (1994)

Metric	Score	Description
Lipping	1	Barely discernable
	2	Sharp ridge
	3	Extensive spicule formation
	4	Ankylosis
Porosity	1	Pinpoint
	2	Coalesced
	3	Pinpoint and coalesced
Eburnation	1	Barely discernible
	2	Polish only
	3	Polish with groove(s)

Table 9: Joints and Associated Landmarks

Joint	Landmark	Bone
Shoulder	Glenoid	Scapula
	Humeral Head	Humerus
Elbow	Capitulum	Humerus
	Trochlea	
	Head	Radius
	Proximal Ulnar Articulation	
	Trochlear Notch	Ulna
	Radial Notch	
Wrist	Ulnar Notch	Radius
	Scaphoid Articulation	
	Lunate Articulation	
	Ulnar Head	Ulna

Sex and Age

Sex and age data were collected using methods outlined in Buikstra and Ubelaker (1994). Sex was assigned via the os coxae and skull. Only adults were chosen for this study, so age was assessed using pubic symphyseal changes (Brooks & Suchey, 1990; Katz & Suchey, 1986), the auricular surface (Bedford et al., 1989; Lovejoy et al., 1985), and if necessary, cranial suture closures (using a method compiled by Buikstra and Ubelaker, 1994, from Baker (1984), Mann et al., (1987), Meindl et al., (1985), and Todd & Lyon (1924; 1925a; 1925b; 1925c)) and dental wear patterns. Only remains from adults were included in this study. Although it has been found that bone plasticity during adolescence can make children a useful group for activity studies (s), the constant remodeling activity of the human skeleton during growth (Ruff et al., 2006) may make it difficult to assess osteoarthritis. Ages were grouped between young adults (YA, 18-29 years), middle adults (MA, 30-45 years), old adults (OA, 46+ years). Data from commingled remains were not included. Because there are so many associations with osteoarthritis and age, sex, and body size (Derevenski, 2000; Eng, 2016; Kahl & Smith, 2000; Merbs, 1983, 2001; Molnar et al., 2011; Waldron, 1997; Weiss, 2005, 2006), it was deemed important for the individuals used within this study to have estimable measures for all three.

Body Size

Previous studies on osteoarthritis have found males to have higher scores for osteoarthritis than females (Schrader, 2012), although clinical research indicates that heritability for arthritis-associated genes may be higher in women than in men (Bergink et al., 2003; Spector & MacGregor, 2004; Wilson et al., 1990). This is usually attributed to differences in biomechanics and body size (or body weight). Statistical analysis can be used to alleviate some of the issues dealing with body size. Weiss (2003, 2004, 2007) outlined methods to standardize body size to allow for a more thorough analysis. Body size was examined by calculating z scores based on humeral and femoral measurements outlined by Weiss (2003, 2004, 2007). Maximum length, maximum head diameter, and epicondylar breadth were collected from the humeri and femora all burials used in this analysis per Buikstra and Ubelaker (1994). Z scores were summed to form an aggregate upper body and lower body score. Sides were compared and found to be not statistically different; thus, scores from either side were averaged to form one score from the upper body and one for the lower body for every individual. Finally, these scores were grouped into bins of small, medium, and large categories. The limits were calculated differently for males and females due to size differences between sexes. These are summarized in Table 10.

Table 10: Bin Limits for Analysis Including Body Size

Limb Limits & Associated Sexes	Small	Medium	Large
Lower Limb Limits: Females	<-0.913	>-0.913, <0.093	>0.093
Upper Limb Limits: Females	<-0.816	>-0.816, <0.266	>0.266
Lower Limb Limits: Males	<-0.419	>-0.419, <0.809	>0.809
Upper Limb Limits: Females	<-0.196	>-0.196, <0.961	>0.961

Statistical Analysis

The spinal column was divided into four discrete zones (Flanders, 2009) for ease of analysis (Figure 6). These zones correspond to different biomechanical behaviors of the spine; zone 1 corresponds to the highly flexible cervical spine, zone 2 corresponds to the relatively inflexible upper thoracic spine (T1 – T8, due to the ribs), zone 3 is the lower thoracic and upper lumbar spine (T9 – L2), and zone 4 is the lower lumbar (L3 – S1). SAS statistical software 9.4 was used to analyze this data and the α was set at 0.05. Bioarchaeological data is frequently zero-inflated, which can make some statistical analyses difficult. Thus, a zero-inflated gamma model was chosen as the appropriate test for this data set, which was zero-heavy. This is a type of multiple linear regression that can accommodate a dataset where the probability distribution is skewed by excessive zeroes (Lambert, 1992). The multiple linear regression (gamma) was chosen to analyze the relationship between a dependent variable (lipping, porosity, eburnation, etc.) and one or more independent variables (age, sex, region, and period). This model is valuable when trying to assess the relationships between a response and explanatory variable, and to detect when there is no linear relationship between dependent and independent variables (Nathans et al., 2012). Relationships between the right and left side were analyzed using Pearson's correlation. If these relationships were found to be non-statistically significant (i.e. no difference between right and left side), the values for each side were averaged to form a composite variable, which was then analyzed farther.

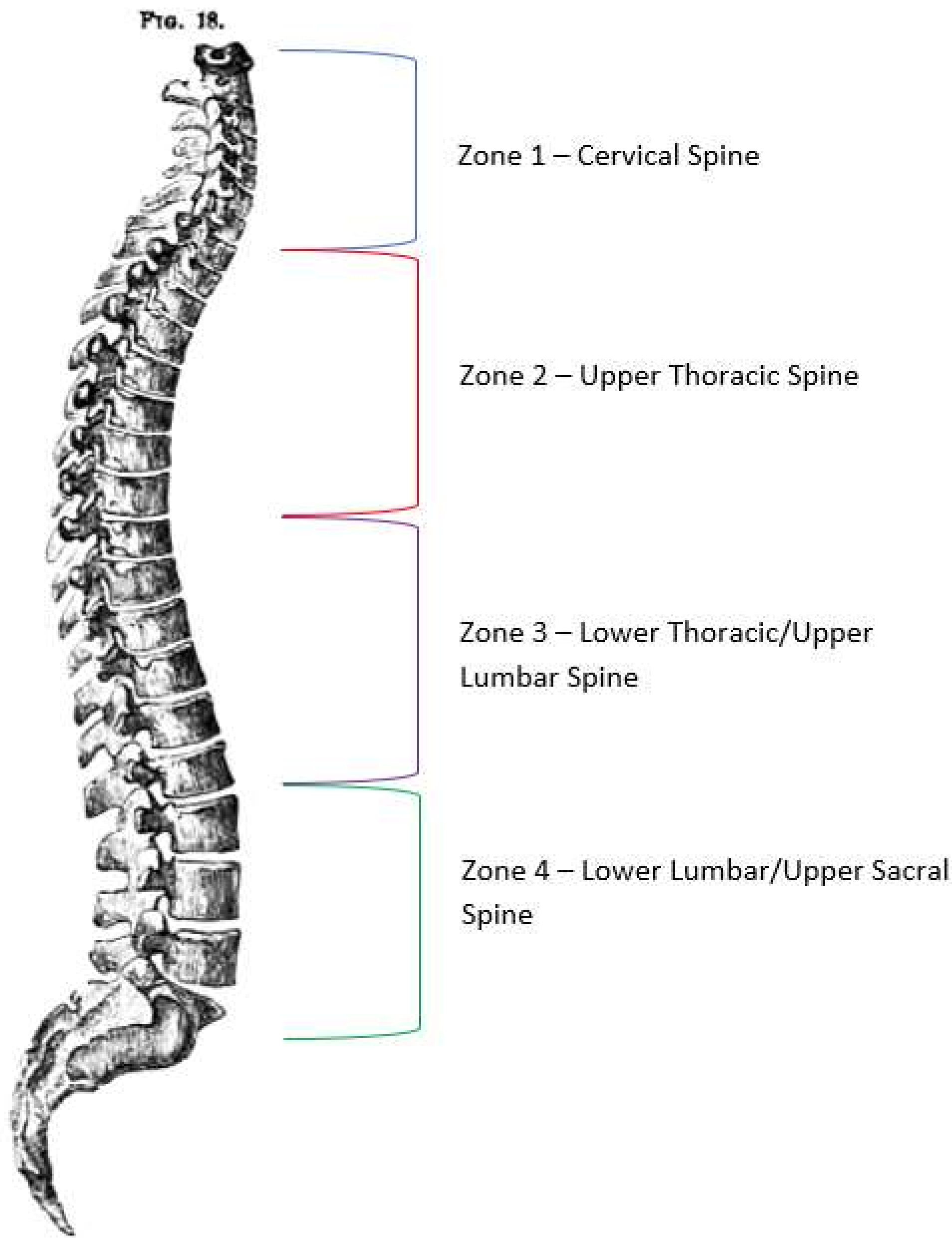

Figure 6: Biomechanical Divisions of the Spinal Column (Bell, 1798)

Results

Summary statistics for upper limb osteoarthritis can be found in Table 88. These data were compared using a Pearson's correlation analysis to determine if there was any detectable statistically significant difference between sides, and this is summarized in Tables 89 – 91. There were none found, so the right and left values were averaged to form a composite variable for each joint. Body size estimates were largely non-statistically significant, except for a few examples. These include eburnation in the elbow between the upper limb lengths of small and medium individuals ($p=0.0267$), and eburnation in the wrist between the lower limb lengths of medium and small individuals ($p=0.0138$) and small and large length individuals ($p=0.0285$).

For lipping in the shoulder joint (Table 93), statistical significance was found between younger ($\mu=0.06$) and older ($\mu=0.86$) individuals ($p=<0.0001$) and middle-aged ($\mu=0.20$) and older ($\mu=0.86$) individuals ($p=<0.0001$). There were no sex differences ($p=0.8110$) or regional differences ($p=0.1879$) found. There were no statistically significant differences found between any group for eburnation in the shoulder (Table 95). This is the same for shoulder joint porosity (Table 97), where no differences were found between sexes, ages, body sizes, regions, or groups.

There were only differences in age groups found for lipping in the elbow (Table 99). Older ($\mu=0.26$) and middle-aged ($\mu=0.04$) adults were found to be statistically significantly difference from one another ($p=<0.0001$). This was the same for young ($\mu=0.01$) and older ($\mu=0.26$) individuals ($p=<0.0001$). Eburnation in the elbow (Table 101) was found to be statistically significant between males ($\mu=0.004$) and females ($\mu=0.02$) ($p=0.0323$). Finally, porosity in the elbow (Table 103) is only statistically significant between older ($\mu=0.06$) and middle-aged ($\mu=0.002$) adults ($p=0.0067$).

The final joint in the upper limb was the wrist. For lipping in the wrist (Table 105), there were statistically significant differences between age groups and regional groups. Older ($\mu=0.33$) and middle-aged ($\mu=0.08$) adults were found to be statistically significantly different ($p=0.0056$), as were young ($\mu=0.07$) and older ($\mu=0.33$) adults ($p=0.0002$). Adriatic ($\mu=0.26$) and continental ($\mu=0.07$) groups were found to be statistically significantly different from one another, as well (p=0.0134). For eburnation in the wrist (Table 107) a statistically significant difference was found between middle-aged adults (μ=0.002) and older adults (μ=0.04) (p=0.0327). Finally, only the same age difference between middle-aged adults (μ=0.011) and older adults (μ=0.10) was found for wrist porosity (Table 109).

Results in the spinal column were unremarkable. Summary statistics for osteoarthritis of vertebral articular facets (Table 110), vertebral osteophytosis (Table 135), and osteoarthritis of the costal facets (Table 160) can be found in the Appendix. By and large, only age was found to be a statistically significant factor in the development of osteoarthritis at the articular facets (Tables 111 – 134), vertebral osteophytosis (Tables 133 – 159), and osteoarthritis at the costal facets (Tables 162 – 173). Older age groups always presented with higher rates of these conditions than middle-aged individuals, who were higher than younger individuals. These results were expected, as previous studies in clinical medicine and bioarchaeology show that age correlates strongly with whether someone develops osteoarthritis and how serious it eventually becomes (Hernborg & Nilsson, 1977; Jurmain & Weiss, 2007; Moscowitz, 1993; Nagy, 1996; Rogers & Waldron, 1995; Rogers et al., 1997).

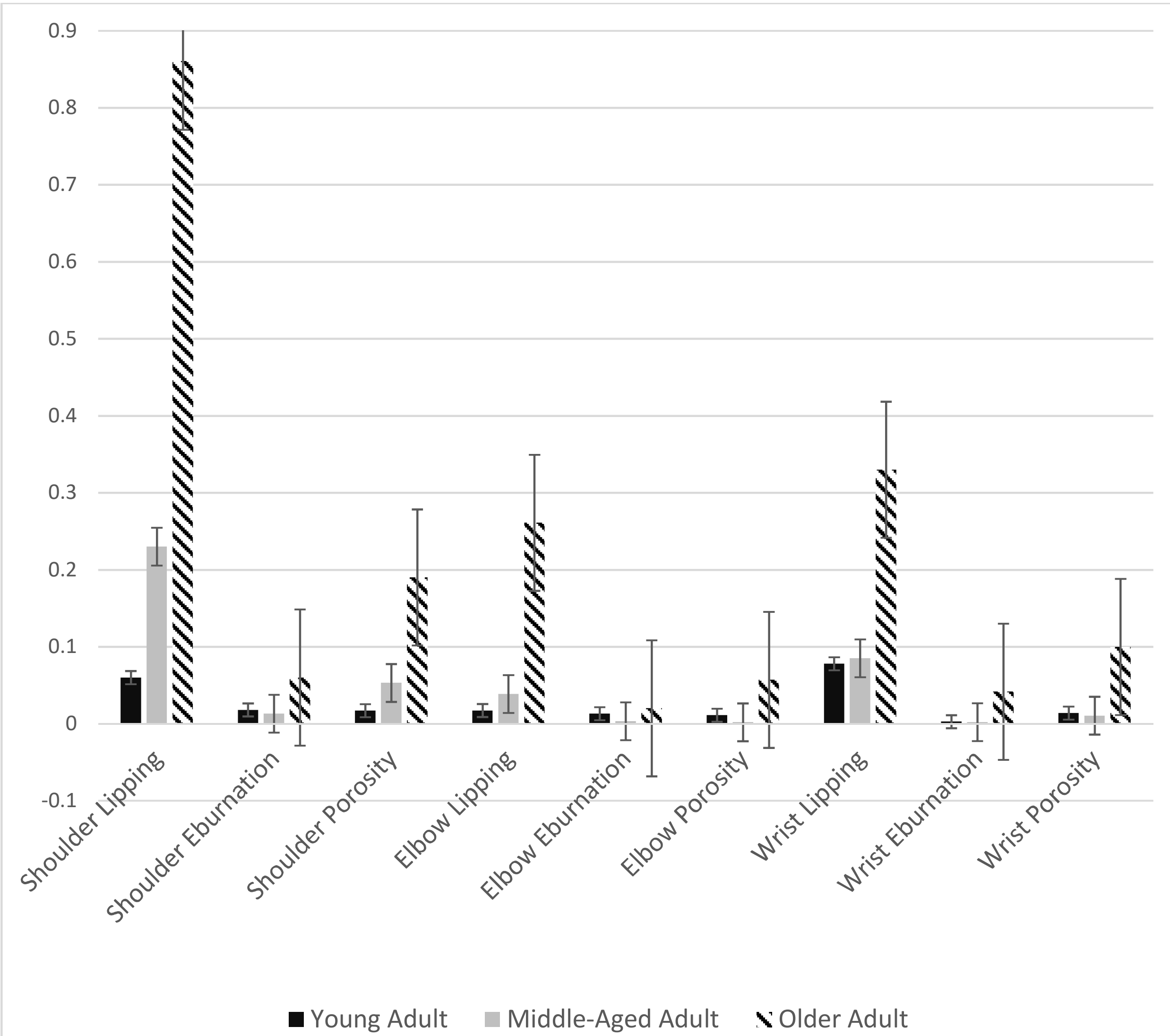

Figure 57: Least Squares Means for Age by Metric for Upper Limb Osteoarthritis

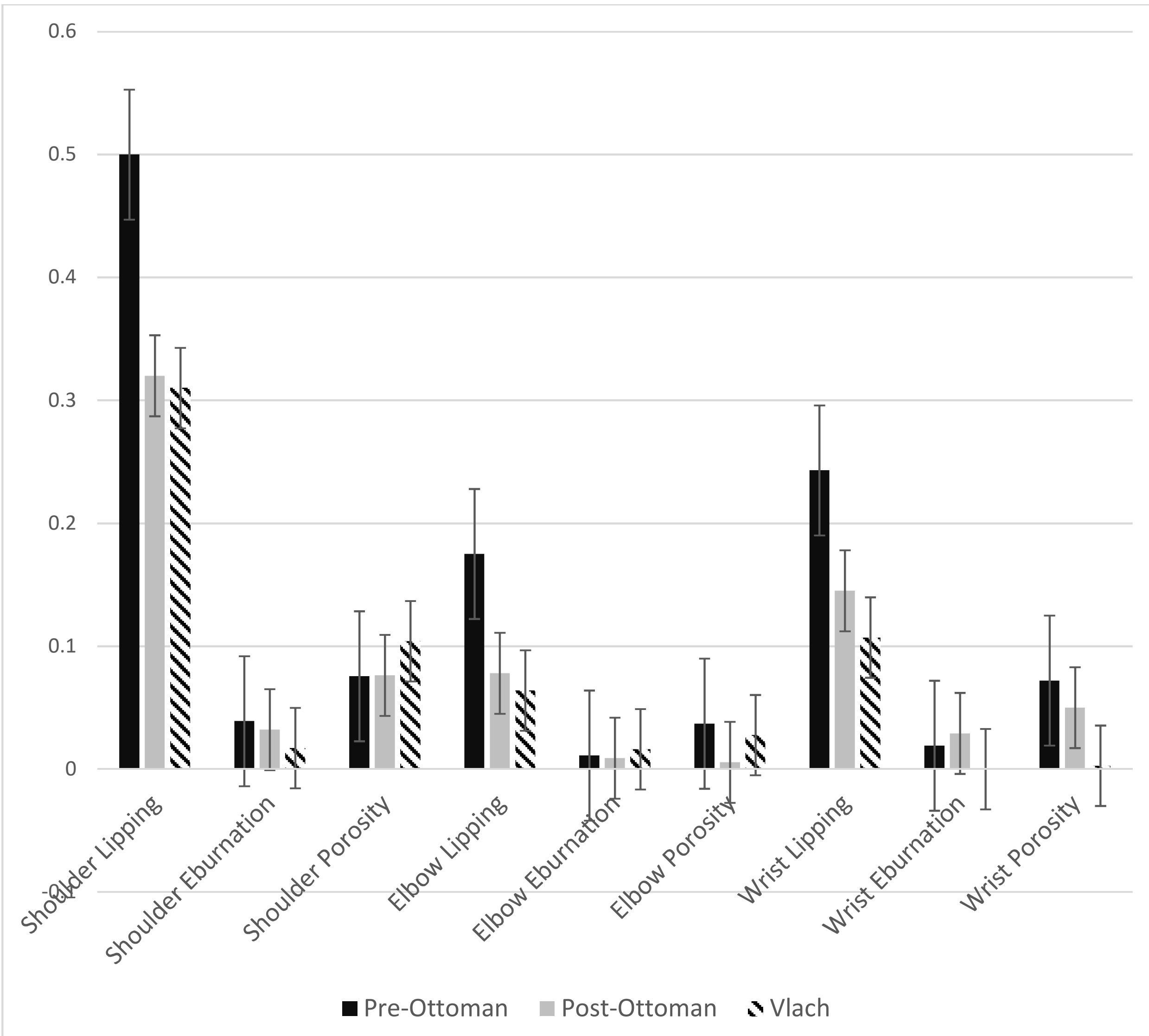

Figure 7: Least Squares Means for Period by Metric for Upper Limb Osteoarthritis

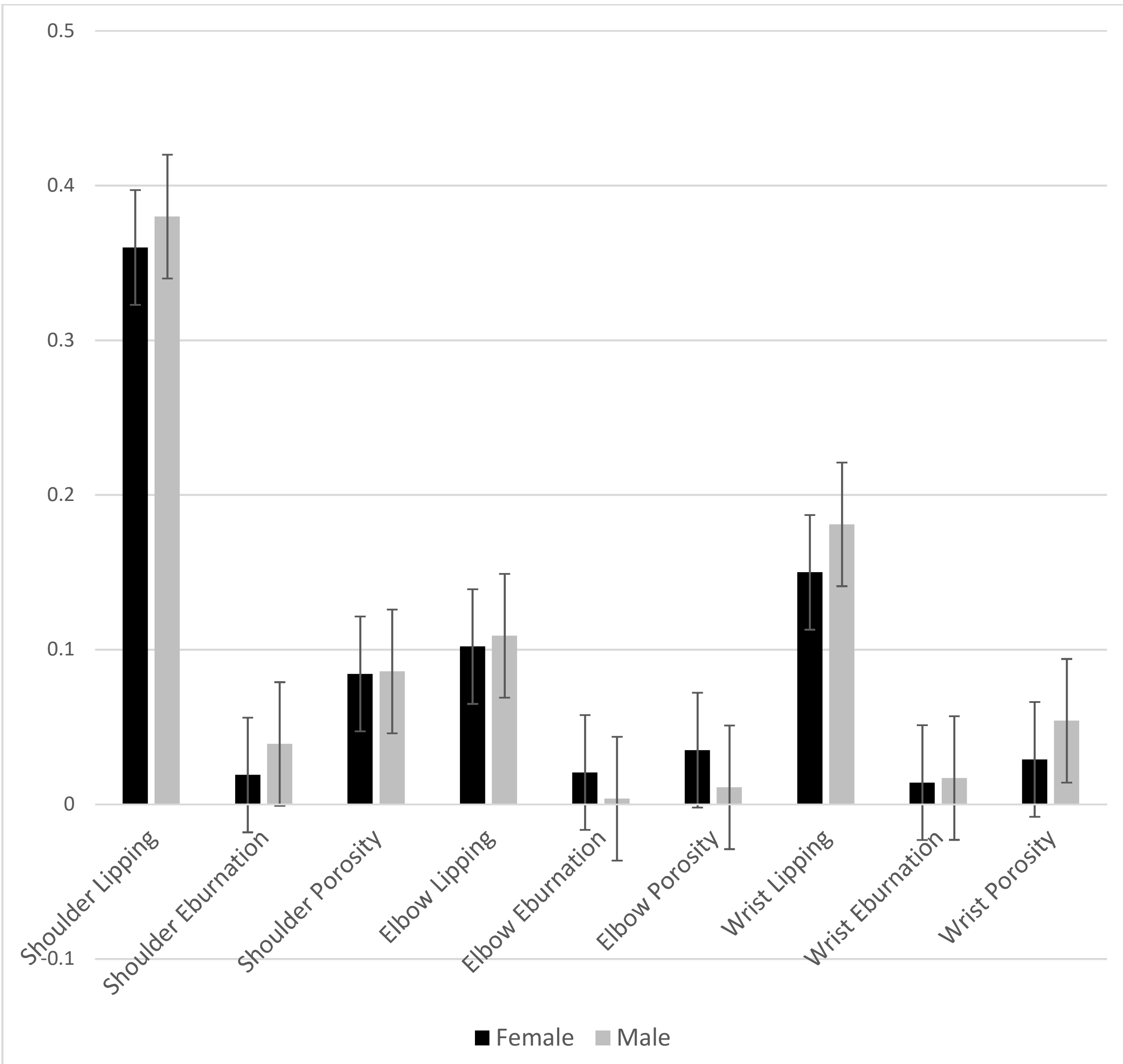

Figure 8: Least Squares Means for Sex by Metric for Upper Limb Osteoarthritis

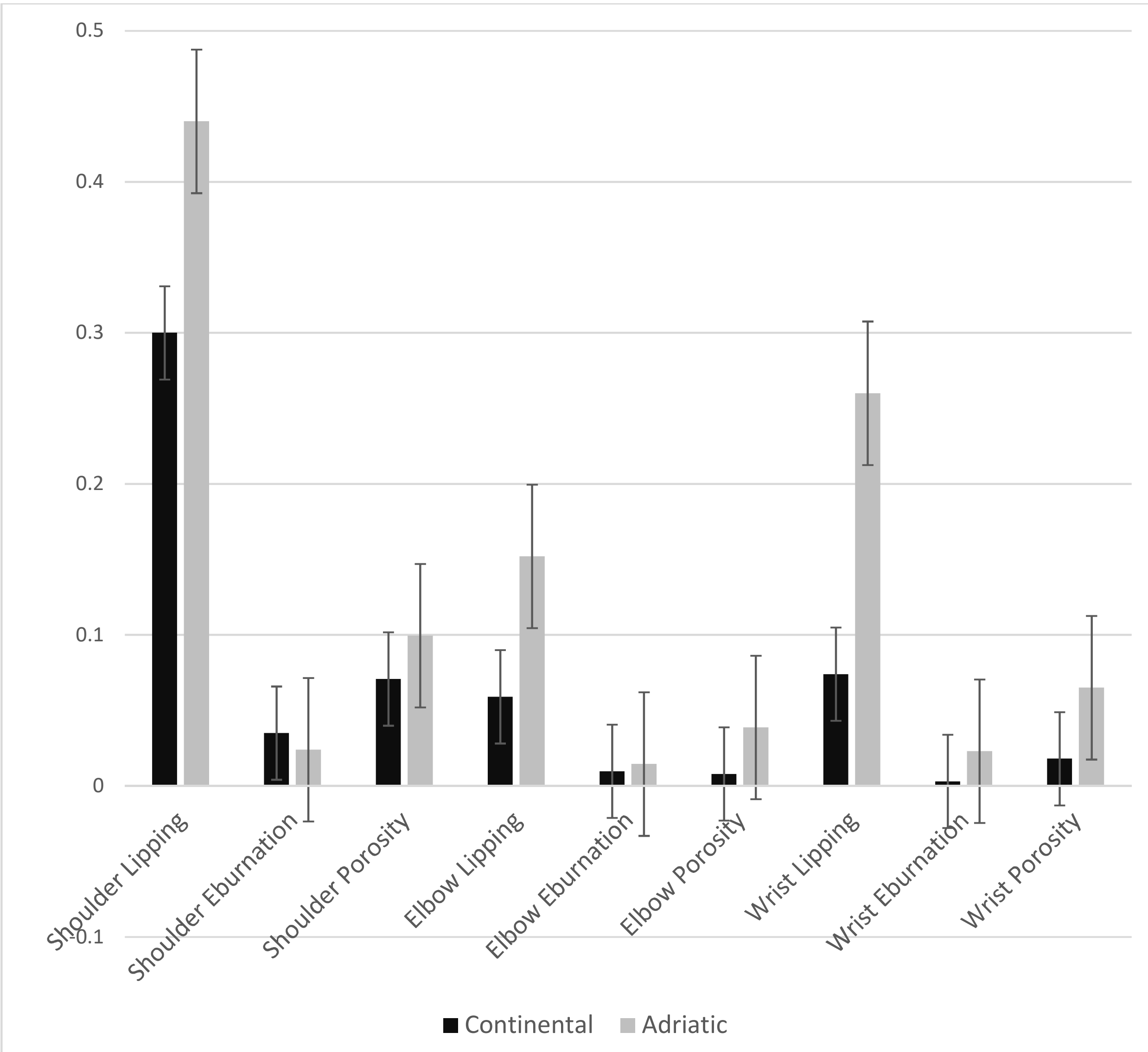

Figure 9: Least Squares Means for Region by Metric for Upper Limb Osteoarthritis

Discussion

The results indicating more severe osteoarthritis in the older populations are simple to interpret in the context of earlier studies, both bioarchaeological and clinical, that indicate osteoarthritis increases in severity over the course of an individual's life (Johnson & Hunter, 2014; Lawrence et al., 2008; Merbs, 2001; Weiss, 2005, 2006). The results imply that these populations in Croatia demonstrate similar patterns in age to other groups, which is expected. There is one exception to this; eburnation in the elbow was found to have the highest means in older adults, with younger adults having higher least squares means than middle-aged adults. However, this is anomalous. It is likely that the small sample sizes have skewed all of the eburnation results, as eburnation was extremely uncommon in the upper limb and spinal column of these populations.

While available historical and contemporary literature suggests that a sexual division of labor existed at these sites (Ivanišević, 1987; Muraj, 2004; Novak & Šlaus, 2011), the data here do not seem to mirror this difference between males and females. However, these metrics are generally considered to be a measure of general physical labor, and not any specific activity. The data therefore could imply that although a sexual division of labor would cause differential allocation of tasks between men and women, it is possible that these different tasks were similarly physically demanding and utilized the same parts of the body. This finding could mean that although a division of labor may have existed, it is not possible to discern this from the bioarchaeological record.

However, clinical research on sex and osteoarthritis may help clarify some of the lack of difference found here. There are anatomical differences that have been found to lead to higher rates of osteoarthritis in females than in males. Knee height is one of these; having a longer shin in conjunction with lower quadriceps strength may lead to higher rates of osteoarthritis (Hunter et al., 2005). Acetabular dysplasia, also found at higher rates in females than males, may also lead to higher rates of osteoarthritis in females (Reijman et al., 2005). Although these factors are hard to examine in skeletonized individuals, and the lower limb was not a part of this analysis, they bring to light that even the anatomy between men and women can skew the results of an analysis of osteoarthritis. It is thus possible that a sexual division of labor may have existed but was not detectable due to anatomical differences making women more predisposed to osteoarthritis.

Although slight, the differences found between Adriatic and continental populations could be attributed to different labor requirements of the Turks, as the Adriatic reason has higher means (0.26) than the continental region (0.07). Historical resources suggest that males in Koprivno in the Adriatic were forced to undergo public labor, or *kulluk*, while individuals in the continental region may not have been obligated to undertake this endeavor. This could have placed a higher burden on those in the Adriatic region, as they were tasked with reestablishing and maintaining important military fortresses within the region to fend off invaders (Mohorovičić, 2008). This only applies to wrist lipping, though, as no other measures were found to have higher means in the Adriatic or the continental region, and no other statistical significance was found between different regional groups.

The lack of statistically significant difference between time periods is of importance to this research. There is no statistically discernible difference between the Pre-Ottoman period, the Post-Ottoman period, or the Vlachs for most of the metrics. Historical records suggest that the Ottomans brought death and destruction to Croatia, caused a dramatic reduction in the population of the country, and forced the occupied populations into slave labor. One may expect to see a statistical difference between Pre-Ottoman and Post-Ottoman populations, given the historical context, especially if individuals were forced to undergo higher amounts of labor during Ottoman occupation. Additionally, considering the different levels of activity between the Vlachs and the agriculturalist neighbors, it might be reasonable to expect that even they would have higher rates of osteoarthritis than either population, but this is not the case. Although the means do vary, there is no statistically significant difference between any of the populations.

One explanation for the lack of distinction between the two time periods is that the intensity of labor may not have changed. The tools of the trade would not have changed, and arable land was still farmed, so individuals may not have changed jobs between these two time periods. Even under Ottoman rule people needed to eat, so it is possible that the people who remained did not change jobs and may not have worked any harder than they did before. Additionally, a lack of change in intensity may not necessarily mean that the activities themselves remained the same. The shift from serfdom to slavery may have brought about a shift from trades and farming to the production of munitions and the refurbishment of fortresses. Although some studies have tried to associate changes at specific joints with specific activities, it is more commonly thought that these metrics are measures of generalized activity. This means that it may not be possible to determine exactly what individuals are doing to cause osteoarthritis. Although intensity of work does not seem to have changed, it is possible that the socioeconomic shift brought about by invasion of the Ottoman Empire may have led to a change in occupation for many people, but that it is not possible to deduce this change from the bioarchaeological record if the intensity of work remained the same.

Additionally, other problems may muddy the waters with analysis such as this one. Clinical and biomechanical research has focused on defining osteoarthritis in living individuals, and this is an aspect of this work that we are unable to grasp fully with skeletal materials. For example, what is considered clinical osteoarthritis? Many individuals do not seek care, and thus are not diagnosed with osteoarthritis, until they begin to feel pain. The diagnosis of osteoarthritis is then done via radiograph and is frequently considered "bone on bone." Some bioarchaeological analyses have attempted to incorporate this (Schrader, 2012), by only classifying osteoarthritis by the presence of eburnation. Eburnation is polish and groove formation caused by the rubbing of bone on bone, and thus would have been diagnosed as "bone-on-bone" arthritis via radiograph in a living individual.

If this were the case, in this analysis, there certainly would not have been any differences found between any of the groups, as eburnation was not only rare, but the data lacked statistical significance between many of the groups. So not only would the presence and severity of osteoarthritis have remained homogenous between sexes, ages, regions, and time periods, but individuals by and large would have been considered to have not presented with osteoarthritis at all as eburnation was relatively rare. Although lipping and porosity are considered evidence of joint breakdown, or wear and tear, they may not be indicative of proper clinically-relevant osteoarthritis.

Conclusion

There seems to be a remarkable lack of variation between sexes, ages, regions, and time periods for the analysis of osteoarthritis. This could suggest a number of things. First, it could indicate that individual's livelihoods did not change dramatically with the invasion of the Ottoman empire. Although this conquest surely led to destruction of property, population disturbance, and mass evacuation of individuals, in the long term, life went on and those who remained continued on their same paths as before. Secondly, this could indicate that the Ottoman empire caused a change in everyday activity of individuals, but that these activities were practiced at the same intensity as before, and thus led to similar patterns of osteoarthrosis formation on the skeleton. At least with regards to osteoarthritis, which is a chronic problem that develops over the course of an individual's life, the invasion of the Ottoman Empire does not seem to have had a dramatic effect. And finally, it may suggest that osteoarthritis is not a good proxy for activity. Because there has been found to be a high degree of genetic contribution (Jonsson et al., 2003; Manek et al., 2003; Min et al., 2005; Spector & MacGregor, 2004; Zhai et al., 2004) and there are questions regarding the diagnosis of osteoarthritis the way it is presented on the skeleton, it may be a poor proxy for activity in the bioarchaeological record.

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CHAPTER 4. THE COMPARABILITY OF THE COIMBRA METHOD & HAWKEY AND MERBS METHOD FOR ENTHESEAL REMODELING

Introduction

Although theories elucidating the importance of the human body and its social context have been more readily adopted in bioarchaeology (Agarwal & Glencross, 2011; Nystrom, 2014; Schepartz, 2017; Sofaer, 2006; Torres-Rouff, 2003), studies incorporating specific analysis of the daily lives of individuals are rare (Gagnon, 2006; Wesp 2015). In particular, methods allowing for the analysis of entheseal remodeling have evolved drastically with in the last couple decades, with suggestion and presentation of a number of different methods (Hawkey & Merbs, 1995; Henderson et al., 2013, 2016, 2017; Mariotti et al., 2004, 2007; Robb, 1998; Villotte, 2006; Villotte et al., 2010a; Wilczak, 1998). The most commonly used methods for collecting entheseal remodeling data found in bioarchaeological literature are Hawkey and Merbs (1995) and Mariotti et al. (2004, 2007), although the method outlined by Henderson et al. (2013; 2016) is the most novel and extensive. The importance of comparison studies cannot be understated; despite this, there has not been a thorough comparison of different entheseal remodeling methodologies. Recent work by Palmer et al. (2019) has assessed the comparability of the Mariotti and Coimbra models; this has largely been the extent of previous work. This is a detriment to the field of activity studies, as these studies would allow for updating and adequate comparison of work using older methodologies. Additionally, because of the plethora of methodologies available to researchers, there is a high likelihood that standardization is unlikely, and researchers will continue using familiar or more popular scoring methods. These two reasons outline the importance of studies highlighting the differences and similarities, as well as the comparability, of entheseal scoring methods. If these different methods can be found to yield similar results, this facilitates comparison and increases the availability of data for regions and time periods.

The purpose of this paper is to compare results found using the Hawkey and Merbs (1995) entheseal remodeling method, and the Coimbra method (Henderson et al., 2013, 2016, 2017) to assess the comparability of the methods. The method of choice for bioarchaeologists analyzing entheseal remodeling has changed throughout the years, although Hawkey and Merbs has been one of the most popular, with adaptations appearing in numerous papers (Campanacho et al., 2012; Eshed et al., 2004; Lieverse et al., 2013; Molnar et al., 2011; Rodrigues, 2005; Schrader, 2012; Schrader & Buzon 2017; Weiss, 2007).

Entheseal Remodeling

Types of Entheses

There are two kinds of entheses that have been documented in both biomechanical and clinical literature: fibrocartilaginous and fibrous entheses. Fibrocartilaginous entheses occur with fibrocartilage and fibrous entheses are marked by dense fibrous connective tissue (Benjamin & McGonagle, 2001; Benjamin & Ralphs, 1997, 1998, 2000; Benjamin et al., 2002). Fibrous entheses have been largely ignored in biomechanical, clinical and even bioarchaeological literature, suggesting a bias against this type. This partiality may be due to the increased tendency for fibrocartilaginous entheses to exhibit overwork injuries. Additionally, a "normal" baseline for fibrous entheses has not been reliably established (Villotte et al., 2016). Fibrocartilaginous entheses are characterized by four histological zones, listed here in order layer from muscle to bone: (i) dense fibrous connective tissue, (ii) uncalcified fibrocartilage, (iii) calcified fibrocartilage, and (iv) bone (Benjamin & Ralphs, 1997, 1998). Zones 2 and 3 are separated by the tidemark, which is the calcification front. It has been suggested that these zones create a gradient that allow for balancing of the elastic moduli between bone and tendon (Knese & Biermann, 1958) by gradually moving from soft tissue to fully ossified bone.

An unmodified fibrocartilaginous enthesis is defined as an enthesis where: "…the tidemark is relatively straight and the fibrocartilage zones avascular, the site of attachment in a healthy enthesis is smooth, well circumscribed, and devoid of vascular foramina' (Benjamin et al., 2002:939). This description fits relatively well with what is seen on the skeleton. A typical enthesis on dry bone exhibits no soft tissue and is characterized by a regular margin, no vascular foramina, and a well-defined imprint (Villotte, 2006, 2009; Villotte et al., 2010a). A modified enthesis will exhibit erosion of calcified fibrocartilage and subchondral bone, tidemark modification, vascularization of the fibrocartilage (pitting and porosity), calcification and ossification of soft tissues (enthesopathies), and avulsions (Villotte, 2006, 2009; Villotte et al., 2010a, 2010b).

Materials

A total of 7 skeletal collections from Croatia were used in this study; 317 for the Hawkey and Merbs analysis (Table 11), and 330 for the Coimbra analysis (Table 1). The chosen sites are from both the continental and Adriatic regions of the country, due to these two areas being differentially affected by Ottoman invasion. sites fall on both sides of the Ottoman invasion (Figure 1); some are within the Late Medieval Period (11th century C.E. – 15th century C.E.) and the others are dated to the Early Modern Period (15th century C.E. – 18th century C.E.). These materials are curated at the Croatian Academy of Sciences and Arts in Zagreb, Croatia. Individuals were excluded if they were missing sex, age, or body size estimates. This is because controlling for complicating factors is essential in an analysis using entheseal change as a proxy for activity. Additionally, individuals were excluded if they were missing greater than 50% of their entheses. Finally, individuals were categorized into three different body size groups. These are highlighted in Table 12.

Table 11: Collections Used in Hawkey and Merbs Entheseal Remodeling Analysis

Site Name	Period	Date (C.E.)	Region	Number of Individuals
Stenjevec	Pre-Ottoman	11th - 13th	Continental	76
Šibenik-Sv.Lovre	Pre-Ottoman	10th - 13th	Adriatic	48
			Pre-Ottoman Total = 124	
Dugopolje	Post-Ottoman	13th - 16th	Adriatic	96
Nova Rača	Post-Ottoman	14th - 16th	Continental	17
			Post-Ottoman Total = 113	
Koprivno-Križ	Vlach	16th - 18th	Adriatic	59
Šarić Struga	Vlach	16th - 17th	Adriatic	7
Drinovci-Greblje	Vlach	16th	Adriatic	14
			Vlach = 80	
			Total = 317	

Table 12: Body Size Distribution for Entheseal Remodeling (Hawkey & Merbs) Analysis

Size Category	Lower Limb Frequency	Upper Limb Frequency
Small	60	72
Medium	169	185
Large	88	60

Methods

For this study, a total of 10 different entheses, all of which were fibrocartilaginous attachment sites, were examined in the upper limb because this is the portion of the body primarily involved in more labor-intensive activities. Although the Hawkey and Merbs (1995) method does not make the distinction between fibrocartilaginous and fibrous entheses, the Coimbra method (Henderson et al., 2013, 2016) was specifically developed for the analysis of fibrocartilaginous entheses, and thus they are the only used in this study. The fibrocartilaginous entheses that were used in this analysis are listed with more detail in Table 3. They include the supraspinatus, infraspinatus, subscapularis, and teres minor, which make up the rotator cuff. These serve to support and move the shoulder joint. Additionally, the triceps brachii, biceps brachii, extensors, flexors, brachialis, and brachioradialis were also used. The functions of these various muscles are also included in Table 3.

Two methods were employed for the analysis of entheseal remodeling: The Hawkey and Merbs (1995) scoring system (Table 13), and the Coimbra Method (Henderson et al., 2013, 2016, 2017) (Table 4). Hawkey and Merbs' method scores entheses from 0-6. On the scale, 0-3 refers to the robusticity of the enthesis (0 – not present, 1 – faint, 2 – moderate) and 4-6 refers to the formation of lesions (4 – faint, 5 – moderate, 6 – strong). There is a third variable, ossification, that is to be analyzed separately from the other two. There are newer entheseal remodeling methods (Cardoso & Henderson, 2010; Havelková et al., 2010; Henderson et al., 2013, 2016, 2017; Mariotti et al., 2004, 2007; Villotte, 2006; Villotte et al., 2010A). These methods are considerate of many different aspects of entheseal morphology and reflect improvements in our understanding of the anatomy and physiology of entheses, and their changes over time. However, the Hawkey and Merbs' method was chosen because of its comparability. Many studies prior to this have used Hawkey and Merbs', thus this method was deemed more useful for comparing this work to other previous studies.

Table 13: Details of the Hawkey and Merbs (1995) Scoring System

Metric	Score	Description	Overall Score (Robusticity and Stress Lesion Only)
Robusticity	0	Absent	0
	1	Faint; slight, but not well-defined	1
	2	Moderate; uneven surface, but no crests or ridges	2
	3	Strong; distinct, sharp crests	3
Stress Lesion	1	Faint; shallow furrow, <1 mm in depth	4
	2	Moderate; deeper pitting, >1 mm in depth but <3 mm, <5 mm in length	5
	3	Strong; >3 mm in depth and/or >5 mm in length	6
Ossification	1	Faint; slight exostosis, extends <2 mm from surface	X
	2	Moderate; distinct exostosis, >2 mm extension	X
	3	Strong; exostosis extends >5 mm from surface	X

The other method that was employed, the Coimbra Method, was developed out of a workshop held in Coimbra, Portugal, in 2009 (Santos et al., 2011). This method attempts to take into consideration not only the anatomy and physiology of entheses, but also the variation commonly seen at them (Henderson et al., 2013, 2016, 2017). This method divides the entheses into two zones. Zone 1 is the “margin of the enthesis at which fibers attach most obliquely to the bone” (F Zone 2 includes the footprint of the enthesis. From there, different features will be examined in each of the zones. From Zone 1, observers will examine bone formation and erosion. On Zone 2, textural change, bone formation, erosion, fine porosity, macro porosity, and cavitation will be examined. This method was chosen not only for its novelty, but because the developers have incorporated new knowledge of the anatomy and physiology of entheses and their associated changes from biomechanical and clinical literature. Additionally, after publication of the original paper, a revision followed in which the authors addressed issues with interobserver error and repeatability, as well as more clearly defined the different features that are to be examined (Henderson et al., 2016).

Sex and Age

Sex and age data were collected using methods outlined in Buikstra and Ubelaker (1994). Only adults were chosen for this study, so age was assessed using changes on the auricular surface (Bedford et al., 1989; Lovejoy et al., 1985; Meindl et al., 1985), pubic symphysis (Brooks & Suchey, 1990; Katz & Suchey, 1986), and if necessary, dental wear patterns and cranial suture closures (using a method compiled by Buikstra and Ubelaker, 1994, from Baker (1984), Mann et al., (1987), Meindl et al., (1985), and Todd and Lyon (1924; 1925a; 1925b; 1925c)). Material was grouped into young adults (18-29 years), middle adults (30-45 years), and old adults (46+ years). Data from commingled remains were not included. Because there are so many associations with entheseal remodeling and age (Cardoso & Henderson, 2010; Hawkey & Merbs, 1995; Weiss, 2003; Zumwalt, 2006), sex (Villotte et al., 2010; Weiss et al., 2012), and body size (Hamrick et al., 2000; Montgomery et al., 2005), it was deemed important for the individuals used within this study to have estimable measures for all three.

Body Size

Previous studies on entheseal remodeling have found males to have higher scores for entheseal changes (Elkasrawy & Hamrick, 2010). This is usually attributed to differences in amount of physical activity (Chapman, 1997; Peterson, 1998), although this seems to ignore the sexual dimorphism seen between males and females regarding strength, overall size, and muscle mass. Elkasrawy and Hamrick (2010) suggest that this may be due to tendon fiber volume rather than the actual tensile stress experienced by the enthesis. Statistical analysis can be used to alleviate some of the issues dealing with body size. Weiss (2003, 2004, 2007) outlined methods to standardize body size to allow for a more thorough analysis. Body size was examined by calculating z scores based on humeral and femoral measurements outlined by Weiss (2003, 2004, 2007). Maximum length, maximum head diameter, and epicondylar breadth were collected from all burials used in this analysis per Buikstra and Ubelaker (1994). Z scores were summed to form an aggregate upper body and lower body score. Sides were compared via Pearson's correlation and found to be not statistically different. Therefore, the sides were averaged, creating a composite score of the overall individual. Finally, these scores were binned into small, medium, and large categories. Cutoffs are summarized in Table 14 and were calculated differently for males and females to account for differences in body size ranges.

Table 14: Bin Limits for Analysis Including Body Size

Limb Limits & Associated Sexes	Small	Medium	Large
Lower Limb Limits: Females	<-0.913	>-0.913, <0.093	>0.093
Upper Limb Limits: Females	<-0.816	>-0.816, <0.266	>0.266
Lower Limb Limits: Males	<-0.419	>-0.419, <0.809	>0.809
Upper Limb Limits: Females	<-0.196	>-0.196, <0.961	>0.961

Statistical Analysis

Neither method outlines a suggested way in which to analyze the data statistically. Most papers using these methods have used nonparametric statistics, such as Spearman's rank correlation coefficient, which tests the relationship between two ranked variables, or the Wilcoxon signed rank test, which tests the statistical relationship between two samples. These types of tests have been chosen historically due to the zero-heavy and non-normally distributed nature of the data. Comparability of the methods was assessed by testing the similarity and correlation between their individual results. Scores recorded via these methods were averaged, giving each individual an average score for left and right sides at each enthesis. This was to alleviate issues with the potential differences between summed composites, where scores for individuals using Hawkey and Merbs (1995) could be calculated between 0 and 6, and scores with Coimbra could fall between 0 and 18. Not all demographic data was present for all individuals; thus, individuals with any missing sex, age, or body size estimates and/or those individuals who are missing more than half of their entheses measurements were excluded from study.

For each method separately, correlation estimates were gathered using SAS 9.4 between the left and right-side using a Pearson correlation, which tests for a statistically significant relationship between two variables. Bioarchaeological data is frequently heavy on zero values due to the nature of the methods and data sets. The data set used here was no different, thus a zero-inflated gamma model, which is a type of multiple linear regression, was used to analyze each of the Coimbra and Hawkey and Merbs data sets independently. This test allows for the detection of relationships between an independent variable and one or more dependent variables (Nathans et al., 2012). The independent variables are sex, age, region, time period, and body size, and the entheseal remodeling data are the dependent variables. These results for each method were then compared to one another using an additional Pearson's correlation. This serves to detect the possible presence of a correlation between the results of one method with another. The α for all tests was set at 0.05.

Results

Left and Right Side Within Methods

With each method evaluated separately, the left and right sides were found to correlate with one another. There were a small number of entheses that did not have a correlation between the right and left side for the Hawkey and Merbs method (Table 47), although for ease of study a composite variable of the averaged sides was calculated and used for the rest of the analyses.

This was probably due the responses being split up into three variables, two of which were continuous with one another. This problem is exacerbated in the Coimbra method, where the responses are even further delineated and there are more discrepancies between the left and right side.

Left and Right Side Between Methods

Pearson's correlation test revealed a positive correlation in scores between the two methods ($p<0.0001$). Because the results for comparisons between left and right side within methods, and left and right side between methods, were both found to be highly correlated, composite variables were calculated for each method. These newly calculated composite variables were used to find sex and age results between methods.

Sex Results

In general, a relationship between entheseal score and sex was found to be not statistically significant using the Coimbra method. This stands for all of the entheses except for the biceps brachii, the infraspinatus, and the flexors; males were found to have higher least squares means for the infraspinatus and biceps brachii, and females had higher least squares means for the flexors. Hawkey and Merbs results were nearly the same, with a similar lack of distinction between males and females. There were a couple notable exceptions to this; this method did detect a difference between males and females regarding the robusticity and stress lesion variable for the supraspinatus, infraspinatus, extensors, and the ossification variable for the flexors. For all four of those entheses females had higher least squares means than males. This means that these two methods were similar enough to detect differences in the same entheses in two of the cases, although the sex with the higher least squares means was switched for the infraspinatus.

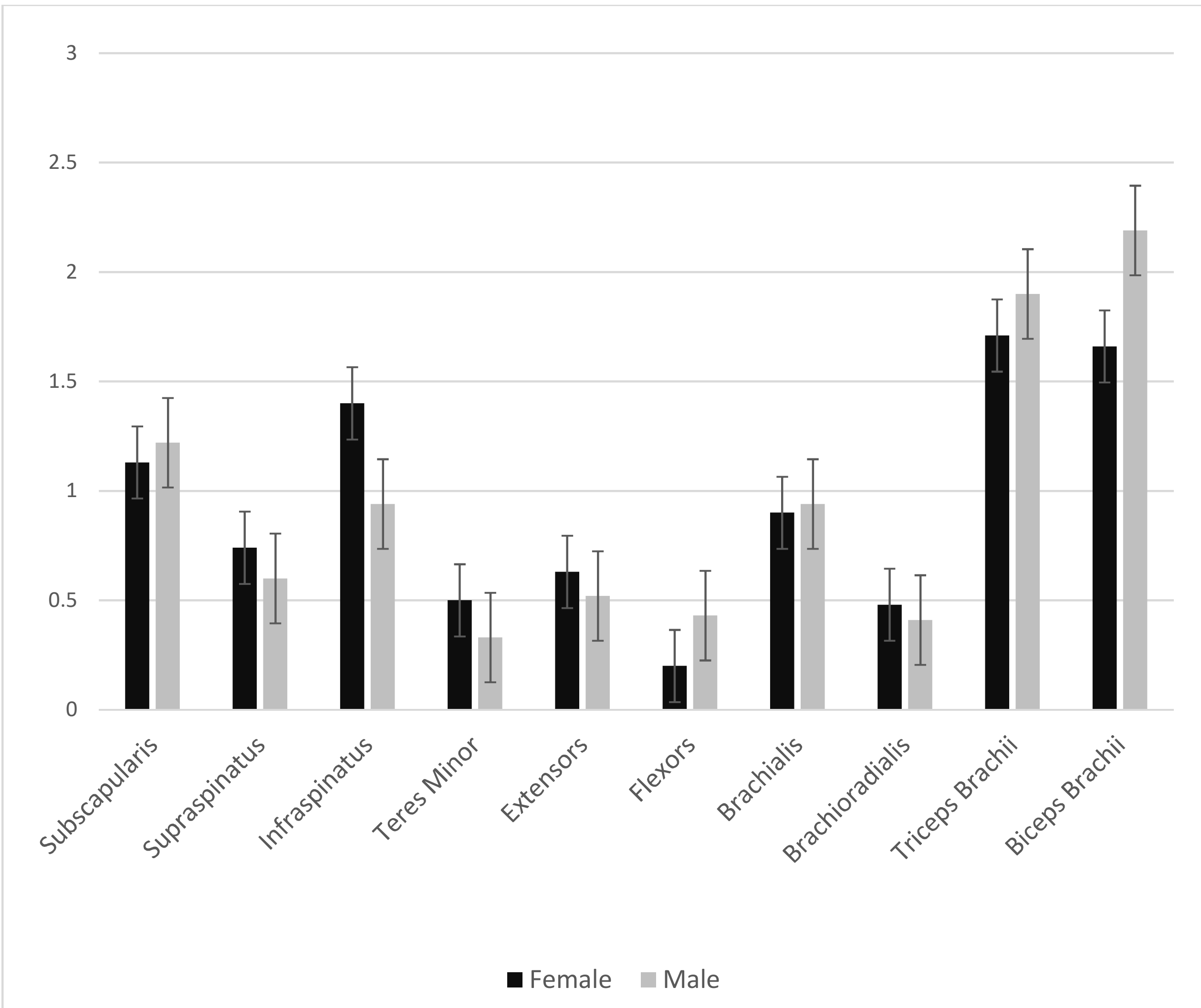

Figure 10: Least Squares Means for Sex by Enthesis Using the Coimbra Method

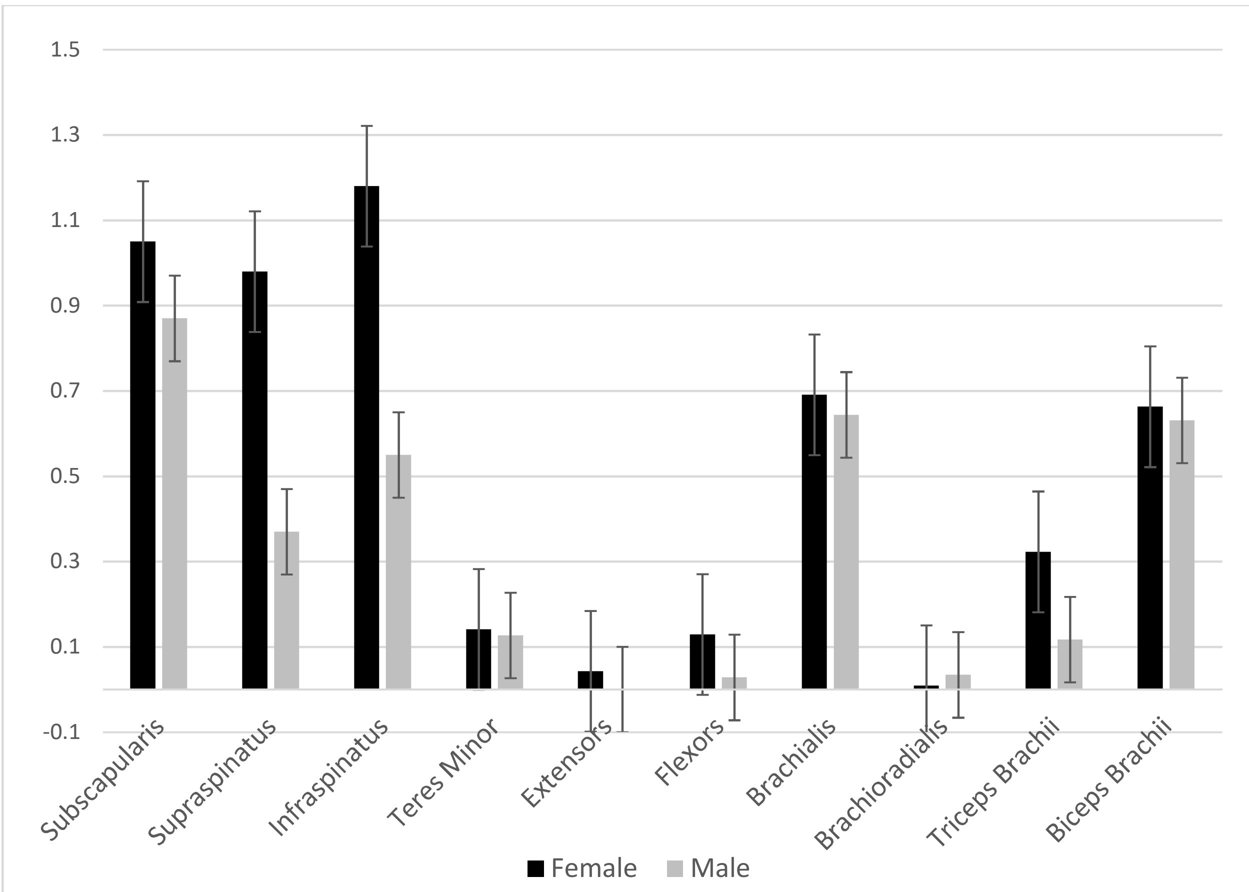

Figure 11: Least Squares Means for Sex by Enthesis Using the Hawkey & Merbs Method - Robusticity/Stress Lesion Variable

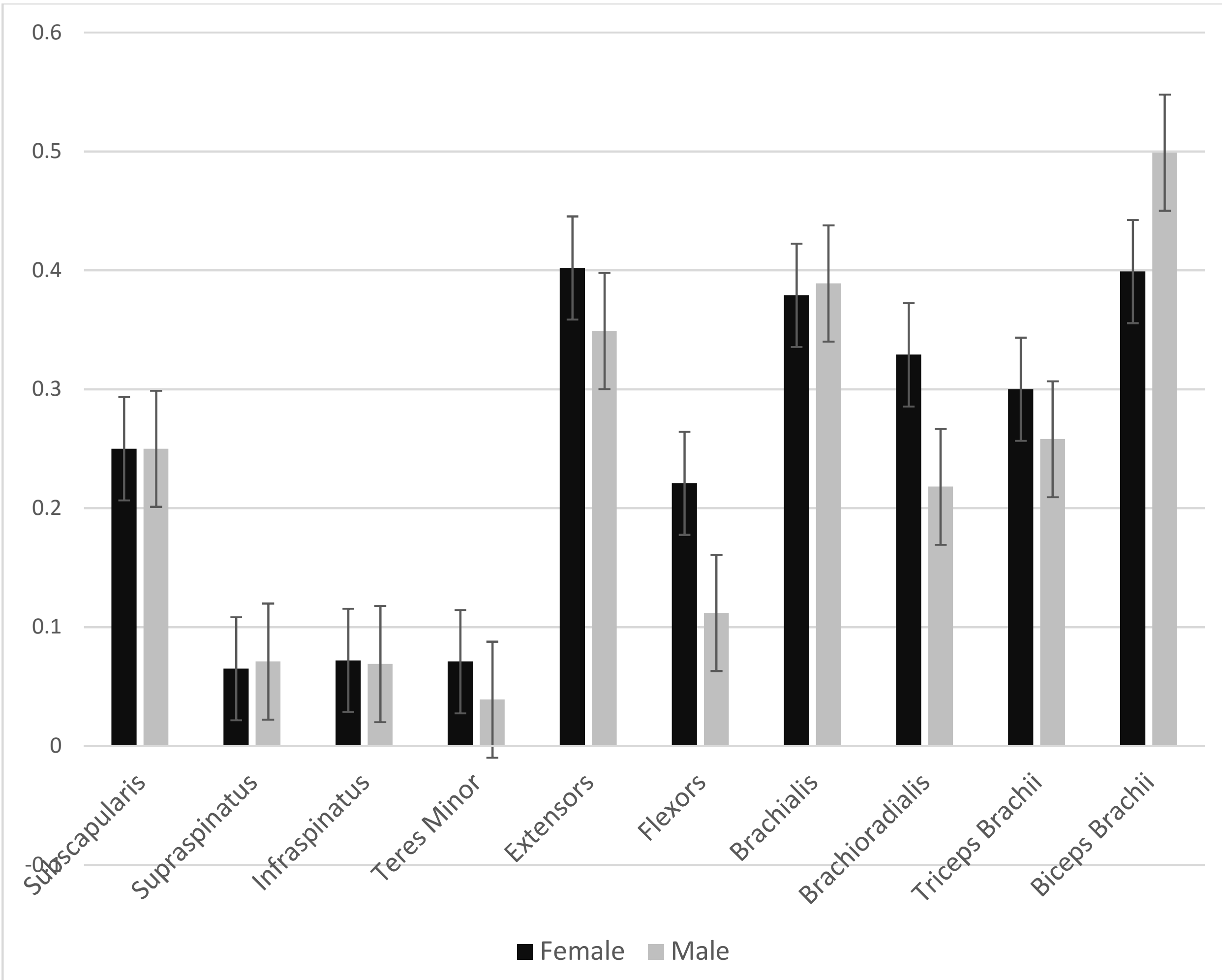

Figure 12: Least Squares Means for Sex by Enthesis Using the Hawkey & Merbs Method - Ossification Variable

Age Results

The Coimbra method revealed statistically-significant differences primarily between older adults and middle-aged adults, and older adults and younger adults, for all entheses (Tables 26 – 45). No muscle attachment showed significant differences between middle-aged adults and younger adults except for the biceps brachii. Hawkey and Merbs' results were also consistent, although slightly less than the Coimbra method (Tables 48 – 87). Six of the twenty comparisons had no statistically discernible difference between the three different age groups; these were not specific to either the robusticity and stress lesion variable, or the ossification variable. Ten of the twenty comparisons showed a statistically significant difference between the older and middle-aged adults and younger and older adults. This method detected the same patterning that the Coimbra method did, with younger individuals having the lowest scores, middle-aged individuals having the middle scores, and older individuals having the highest scores, in general. These results seem to indicate that while the Hawkey and Merbs method is still sensitive enough to detect similar statistical differences in age groups, there is still some discrepancy in what the two methods are able to find with the data.

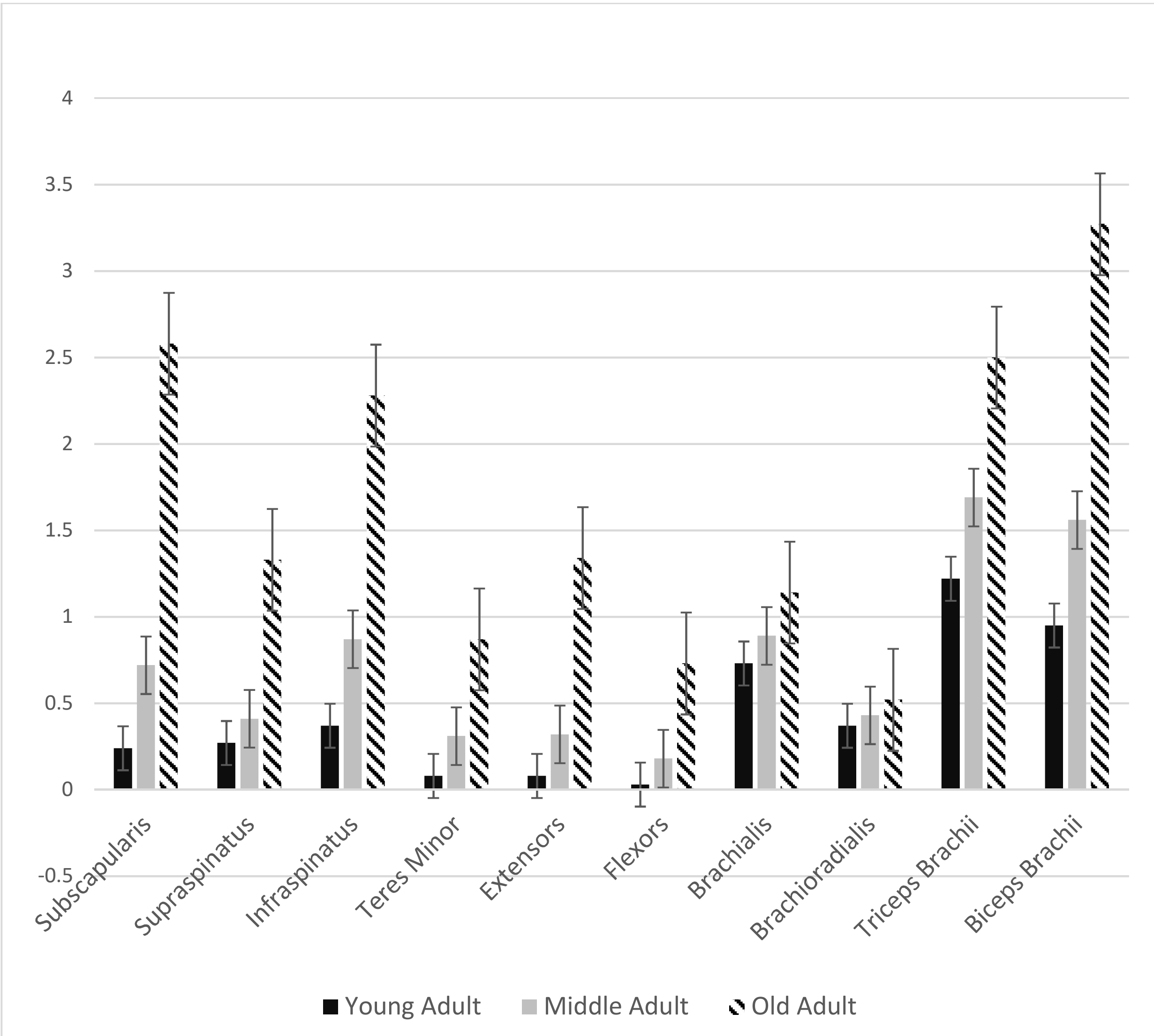

Figure 13: Least Squares Means for Age by Enthesis Using the Coimbra Method

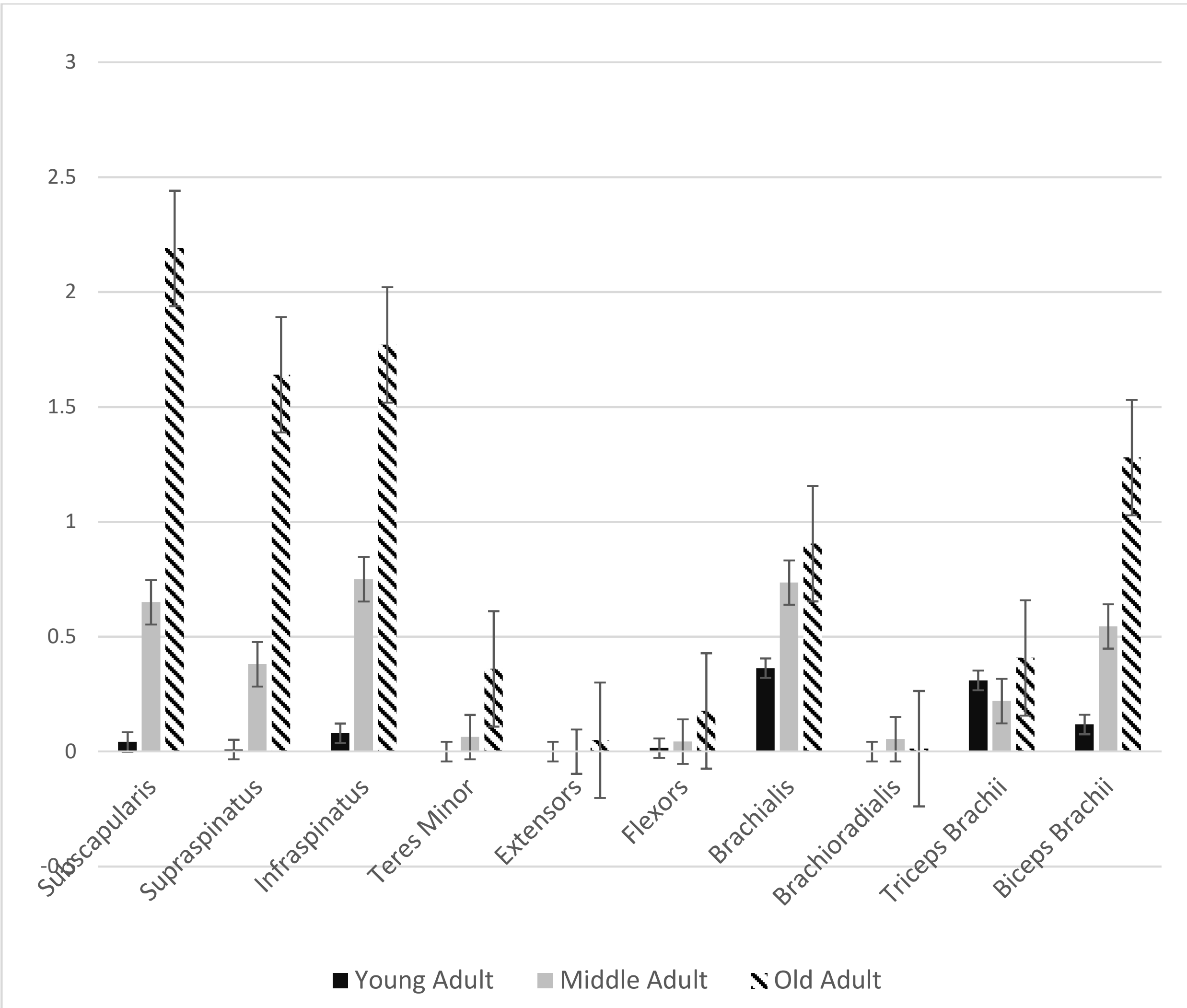

Figure 14: Least Squares Means for Age by Enthesis Using the Hawkey & Merbs Method - Robusticity/Stress Lesion Variable

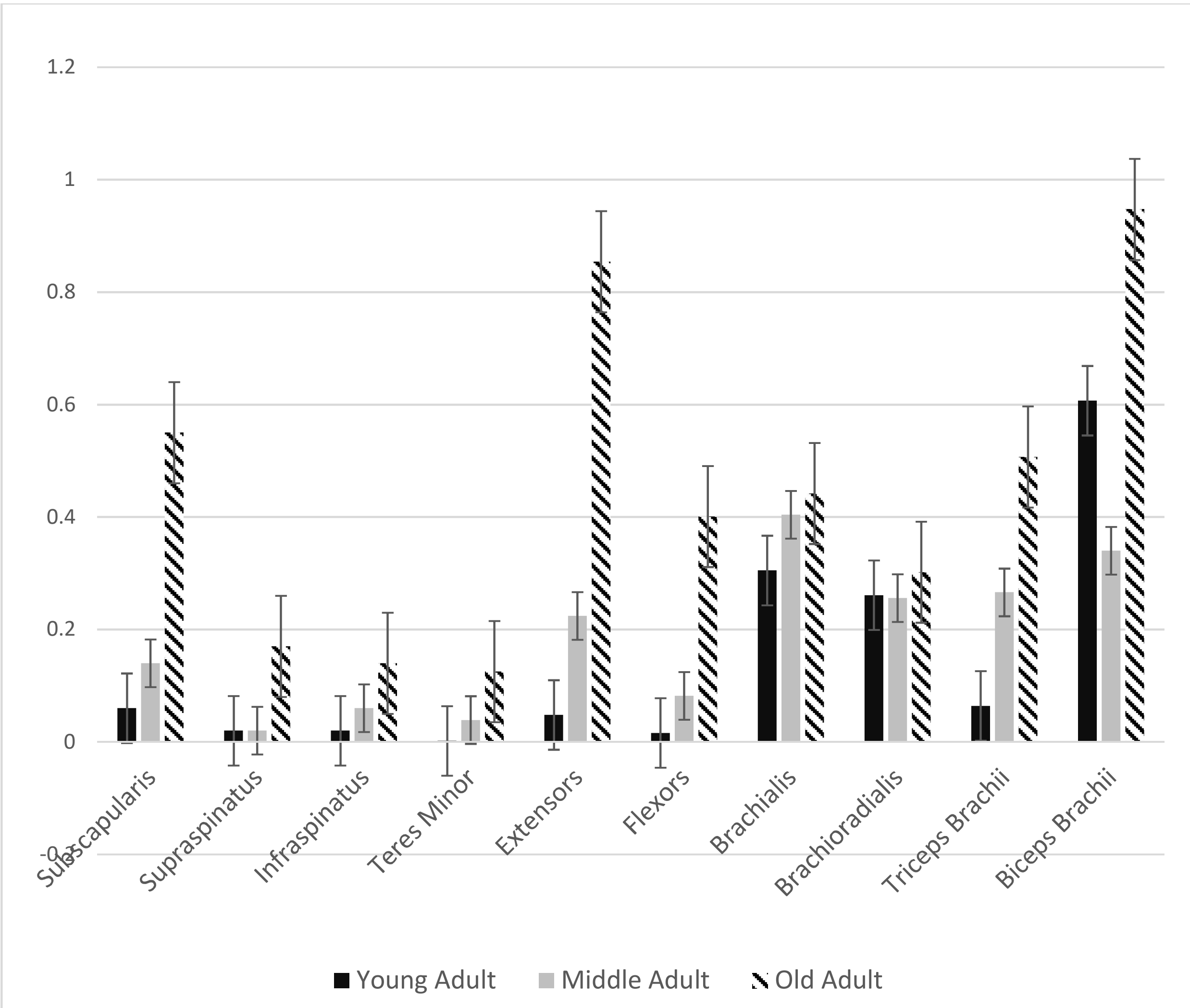

Figure 15: Least Squares Means for Age by Enthesis Using the Hawkey & Merbs Method - Ossification Variable

Pre/Post-Ottoman Significance – Coimbra Method

For the subscapularis (Table 27), the only statistically significant difference found was between the different groups is between the Post-Ottoman (μ=1.48) and Vlachs (μ=0.78) (p=0.0140). The supraspinatus (Table 29) revealed statistically significant differences were found between the Post-Ottoman (μ=0.58) and Vlach (μ=1.06) periods (p=0.0137) and the Vlach (μ=1.06) and Pre-Ottoman (μ=0.38) periods (p=0.0015). The only periods that were found to be statistically significantly different in the infraspinatus (Table 31) were between the Pre-Ottoman (μ=0.70) and Vlach (μ=1.67) groups (p=0.0008). The teres minor (Table 33) had significant differences between the Post-Ottoman (μ=0.55) and Pre-Ottoman (μ=0.12) groups (p=0.0030) and Pre-Ottoman (μ=0.12) and Vlach (μ=0.59) groups (p=0.0037).

Neither the extensors (Table 35) nor the flexors (Table 37) had any statistical significance between different groups. For the triceps brachii (Table 39), there were differences found in between the Post-Ottoman (μ=2.27) and Pre-Ottoman (μ=1.41) groups (p=0.0004) and the Post-Ottoman (μ=2.27) and Vlach (μ=1.72) periods (p=0.0394). The bices brachii (Table 43) revealed no statistically significant differences between any group. The final two muscles, the brachialis (Table 41) and the brachioradialis (Table 45), had differences between the Pre-Ottoman (μ=0.47) and Post-Ottoman (μ=0.94) (p=0.0006), Post-Ottoman (μ=0.94) and Vlach (μ=1.35) (p=0.0032), Pre-Ottoman (μ=0.47) and Vlach (μ=1.35) (p=<0.0001), and the Post-Ottoman (μ=0.59) and Pre-Ottoman (μ=0.17) (p=0.0003) and Pre-Ottoman (μ=0.17) and Vlach (μ=0.59) groups (p=0.0004), respectively.

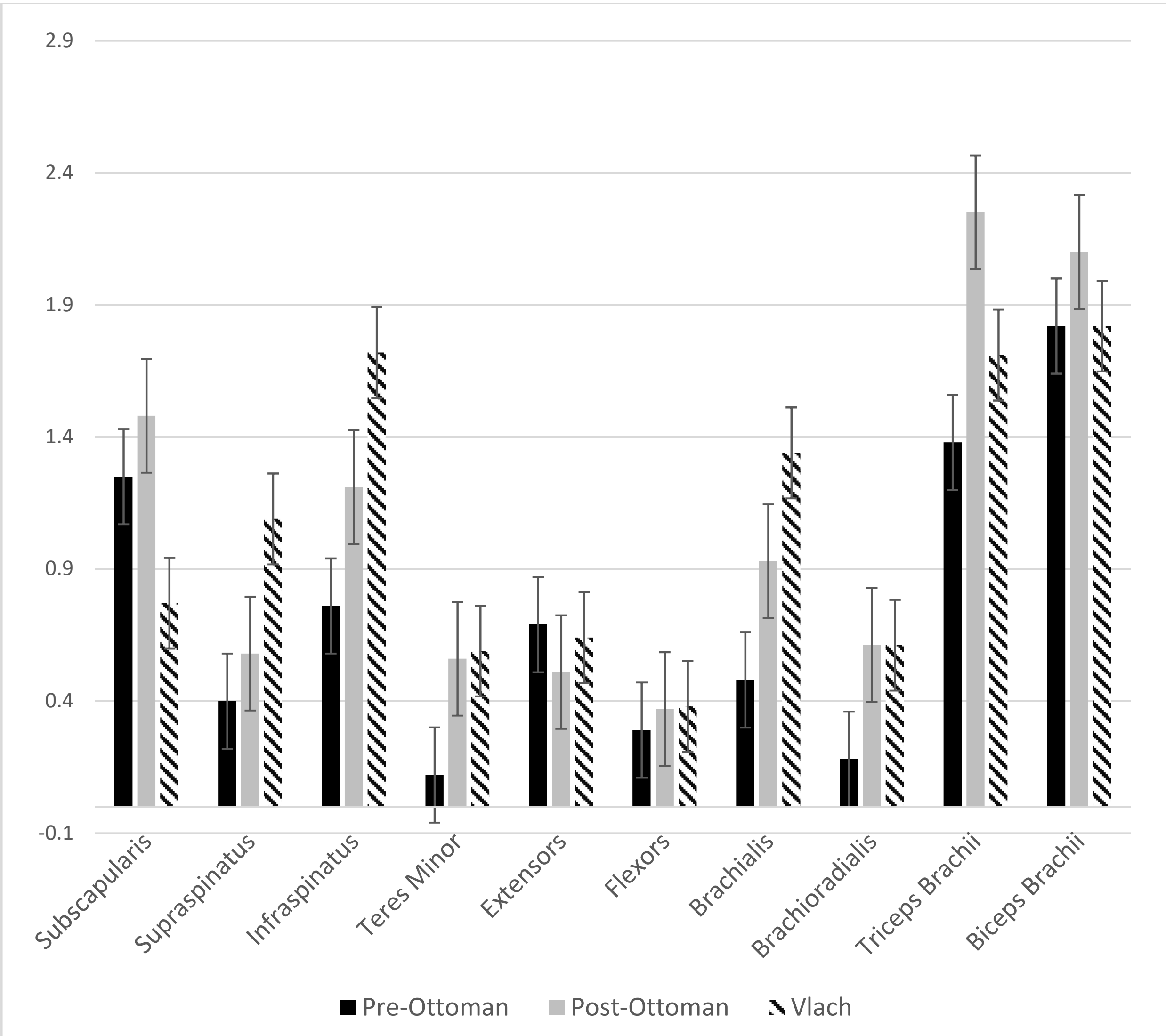

Figure 16: Least Squares Means for Group by Enthesis Using the Coimbra Method

Pre/Post-Ottoman Significance – Hawkey and Merbs

Hawkey and Merbs revealed a statistically significant difference in the robusticity/stress lesion variable for the subscapularis (Table 49) between the Post-Ottoman (μ=1.30) and Pre-Ottoman (μ=0.40) (p=0.0028) groups and Pre-Ottoman (μ=0.40) and Vlach (μ=1.18) (p=0.0275) groups. The ossification variable for the supraspinatus (Table 55) was found to be statistically significant between the Post-Ottoman (μ=0.13) and Pre-Ottoman (μ=0.036) groups (p=0.0291). The ossification variable for the extensors (Table 67) reveals a statistical significance between the Post-Ottoman (μ=0.27) and the Pre-Ottoman (μ=0.51) (p=0.0172). The robusticity/stress lesion variable for the triceps brachii (Table 73) has one statistically significant comparison; much like the others, the Post-Ottoman (μ=0.41) and Pre-Ottoman (μ=0.10) groups are found to be statistically significantly different (p=0.0295). The brachialis robusticity/stress lesion variable (Table 77) had statistical significance between one of the three groups; the Post-Ottoman (μ=0.40) and Vlach (μ=0.96) groups (p=<0.0001) were found to be statistically significantly different from one another. Ossification of the brachialis (Table 79) has one statistically significant comparison between the Pre-Ottoman (μ=0.25) and Vlach (μ=0.53) groups (p=0.0031). Despite these incidences of statistical significance, many of the variables showed no statistical difference between any of the three comparison groups for this study. This includes the robusticity/stress lesion variable for the infraspinatus and extensors, and both variables for the teres minor, flexors, brachioradialis, and biceps brachii.

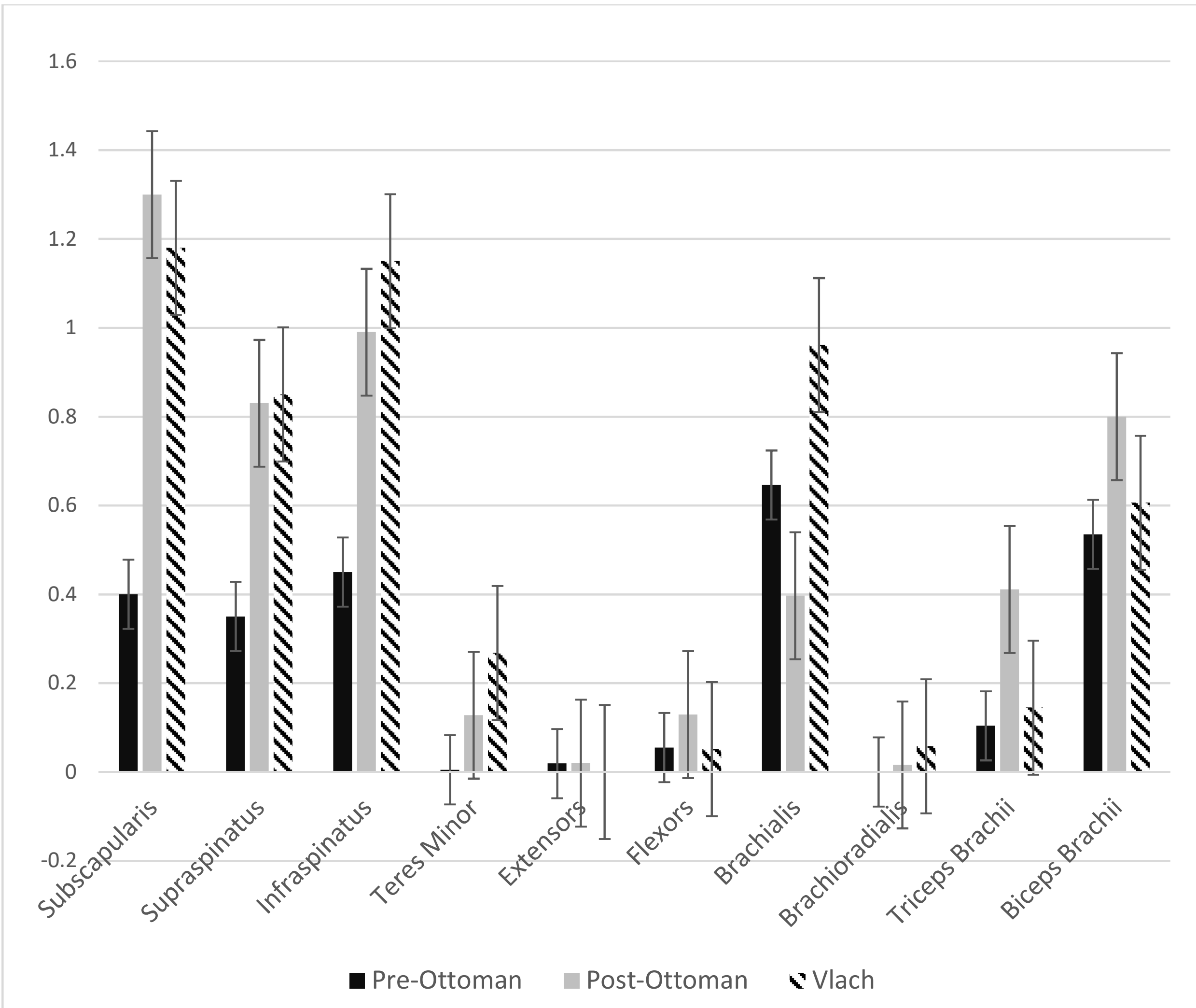

Figure 17: Least Squares Means for Group by Enthesis Using the Hawkey & Merbs Method - Robusticity/Stress Lesion Variable

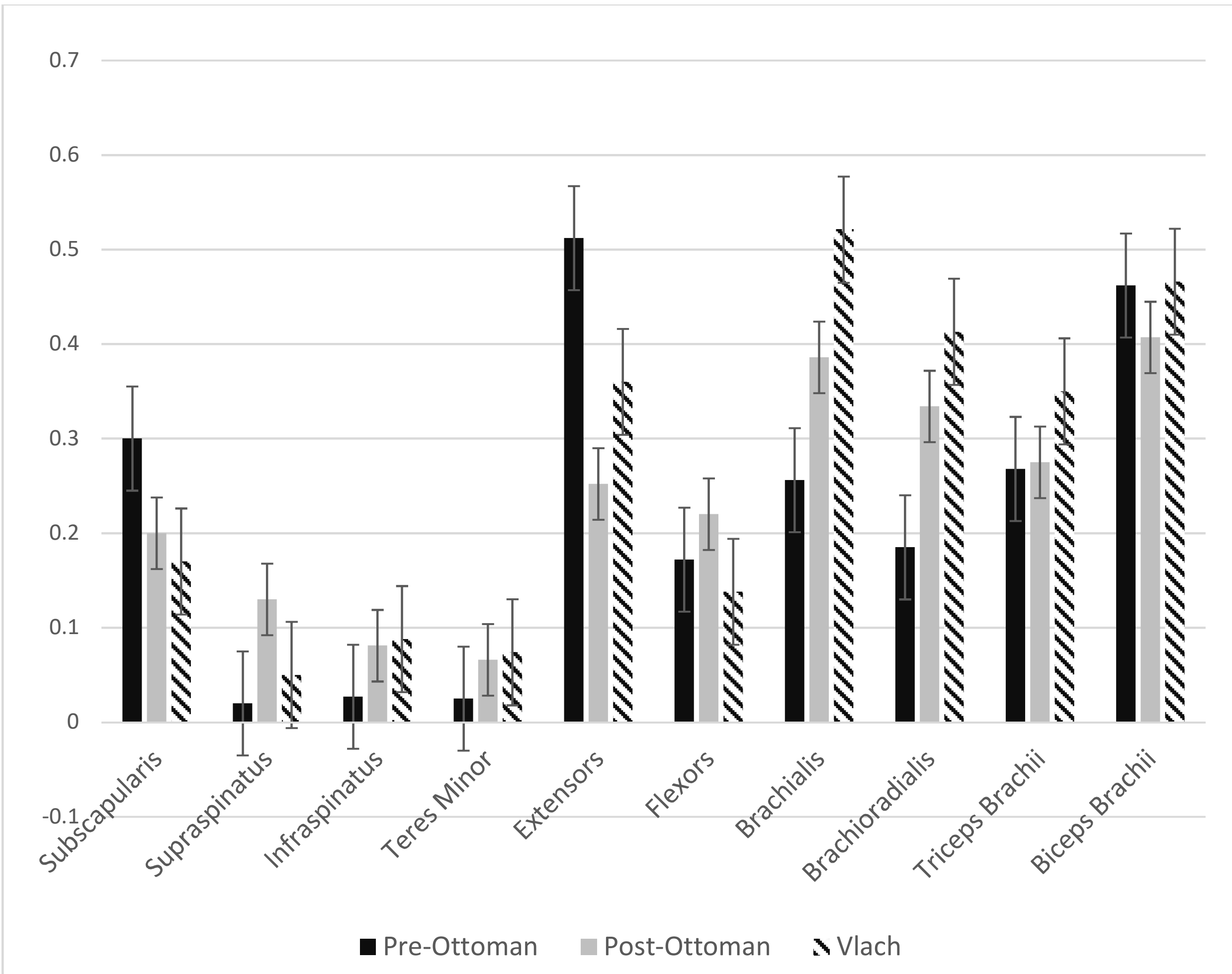

Figure 18: Least Squares Means for Age by Enthesis Using the Hawkey & Merbs Method - Ossification Variable

Comparison of Composite Variables

Because the Coimbra variables were merged into a composite variable, for the sake of performing the Pearson correlation, the Hawkey and Merbs variables were as well. These were kept separated by left and right because of the numerous Coimbra features that were found to not correlate between the left and right side. When the Hawkey and Merbs left composite is compared to the Coimbra left composite, the p value is calculated at <0.0001, indicating statistical significance. This is also shown to be the case for the right side; the calculated p value is <0.0001. This means that the two data sets are strongly correlated with one another. The summary statistics are listed in Table 174 and the Pearson correlation results are summarized in Table 175.

Discussion

Given that both methods use different categories, and different numbers of categories, for the analysis of entheseal remodeling (three for Hawkey and Merbs and seven for Coimbra) it may not be clear initially that these methods are readily comparable. The Hawkey and Merbs method does not distinguish between fibrous and fibrocartilaginous entheses, while the Coimbra method makes this distinction and also incorporates a large body of clinical research into its development. Differences appear larger using the Coimbra method because composite variables were formed from the seven different variables, and although the Hawkey and Merbs method has the potential to reveal large values for individuals (it can range up to 6), these values illustrate very severe entheseal remodeling, and thus are rare.

Both methods seem to assess entheseal remodeling with regards to relationships between the different sexes similarly. Not only do they show a similar pattern in statistical significance, but they also managed to find the same entheses statistically relevant, with similar patterns of least squares means. This is not necessarily the case with age. While the Coimbra method seems to be more stable when detecting age changes, the Hawkey and Merbs seems to find more random relationships between age groups. While the Coimbra method detected an age difference between old adults/young adults and young adults/middle-aged adults in almost every enthesis, the Hawkey and Merbs results were more widely spread, and not as consistent. However, between the different variables, it seems that there are the same general patterns in age found. Across the board, older adults have higher least squares means for entheseal remodeling values than younger adults do, whether those results are statistically significant or not. This analysis of age and sex allows for a comfortable conclusion that comparison of these methods to one another with regards to age and sex results are is possible.

Some of the biggest differences seem to appear between the two methods with regards to assessing entheseal remodeling between Croatian groups. Many of the general trends are there between the two methods, but the Hawkey and Merbs method does not seem to detect as many differences between the different groups as the Coimbra method. This could be due to the scores being split up into two different variables, instead of the eight representing the Coimbra method. There may be less sensitivity in the method, and thus it is not detecting minute differences between groups that Coimbra may be picking up because the Coimbra method has a larger number of factors to consider that the Hawkey and Merbs method does not take into consideration. However, when the results from Hawkey and Merbs are merged into a single composite variable for each individual and this is compared via Pearson's correlation with the Coimbra composite variables, the results are statistically significant, indicating a strong correlation between the two data sets. Although the results between the two are slightly different, the results themselves are similar enough to indicate that they may be appropriate to compare across studies.

Implications for the Comparability of Methods

These results are promising for the potential comparability of each of the methods, although careful methodological steps must be undertaken. Age and sex results seem to be comfortably comparable; although Coimbra age and sex results seemed to have a higher magnitude, it does appear that the general trends are the same between methods. However, the comparisons between groups did not relate as cleanly. Although some of the same general trends were found, there was a drastic loss of sensitivity of the Coimbra method by creating composite variables for each individual, and probably a marginal loss of sensitivity for doing the same for the Hawkey and Merbs method.

If individuals would have shown a statistical significance within the category of bone formation, this may have been more easily comparable to the ossification variable found within the Hawkey and Merbs method. A more useful method of analysis may be to keep each of the Coimbra and Hawkey and Merbs variables separate from one another in the analysis and avoid the calculation of composite variables; although this may lead to a more cumbersome analysis due to the sheer number of data points, it most certainly would allow for a more sensitive analysis of entheseal remodeling. However, for the sake of comparison, this was unfortunately not possible due to the methods chosen in this analysis for comparison (namely the Pearson correlation). Knowing now that the results are relatively comparable, moving forward, a more accurate way to utilize either of these methods would be to avoid the use of composite variables. This would allow for maximum accuracy of the methods while still allowing for the comparison of the overall conclusion of the research. However, the different limitations and strengths of each method must be taken in account to contend with different statistical outcomes, which are bound to happen in some cases. One way to solve part of this problem would be to undertake research on populations with known occupations; this could allow for deductions of not only the similarity of the methods, but the accuracy of each at predicting past activities, adding another facet to this research.

Strengths and Weaknesses of Each of the Methods

Because Hawkey and Merbs is such an old method, it has been used in more research than Coimbra. This allows for a larger data set to compare within. Additionally, the method is more simplistic, which may make it easier for individuals to learn. There are limitations, however. This method does not consider the differences between fibrous and fibrocartilaginous entheses. This is important due to the different progression of ossification and attachment of these two different entheses. Because fibrous entheses connect to bones in large sheets traditional methods for the analysis of entheseal remodeling will not adequately highlight the important features to be found on the enthesis. This method has been largely used for fibrocartilaginous entheses, although it does not make a distinction between the two, which may lead some researchers to use this method to little effect on fibrous entheses. Finally, there is no normal baseline for fibrous entheses, so it is hard to know exactly where the scale should begin (Villotte et al., 2016).

Although the Coimbra method is more refined, its large number of variables can make it cumbersome for statistical analysis. Large bodies of data become even larger bodies of statistical output. However, this sensitivity may allow for exact determination of the source of entheseal remodeling and perhaps a more sensitive result because of it. It more adequately assesses the different grades of entheseal remodeling, from mild textural change all the way up to the formation of massive cavitations in the bone. Additionally, the distinction between fibrous and fibrocartilaginous entheses is important. This method was designed with fibrocartilaginous entheses in mind, meaning it's formulated for the changes seen at these entheses. Additionally, because of the complicated nature of this method, it would behoove those using it to do so through a workshop or other in-person lesson. More recent publications (Henderson et al., 2016) feature more informative photographs of the different features to be analyzed. The authors are making the method more accessible in this way, allowing for those who cannot make it to a workshop to at least begin utilizing the method.

Conclusion

There are numerous results found int his study that make these two methods more comparable than originally thought. Age and sex data seem to pair up well, allowing for easy comparability between entheseal studies involving age and sex. The group analysis highlighted some of the methodological issues with scaling complicated methods down to a composite variable for individuals, but highlighted the high statistical significance found between results of the two methods. It is promising that the two methods are so highly correlated with one another, but the results of this study suggest that it is perhaps better to avoid composite variables in these cases and use the methods in their uncondensed, more specific, albeit more complicated, forms. This allows for maximum sensitivity of the methods and provides the most informative results. Despite this, it is highly possible that results of these two methods are able to be compared in their raw form, as long as adequate precautions are taken.

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CHAPTER 5. DISCUSSION AND CONCLUSIONS

Introduction

This dissertation has highlighted several very important points with regards to social change under Ottoman rule. Although there are numerous factors that could have contributed to the findings in this dissertation, it seems that in some ways the Ottoman Turks did have an influence on the daily lives and activities of Croatians during this time period. Through the lens of embodiment theory, in conjunction with a bioarchaeological analysis of activity changes, it was possible to detect some changes at entheses that may indicate that the Ottomans may have influenced some aspects of daily life in a way that increased the demand on the body during the time of invasion. However, it seems that this workload increase may not have been as dramatic as originally expected.

General Findings and Overall Trends

Entheseal Remodeling

Entheseal remodeling results shed some light on the influence the Ottoman Empire had on the people of Croatia. Age results follow the same trend that is to be expected from other studies; young people have lower entheseal remodeling scores than older people. The results for sex seem to counter historical and ethnographic data that indicates the existence of a division of labor (Ivanišević, 1987; Voynović Traživuk, 2001; Muraj, 2004; Šestan, 2008), although it is possible that men and women were performing different tasks that involved the same gross muscle movements. there is a difference in the tendency of men and women to develop remodeling at entheses, with men having generally higher scores. There being a lack of sex difference is interesting here; it is possible that the perceived workload of the men in the area was not as high as predicted, or that the women were working harder than expected. Not only would they have performed all of their regular household duties but would have taken over more responsibility, perhaps around the farm, when men went to war.

The general trend for the groups is that the Post-Ottomans and Vlachs have the highest values for entheseal remodeling, with Post-Ottoman groups having slightly more statistically significant results than the Vlachs. This is almost certainly due to the harder lifestyles lived by these two different groups over that of the Pre-Ottoman population. The Post-Ottoman individuals who were not killed and did not abandon their homes were probably performing their normal day-to-day activities at a higher rate or intensity; this was likely due to the extra pressure of food to pay both tribute and feed invading armies, and the extra work load enforced upon Ottoman subjects. The Vlachs had a similar dilemma. As vassals of the Ottoman Empire, they were not only performing their normal work as transhumant pastoralist cattle-breeders who farmed very rugged lands, but they were also performing extra work for the Ottomans, such as rebuilding fortresses, clearing conquered land, and rebuilding roads and bridges (Jurin-Starčević, 2008).

Osteoarthritis

The results for age are found to mirror entheseal remodeling and follow predictable patterns. Older adults have higher measurements for osteoarthritis than younger adults. There was no difference found between the sexes; this could be due to a lack of division of labor between men and women, although it is equally as likely to be due to anatomical differences between men and women that predispose women to the development of arthritis (Reijman et al. 2005).

Although statistical significance was found between the Adriatic and continental regions, with the Adriatic region having higher least squares means, there was no statistically significant differences found between any of the groups analyzed for most of the metrics. This can be explained by several different factors, such as a lack of higher intensity labor with the Ottoman Turks. If the tools did not change and land was still farmed, most people were probably still performing the same duties they had been before. Because most people were farmers and they certainly needed to continue eating and feeding others, it is extremely likely that at least some of the people would not have changed occupations. Additionally, it is equally possible that individuals did change jobs, but were performing tasks that were similar to their previous responsibilities, so the wear on their joints may not have changed. Finally, it is possible that despite its ubiquitous use in bioarchaeological studies, that osteoarthritis may not be the best metric for the study of activity because of its close relationship to genetics and problems with diagnosis.

Did the Ottomans Influence the Daily Lives of Croatians?

Although there are some results that seem to indicate that the Ottomans would have had an influence on Croatians during this time period, the evidence is not unequivocal. The very nature of analyzing skeletal remains in this manner leaves room for a healthy amount of doubt because it is hard to assess conditions that have soft tissue involvement without the presence of soft tissue. As these soft tissues are used throughout an individual's daily life, they modify the underlying bone, embodying activity on the skeleton. Although having them present to measure muscle belly width or the width of the joint margin would make the analysis of activity change easier, embodiment theory highlights the ways in which we can interpret the changes on bone in a way that illuminates biological change in the context of social change.

Entheseal remodeling results suggest that the Ottomans probably had high levels of influence on the Vlachs and the Post-Ottoman populations. The Pre-Ottoman population had the lowest least squares means than the Post-Ottoman population and the Vlach populations. However, statistical significance was typically only found between the Vlachs and the other two groups. The Vlachs were vassals of the Ottoman Empire and were brought in to occupy land they captured and cleared. They had special privileges under Ottoman rule but were also expected to be stewards of the land and maintain the fortresses, farmlands, and civil structures under their rule. Because they lived primarily as transhumant pastoralists who raised cattle and farmed the land they settled on seasonally, they also lived a very rugged lifestyle that involved movement along the landscape. This necessitated the carrying of supplies with them, which may have stressed the upper limb and would explain at least some of the increased rates of entheseal remodeling found within their population. Additionally, the rocky landscape they farmed along the Adriatic coast would have also made their day to day lives much harder than someone performing agriculture in the lowlands.

As for the Pre-Ottoman and Post-Ottoman, entheseal remodeling suggests that there may not have been a dramatic change in the intensity of activities between the two different time periods.

In most cases the least squares means seem to be higher for the Post-Ottoman populations, indicating that they had higher values for entheseal remodeling and osteoarthritis, those differences are infrequently statistically significant. This does not mean they are unimportant; it just means the magnitude is not high enough to indicate a drastic change. There are a number of reasons for this, but two are most important. The first is that it is possible that the lifestyle of a serf is difficult, no matter who the master it. If Croatians under Croatian lords were working their hands to the bone raising cattle or farming land, then it is equally likely that those skills would have been valued under Ottoman tutelage and those individuals would have been performing the same tasks. Second, because occupation information is lacking, and it is impossible to know exactly what people were doing, it is extremely possible that individuals switched occupations and it is undetectable. Previous research has highlighted the limitations of entheseal remodeling and osteoarthritis with regards to pinpointing exact activities (Churchill and Morris, 1998; Jurmain, 2013; Robb, 1998; Weiss, 2009); if different activities use similar muscles or joints, they will be embodied similarly on the skeleton. This limits the ability of bioarchaeologists to pinpoint exact activity, except in the case where an activity involves specialized, uncommon movements of the body. It is thus extremely possible that the Ottomans caused a change in lifestyle that we are unable to detect because the muscle groups that were used would have been similar.

Implications for Future Work

The final article in this dissertation discussed the comparison between a newer method for the analysis of entheseal remodeling, the Coimbra method (Henderson et al., 2013, 2016, 2017), and an older, more commonly used method, the Hawkey and Merbs method (1995). The Coimbra method has numerous strengths, including the inclusion of more clinical data, distinguishing between fibrous and fibrocartilaginous entheses, and more narrowed features. This makes it an excellent method to begin testing on different populations. This final article served to compare the results from this study that were collected using both methods to one another. The findings indicate that both methods are highly comparable when it comes to age and sex data; very little variation was found in the results, with similar least squares means patterns being indicated by both methods. Older adults trended higher than younger adults for both methods, and although men were not always higher than women, the same general trend was found between the methods.

The difficulty came when the different groups were then compared. Because a Pearson correlation was used to compare the data, I was forced to calculate a composite variable for each individual and then compare that composite variable. This revealed that the methods were highly correlated with one another ($p=<0.0001$ for the right and left side), but also caused a drastic loss in sensitivity of the methods themselves. Each of the methods has strengths and weaknesses that were summarized in the article, but these strengths and weaknesses could lead to discrepancies in the statistical outcomes, and thus affect this correlation of results. As of now, it is concluded that results can be tentatively compared as long as due diligence is performed.

Conclusion

This dissertation reveals the patterns found in entheseal remodeling and osteoarthritis in two Pre-Ottoman and Post-Ottoman population of Croatians and helps clarify some of the changes found in the skeletons of individuals from this time period. The osteoarthritis data seems to suggest that perhaps lifestyles did not change as dramatically as the historical data suggests, or perhaps that the change is not detectable using osteoarthritis studies in bioarchaeology. Values for entheseal remodeling suggest that although there was not a dramatic difference to be found between the Pre-Ottoman and Post-Ottoman populations, the Vlach population showed higher values of entheseal remodeling than either of them and many of those were statistically significant. For the native Croatian populations, this suggests a similar result to the osteoarthritis study; that either lifestyle did not change drastically enough to leave evidence of embodied activities on the bones, or activities changed in such a way that we are unable to detect them using our current methods. However, it was revealed that the Vlach population appeared to have been working quite hard, indicating that the Ottomans may have expected a great deal out of individuals within the realm of their rule who had given their fealty in exchange for land to work. Historical sources from this time period indicate that the Ottoman Empire brought destruction and drastic sociopolitical change in their wake, and the materials we have that highlight the nature and effectiveness of the Ottoman military seem to corroborate this. Although this study does not definitively lend credence to this idea, it does not exclude the possibility that the Ottoman Turks could have had a dramatic effect on the long-term daily lives of Croatians. However, it is possible that there are some levels of society that cannot be shaken by overarching imperial occupation. Armies and occupying individuals still need to eat, and the majority of individuals involved in this study were serfs or free farmers and ranchers. They would have served an invaluable place in society, and thus their lives would not have been as violently upturned as the nobility, middle class, or urban dwellers. Because of the essential nature of their work, they could have been spared the tumultuous changes brought about by the invasion of the Ottoman Empire.

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APPENDIX

Summary Statistics – Entheseal Remodeling (Coimbra Method)

Table 15: Summary Statistics – Entheseal Remodeling (Coimbra Method)

Variable	N	Mean	Std Dev	Min	Max
Subscapularis Composite Variable	257	1.28599	1.78068	0	8.50
Supraspinatus Composite Variable	330	0.61818	1.27686	0	7.00
Infraspinatus Composite Variable	255	1.11569	1.67230	0	9.00
Teres Minor Composite Variable	235	0.35319	0.81436	0	4.00
Extensors Composite Variable	278	0.64647	1.01246	0	4.50
Flexors Composite Variable	293	0.34300	0.80085	0	6.50
Triceps Brachii Composite Variable	269	1.74535	1.43751	0	8.00
Brachialis Composite Variable	310	0.76613	0.85860	0	5.00
Biceps Brachii Composite Variable	294	2.00680	1.79208	0	9.00
Brachioradialis Composite Variable	213	0.37089	0.51257	0	2.00

Pearson Correlation Results – Entheseal Remodeling (Coimbra Method)

Table 16: Pearson Correlation Results – Entheseal Remodeling (Subscapularis, Coimbra Method)

Variable	Variable	Pearson's R	P Value
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.60921	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	0.25426	0.0014
Zone 2 Textural Change Left	Zone 2 Textural Change Right	0.15973	0.0464
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.56532	<0.0001
Zone 2 Erosion Left	Zone 2 Erosion Right	0.52523	<0.0001
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.25738	0.0012
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	0.34427	<0.0001
Zone 2 Cavitation Left	Zone 2 Cavitation Right	-0.00915	0.9097

Table 17: Pearson Correlation Results – Entheseal Remodeling (Supraspinatus, Coimbra Method)

Variable	Variable	Pearson's R	P Value
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.23178	0.0068
Zone 1 Erosion Left	Zone 1 Erosion Right	0.55184	<0.0001
Zone 2 Textural Change Left	Zone 2 Textural Change Right	0.13218	0.1209
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.50527	<0.0001
Zone 2 Erosion Left	Zone 2 Erosion Right	0.43223	<0.0001
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.07743	0.3649
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	0.30498	0.0003
Zone 2 Cavitation Left	Zone 2 Cavitation Right	-0.01029	0.9043

Table 18: Pearson Correlation Results – Entheseal Remodeling (Infraspinatus, Coimbra Method)

Variable	**Variable**	**Pearson's R**	**P Value**
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.49261	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	0.18721	0.0268
Zone 2 Textural Change Left	Zone 2 Textural Change Right	0.52305	<0.0001
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.44650	<0.0001
Zone 2 Erosion Left	Zone 2 Erosion Right	0.42476	<0.0001
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.37519	<0.0001
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	0.13488	0.1082
Zone 2 Cavitation Left	Zone 2 Cavitation Right	Non est.	Non est.

Table 19: Pearson Correlation Results – En7theseal Remodeling (Teres Minor, Coimbra Method)

Variable	Variable	Pearson's R	P Value
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.41488	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	Not est..	Not est.
Zone 2 Textural Change Left	Zone 2 Textural Change Right	0.42535	<0.0001
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.30305	0.0009
Zone 2 Erosion Left	Zone 2 Erosion Right	0.14246	0.1255
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.16383	0.0776
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	-0.02530	0.7866
Zone 2 Cavitation Left	Zone 2 Cavitation Right	Non est.	Non est.

Table 20: Pearson Correlation Results – Entheseal Remodeling (Extensors, Coimbra Method)

Variable	**Variable**	**Pearson's R**	**P Value**
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.66787	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	Non est.	Non est.
Zone 2 Textural Change Left	Zone 2 Textural Change Right	Non est.	Non est.
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.59312	<0.0001
Zone 2 Erosion Left	Zone 2 Erosion Right	0.37143	<0.0001
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.13214	0.0969
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	0.49363	<0.0001
Zone 2 Cavitation Left	Zone 2 Cavitation Right	Non est.	Non est.

Table 21: Pearson Correlation Results – Entheseal Remodeling (Flexors, Coimbra Method)

Variable	Variable	Pearson's R	P Value
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.67890	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	Non est.	Non est.
Zone 2 Textural Change Left	Zone 2 Textural Change Right	-0.01111	0.8817
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.27493	0.0002
Zone 2 Erosion Left	Zone 2 Erosion Right	-0.01300	0.8618
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.55734	<0.0001
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	-0.02543	0.7333
Zone 2 Cavitation Left	Zone 2 Cavitation Right	Non est.	Non est.

Table 22: Pearson Correlation Results – Entheseal Remodeling (Triceps Brachii, Coimbra Method)

Variable	**Variable**	**Pearson's R**	**P Value**
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.53661	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	0.18823	0.0152
Zone 2 Textural Change Left	Zone 2 Textural Change Right	0.43217	<0.0001
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	-0.03277	0.6742
Zone 2 Erosion Left	Zone 2 Erosion Right	0.14611	0.0596
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.44411	<0.0001
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	0.05584	0.4735
Zone 2 Cavitation Left	Zone 2 Cavitation Right	Non est.	Non est.

Table 23: Pearson Correlation Results – Entheseal Remodeling (Brachialis, Coimbra Method)

Variable	**Variable**	**Pearson's R**	**P Value**
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.44428	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	0.79840	<0.0001
Zone 2 Textural Change Left	Zone 2 Textural Change Right	0.34563	<0.0001
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.52390	<0.0001
Zone 2 Erosion Left	Zone 2 Erosion Right	0.72553	<0.0001
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.40073	<0.0001
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	-0.01914	0.7748
Zone 2 Cavitation Left	Zone 2 Cavitation Right	Non est.	Non est.

Table 24: Pearson Correlation Results – Entheseal Remodeling (Biceps Brachii, Coimbra Method)

Variable	**Variable**	**Pearson's R**	**P Value**
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.59493	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	0.71197	<0.0001
Zone 2 Textural Change Left	Zone 2 Textural Change Right	0.40734	<0.0001
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.24482	0.0004
Zone 2 Erosion Left	Zone 2 Erosion Right	0.30323	<0.0001
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	0.38161	<0.0001
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	0.14021	0.0466
Zone 2 Cavitation Left	Zone 2 Cavitation Right	Non est.	Non est.

Table 25: Pearson Correlation Results – Entheseal Remodeling (Brachioradialis, Coimbra Method)

Variable	**Variable**	**Pearson's R**	**P Value**
Zone 1 Bone Formation Left	Zone 1 Bone Formation Right	0.47308	<0.0001
Zone 1 Erosion Left	Zone 1 Erosion Right	Non est.	Non est.
Zone 2 Textural Change Left	Zone 2 Textural Change Right	0.57155	<0.0001
Zone 2 Bone Formation Left	Zone 2 Bone Formation Right	0.31293	0.0014
Zone 2 Erosion Left	Zone 2 Erosion Right	Non est.	Non est.
Zone 2 Fine Porosity Left	Zone 2 Fine Porosity Right	-0.03244	0.7474
Zone 2 Macro Porosity Left	Zone 2 Macro Porosity Right	-0.02487	0.8050
Zone 2 Cavitation Left	Zone 2 Cavitation Right	Non est.	Non est.

Zero-Inflated GLM Results – Entheseal Remodeling (Coimbra Method)

Table 26: Model Summary – Entheseal Remodeling (Subscapularis, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	P Value
Model	10	268.3355430	26.8335543	12.15	<0.0001
Error	246	543.3940289	2.2089188		
Corrected Total	256	811.7295720			

Table 27: Zero-Inflated GLM for Entheseal Remodeling – Subscapularis (Coimbra Method)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	172.1356150	86.0678075	38.96	<0.0001
Groups	2	17.7723823	8.8861912	4.02	0.0191
Sex	1	0.4206416	0.4206416	0.19	0.6629
Region	1	14.8247609	14.8247609	6.71	0.0102
Lower Limb	2	3.1563446	1.5781723	0.71	0.4905
Upper Limb	2	2.5558751	1.2779376	0.58	0.5615
Comparison			**P Value**		
Young adult/Middle-aged adult			0.1461		
Young adult/Older adult			<0.0001		
Middle-aged adult/Older adult			<0.0001		
Post-Ottoman/Pre-Ottoman			0.6698		
Post-Ottoman/Vlach			0.0140		
Pre-Ottoman/Vlach			0.1919		
Male/Female			0.6629		
Adriatic/Continental			0.0102		
Large lower limb/Medium lower limb			0.6213		
Medium lower limb/Small lower limb			0.7795		
Large lower limb/Small lower limb			0.4774		
Large upper limb/Medium upper limb			0.5323		
Medium upper limb/Small upper limb			0.9852		
Large upper limb/Small upper limb			0.7823		
Least Squares Means for Different Sources					
OA (2.58) > MA (0.73) > YA (0.24)					
Post-Ottoman (1.48) > Pre-Ottoman (1.27) > Vlach (0.78)					
Male (1.23) > Female (1.13)					
Adriatic (1.53) > Continental (0.83)					
Large LL (1.41) > Medium LL (1.17) > Small LL (0.96)					
Large UL (1.38) > Small UL (1.11) > Medium UL (1.06)					

Table 28: Model Summary – Entheseal Remodeling (Supraspinatus, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	P Value
Model	10	113.9429804	11.3942980	8.60	<0.0001
Error	319	422.4479287	1.3242882		
Corrected Total	329	536.3909091			

Table 29: Zero-Inflated GLM for Entheseal Remodeling – Supraspinatus (Coimbra Method)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	51.41451162	25.70725581	19.41	<0.0001
Groups	2	17.52808094	8.76404047	6.62	0.0015
Sex	1	1.14388830	1.14388830	0.86	0.3534
Region	1	0.02905781	0.02905781	0.02	0.8823
Lower Limb	2	4.07019380	2.03509690	1.54	0.2167
Upper Limb	2	0.66864723	0.33432362	0.25	0.7770

Comparison	**P Value**
Young adult/Middle-aged adult	0.7132
Young adult/Older adult	<0.0001
Middle-aged adult/Older adult	<0.0001
Post-Ottoman/Pre-Ottoman	0.4598
Post-Ottoman/Vlach	0.0137
Pre-Ottoman/Vlach	0.0015
Male/Female	0.3534
Adriatic/Continental	0.8823
Large lower limb/Medium lower limb	0.9841
Medium lower limb/Small lower limb	0.1888
Large lower limb/Small lower limb	0.3730
Large upper limb/Medium upper limb	0.8065
Medium upper limb/Small upper limb	0.8979
Large upper limb/Small upper limb	0.9912

Least Squares Means for Different Sources
OA (1.33) > MA (0.41) > YA (0.27)
Vlach (1.06) > Post-Ottoman (0.58) > Pre-Ottoman (0.38)
Female (0.74) > Male (0.60)
Adriatic (0.69) > Continental (0.66)
Medium LL (0.80) > Large LL (0.77) > Small LL (0.45)
Large UL (0.72) > Small UL (0.69) > Medium UL (0.61)

Table 30: Model Summary – Entheseal Remodeling (Infraspinatus, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	P Value
Model	10	239.5243298	23.9524330	12.41	<0.0001
Error	244	470.8129251	1.9295612		
Corrected Total	254	710.3372549			

Table 31: Zero-Inflated GLM for Entheseal Remodeling – Infraspinatus (Coimbra Method)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	102.7871880	51.3935940	26.63	<0.0001
Groups	2	26.2540285	13.1270143	6.80	0.0013
Sex	1	9.7479538	9.7479538	5.05	0.0255
Region	1	0.2076440	0.2076440	0.11	0.7432
Lower Limb	2	9.4982536	4.7491268	2.46	0.0874
Upper Limb	2	2.4879406	1.2439703	0.64	0.5257

Comparison	P Value
Young adult/Middle-aged adult	0.1091
Young adult/Older adult	<0.0001
Middle-aged adult/Older adult	<0.0001
Post-Ottoman/Pre-Ottoman	0.1348
Post-Ottoman/Vlach	0.0672
Pre-Ottoman/Vlach	0.0008
Male/Female	0.0255
Adriatic/Continental	0.7432
Large lower limb/Medium lower limb	0.6940
Medium lower limb/Small lower limb	0.1164
Large lower limb/Small lower limb	0.0855
Large upper limb/Medium upper limb	0.5491
Medium upper limb/Small upper limb	0.9321
Large upper limb/Small upper limb	0.5569

Least Squares Means for Different Sources
OA (2.28) > MA (0.87) > YA (0.38)
Vlach (1.67) > Post-Ottoman (1.15) > Pre-Ottoman (0.70)
Female (1.40) > Male (0.94)
Continental (1.21 > Adriatic (1.13)
Large LL (1.50) > Medium LL (1.30) > Small LL (0.71)
Large UL (1.40) > Small UL (1.11) > Medium UL (1.01)

Table 32: Model Summary – Entheseal Remodeling (Teres Minor, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	P Value
Model	10	33.8577146	3.3857715	6.25	<0.0001
Error	224	121.3273918	0.5416401		
Corrected Total	234	155.1851064			

Table 33: Zero-Inflated GLM for Entheseal Remodeling – Teres Minor (Coimbra Method)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	15.80283597	7.90141799	14.59	<0.0001
Groups	2	7.51248575	3.75624288	6.93	0.0012
Sex	1	1.25018733	1.25018733	2.31	0.1301
Region	1	2.44397910	2.44397910	4.51	0.0348
Upper Limb	2	4.11515705	2.05757852	3.80	0.0239
Lower Limb	2	1.93693304	0.96846652	1.79	0.1697

Comparison	P Value
Young adult/Middle-aged adult	0.2398
Young adult/Older adult	<0.0001
Middle-aged adult/Older adult	<0.0001
Post-Ottoman/Pre-Ottoman	0.0030
Post-Ottoman/Vlach	0.9601
Pre-Ottoman/Vlach	0.0037
Male/Female	0.1301
Adriatic/Continental	0.0348
Large lower limb/Medium lower limb	0.8421
Medium lower limb/Small lower limb	0.0183
Large lower limb/Small lower limb	0.1778
Large upper limb/Medium upper limb	0.6078
Medium upper limb/Small upper limb	0.1991
Large upper limb/Small upper limb	0.8696

Least Squares Means for Different Sources
OA (0.87) > MA (0.31) > YA (0.08)
Vlach (0.59) > Post-Ottoman (0.55) > Pre-Ottoman (0.12)
Female (0.50) > Male (0.33)
Continental (0.57) > Adriatic (0.27)
Medium LL (0.59) > Large LL (0.51) > Small LL (0.15)
Small UL (0.54) > Large UL (0.43) > Medium UL (0.28)

Table 34: Model Summary – Entheseal Remodeling (Extensors, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	P Value
Model	10	90.5535240	9.0553524	12.50	<0.0001
Error	267	193.3898213	0.7243064		
Corrected Total	277	283.9433453			

Table 35: Zero-Inflated GLM for Entheseal Remodeling – Extensors (Coimbra Method)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	60.15117613	30.07558806	41.52	<0.0001
Groups	2	1.36660932	0.68330466	0.94	0.3906
Sex	1	0.64083389	0.64083389	0.88	0.3478
Region	1	1.57677367	1.57677367	2.18	0.1413
Upper Limb	2	0.63792200	0.31896100	0.44	0.6443
Lower Limb	2	5.73855271	2.86927636	3.96	0.0202

Comparison	**P Value**
Young adult/Middle-aged adult	0.2405
Young adult/Older adult	<0.0001
Middle-aged adult/Older adult	<0.0001
Post-Ottoman/Pre-Ottoman	0.4419
Post-Ottoman/Vlach	0.5412
Pre-Ottoman/Vlach	0.9887
Male/Female	0.3478
Adriatic/Continental	0.1413
Large lower limb/Medium lower limb	0.9093
Medium lower limb/Small lower limb	0.7409
Large lower limb/Small lower limb	0.6198
Large upper limb/Medium upper limb	0.9656
Medium upper limb/Small upper limb	0.0189
Large upper limb/Small upper limb	0.0592

Least Squares Means for Different Sources
OA (1.33) > MA (0.32) > YA (0.08)
Pre-Ottoman (0.64) > Vlach (0.62) > Post-Ottoman (0.47)
Female (0.69) > Male (0.47)
Adriatic (0.70) > Continental (0.52)
Small LL (0.68) > Medium LL (0.56) > Large LL (0.50)
Large UL (0.75) > Medium UL (0.71) > Small UL (0.27)

Table 36: Model Summary – Entheseal Remodeling (Flexors, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	34.6204084	3.4620408	6.40	<0.0001
Error	282	152.6577486	0.5413395		
Corrected Total	292	187.2781570			

Table 37: Zero-Inflated GLM for Entheseal Remodeling – Flexors (Coimbra Method)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	17.69360382	8.84680191	16.34	<0.0001
Groups	2	0.31642293	0.15821146	0.29	0.7468
Sex	1	2.87481514	2.87481514	5.31	0.0219
Region	1	0.71300096	0.71300096	1.32	0.2521
Lower Limb	2	0.25178762	0.12589381	0.23	0.7927
Upper Limb	2	3.15602688	1.57801344	2.92	0.0558

Comparison	P Value
Young adult/Middle-aged adult	0.4772
Young adult/Older adult	<0.0001
Middle-aged adult/Older adult	<0.0001
Post-Ottoman/Pre-Ottoman	0.7460
Post-Ottoman/Vlach	0.9980
Pre-Ottoman/Vlach	0.8291
Male/Female	0.0219
Adriatic/Continental	0.2521
Large lower limb/Medium lower limb	0.8442
Medium lower limb/Small lower limb	0.8748
Large lower limb/Small lower limb	0.9997
Large upper limb/Medium upper limb	0.9990
Medium upper limb/Small upper limb	0.0482
Large upper limb/Small upper limb	0.1467

Least Squares Means for Different Sources
OA (0.73) > MA (0.18) > YA (0.03)
Post-Ottoman (0.34) > Vlach (0.36) > Pre-Ottoman (0.26)
Female (0.43) > Male (0.20)
Adriatic (0.38) > Continental (0.24)
Small LL (0.34) > Large LL (0.33) > Medium LL (0.27)
Large UL (0.42) > Medium UL (0.416) > Small UL (0.10)

Table 38: Model Summary – Entheseal Remodeling (Triceps Brachii, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	95.2968497	9.5296850	5.36	<0.0001
Error	258	458.5098417	1.7771699		
Corrected Total	268	553.8066914			

Table 39: Zero-Inflated GLM for Entheseal Remodeling – Triceps Brachii (Coimbra Method)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	45.92876531	22.96438266	12.92	<0.0001
Groups	2	29.32419722	14.66209861	8.25	0.0003
Sex	1	1.69950846	1.69950846	0.96	0.3290
Region	1	2.19916968	2.19916968	1.24	0.2670
Lower Limb	2	1.03928403	0.51964202	0.29	0.7467
Upper Limb	2	7.34517125	3.67258562	2.07	0.1287

Comparison	P Value
Young adult/Middle-aged adult	0.1098
Young adult/Older adult	<0.0001
Middle-aged adult/Older adult	0.0003
Post-Ottoman/Pre-Ottoman	0.0004
Post-Ottoman/Vlach	0.0394
Pre-Ottoman/Vlach	0.4335
Male/Female	0.3290
Adriatic/Continental	0.2670
Large lower limb/Medium lower limb	0.9821
Medium lower limb/Small lower limb	0.7581
Large lower limb/Small lower limb	0.7566
Large upper limb/Medium upper limb	0.1633
Medium upper limb/Small upper limb	0.8295
Large upper limb/Small upper limb	0.1594

Least Squares Means for Different Sources
OA (2.49) > MA (1.69) > YA (1.22)
Post-Ottoman (2.27) > Vlach (1.72) > Pre-Ottoman (1.41)
Male (1.86) > Female (1.71)
Continental (1.93) > Adriatic (1.67)
Large LL (1.89) > Medium LL (1.85) > Small LL (1.66)
Large UL (2.14) > Medium UL (1.70) > Small UL (1.55)

Table 40: Model Summary – Entheseal Remodeling (Brachialis, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	32.7788399	3.2778840	5.03	<0.0001
Error	299	195.0155150	0.6522258		
Corrected Total	309	227.7943548			

Table 41: Zero-Inflated GLM for Entheseal Remodeling – Brachialis (Coimbra Method)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	5.28643361	2.64321680	4.05	0.0183
Groups	2	24.97394231	12.48697116	19.15	<0.0001
Sex	1	0.08364757	0.08364757	0.13	0.7205
Region	1	10.68169624	10.68169624	16.38	<0.0001
Upper Limb	2	0.21798763	0.10899381	0.17	0.8462
Lower Limb	2	0.00544627	0.00272313	0.00	0.9958

Comparison	P Value
Young adult/Middle-aged adult	0.4097
Young adult/Older adult	<0.0174
Middle-aged adult/Older adult	0.0883
Post-Ottoman/Pre-Ottoman	0.0006
Post-Ottoman/Vlach	0.0032
Pre-Ottoman/Vlach	<0.0001
Male/Female	0.7205
Adriatic/Continental	<0.0001
Large lower limb/Medium lower limb	0.8999
Medium lower limb/Small lower limb	0.9460
Large lower limb/Small lower limb	0.8406
Large upper limb/Medium upper limb	0.9980
Medium upper limb/Small upper limb	0.9981
Large upper limb/Small upper limb	0.9954

Least Squares Means for Different Sources
OA (1.14) > MA (0.89) > YA (0.73)
Vlach (1.35) > Post-Ottoman (0.94) > Pre-Ottoman (0.47)
Male (0.94) > Female (0.90)
Continental (1.18) > Adriatic (0.66)
Large LL (0.97) > Medium LL (0.92) > Small LL (0.87)
Large UL (0.93) > Medium UL (0.92) > Small UL (0.91)

Table 42: Model Summary – Entheseal Remodeling (Biceps Brachii, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	263.5015164	26.3501516	11.01	<0.0001
Error	283	677.4848781	2.3939395		
Corrected Total	293	940.9863946			

Table 43: Zero-Inflated GLM for Entheseal Remodeling – Biceps Brachii (Coimbra Method)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	187.9493495	93.9746747	39.26	<.0001
Groups	2	4.0933371	2.0466685	0.85	0.4264
Sex	1	15.1055178	15.1055178	6.31	0.0126
Region	1	1.6663894	1.6663894	0.70	0.4048
Lower Limb	2	1.0546945	0.5273473	0.22	0.8024
Upper Limb	2	5.9819676	2.9909838	1.25	0.2883

Comparison	P Value
Young adult/Middle-aged adult	0.0446
Young adult/Older adult	<0.0001
Middle-aged adult/Older adult	<0.0001
Post-Ottoman/Pre-Ottoman	0.4801
Post-Ottoman/Vlach	0.5765
Pre-Ottoman/Vlach	0.9904
Male/Female	0.0126
Adriatic/Continental	0.4048
Large lower limb/Medium lower limb	0.7883
Medium lower limb/Small lower limb	0.9806
Large lower limb/Small lower limb	0.9517
Large upper limb/Medium upper limb	0.3295
Medium upper limb/Small upper limb	0.8823
Large upper limb/Small upper limb	0.3344

Least Squares Means for Different Sources
OA (3.27) > MA (1.56) > YA (0.95)
Post-Ottoman (2.10) > Vlach (1.86) > Pre-Ottoman (1.82)
Male (2.20) > Female (1.66)
Adriatic (2.03) > Continental (1.82)
Medium LL (2.00) > Large LL (1.83) > Small LL (1.94)
Large UL (2.22) > Medium UL (1.84) > Small UL (1.70)

Table 44: Model Summary – Entheseal Remodeling (Brachioradialis, Coimbra Method)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	7.43260077	0.74326008	3.11	0.0010
Error	202	48.26692975	0.23894520		
Corrected Total	212	55.69953052			

Table 45: Zero-Inflated GLM for Entheseal Remodeling – Brachioradialis (Coimbra Method)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.46977730	0.23488865	0.98	0.3760
Groups	2	4.58126003	2.29063001	9.59	0.0001
Sex	1	0.18054690	0.18054690	0.76	0.3857
Region	1	3.00360571	3.00360571	12.57	0.0005
Lower Limb	2	1.44015129	0.72007564	3.01	0.0513
Upper Limb	2	0.30161571	0.15080786	0.63	0.5330

Comparison	P Value
Young adult/Middle-aged adult	0.8366
Young adult/Older adult	0.3727
Middle-aged adult/Older adult	0.5299
Post-Ottoman/Pre-Ottoman	0.0003
Post-Ottoman/Vlach	0.9692
Pre-Ottoman/Vlach	0.0004
Male/Female	0.3857
Adriatic/Continental	0.0005
Large lower limb/Medium lower limb	0.1682
Medium lower limb/Small lower limb	0.1481
Large lower limb/Small lower limb	0.9388
Large upper limb/Medium upper limb	0.5435
Medium upper limb/Small upper limb	0.9745
Large upper limb/Small upper limb	0.5998

Least Squares Means for Different Sources
OA (0.52) > MA (0.43) > YA (0.37)
Vlach (0.59) > Post-Ottoman (0.59) > Pre-Ottoman (0.17)
Female (0.48) > Male (0.41)
Continental (0.62) > Adriatic (0.26)
Medium LL (0.57) > Large LL (0.40) > Small LL (0.36)
Large UL (0.52) > Medium UL (0.51) > Small UL (0.40)

Summary Statistics – Entheseal Remodeling (Hawkey & Merbs Method)

Table 46: Summary Statistics – Entheseal Remodeling (Hawkey & Merbs Method)

Variable	N	Mean	Std Dev	Min	Max
Subscapularis Robusticity & Stress Lesion Composite	247	1.82446	1.73474	0	6.00
Subscapularis Ossification Variable	249	0.23293	0.50796	0	3.00
Supraspinatus Robusticity & Stress Lesion Composite	243	0.66872	1.56482	0	6.00
Supraspinatus Ossification Variable	244	0.04713	0.21473	0	2.00
Infraspinatus Robusticity & Stress Lesion Composite	246	1.80249	1.57312	0	6.00
Infraspinatus Ossification Variable	246	0.05081	0.26430	0	3.00
Teres Minor Robusticity & Stress Lesion Composite	227	0.11894	0.56360	0	5.00
Teres Minor Ossification Variable	227	0.04625	0.21824	0	2.00
Extensors Robusticity & Stress Lesion Composite	263	0.03992	0.2534	0	3.00
Extensors Ossification Variable	267	0.41947	0.62683	0	3.50
Flexors Robusticity & Stress Lesion Composite	268	0.09141	0.51752	0	5.00
Flexors Ossification Variable	272	0.17830	0.42130	0	2.50
Brachialis Robusticity & Stress Lesion Composite	296	0.65202	0.81958	0	5.00
Brachialis Ossification Variable	297	0.28619	0.50226	0	2.50
Brachioradialis Robusticity & Stress Lesion Composite	197	0.048223	0.32570	0	4.00
Brachioradialis Ossification Variable	197	0.25126	0.45910	0	3.00
Biceps Brachii Robusticity & Stress Lesion Composite	280	0.74821	1.26434	0	6.00
Biceps Brachii Ossification Variable	283	0.45759	0.65366	0	3.00
Triceps Brachii Robusticity & Stress Lesion Composite	257	0.21011	0.73195	0	5.00
Triceps Brachii Ossification Variable	257	0.31128	0.55760	0	3.00

Pearson Correlation Results – Entheseal Remodeling (Hawkey & Merbs Method)

Table 47: Pearson Correlation Results – Entheseal Remodeling (Subscapularis, Coimbra Method)

Variable	Variable	Pearson's R	P Value
Subscapularis Left Composite Variable	Subscapularis Right Composite Variable	0.71941	<0.0001
Subscapularis Ossification Variable	Subscapularis Ossification Variable	0.38984	0.0117
Supraspinatus Left Composite Variable	Supraspinatus Right Composite Variable	0.64541	<0.0001
Supraspinatus Ossification Variable	Supraspinatus Ossification Variable	0.28128	0.0828
Infraspinatus Left Composite Variable	Infraspinatus Right Composite Variable	0.29149	0.0718
Infraspinatus Ossification Variable	Infraspinatus Ossification Variable	0.80568	<0.0001
Teres Minor Left Composite Variable	Teres Minor Right Composite Variable	0.41251	0.0138
Teres Minor Ossification Variable	Teres Minor Ossification Variable	-0.04100	0.8124
Extensors Left Composite Variable	Extensors Right Composite Variable	0.66564	<0.0001
Extensors Ossification Variable	Extensors Ossification Variable	0.76241	<0.0001
Flexors Left Composite Variable	Flexors Right Composite Variable	Non est.	Non est.
Flexors Ossification Variable	Flexors Ossification Variable	0.67821	<0.0001
Brachialis Left Composite Variable	Brachialis Right Composite Variable	0.66976	<0.0001
Brachialis Ossification Variable	Brachialis Ossification Variable	0.53043	<0.0001
Brachioradialis Left Composite Variable	Brachioradialis Right Composite Variable	Non est.	Non est.
Brachioradialis Ossification Variable	Brachioradialis Ossification Variable	0.24286	0.2043
Biceps Brachii Left Composite Variable	Biceps Brachii Right Composite Variable	0.16777	0.2393
Biceps Brachii Ossification Variable	Biceps Brachii Ossification Variable	0.54025	<0.0001
Triceps Brachii Left Composite Variable	Triceps Brachii Right Composite Variable	Non est.	Non est.
Triceps Brachii Ossification Variable	Triceps Brachii Ossification Variable	0.23082	0.1227

Zero-Inflated GLM Results – Entheseal Remodeling (Hawkey & Merbs Method)

Table 48: Model Summary – Subscapularis (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	250.4286481	25.0428648	10.40	<0.0001
Error	236	568.4256029	2.4085831		
Corrected Total	246	818.8542510			

Table 49: Zero-Inflated GLM for Entheseal Remodeling – Subscapularis (Robusticity & Stress Lesion Variable)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	0.46977730	0.23488865	0.98	0.3760
Groups	2	4.58126003	2.29063001	9.59	0.0001
Sex	1	0.18054690	0.18054690	0.76	0.3857
Region	1	3.00360571	3.00360571	12.57	0.0005
Lower Limb	2	1.44015129	0.72007564	3.01	0.0513
Upper Limb	2	0.30161571	0.15080786	0.63	0.5330

Comparison	**P Value**
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.0881
Post-Ottoman/Pre-Ottoman	0.0028
Pre-Ottoman/Vlach	0.0275
Post-Ottoman/Vlach	0.8824
Male/Female	0.4555
Adriatic/Continental	0.5160
Large lower limb/Medium lower limb	0.8466
Medium lower limb/Small lower limb	0.3408
Large lower limb/Small lower limb	0.7428
Large upper limb/Medium upper limb	0.4711
Medium upper limb/Small upper limb	0.9939
Large upper limb/Small upper limb	0.6106

Least Squares Means for Different Sources
OA (2.19) > MA (0.69) > YA (0.04)
Post-Ottoman (1.30) > Vlach (1.18) > Pre-Ottoman (0.40)
Female (1.08) > Male (0.87)
Adriatic (1.05) > Continental (0.87)
Medium LL (1.17) > Large LL (1.01) > Small LL (0.70)
Large UL (1.23) > Medium UL (0.84) > Small UL (0.81)

Table 50: Model Summary – Subscapularis (Ossification Variable)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	11.36264695	1.13626470	5.14	<0.0001
Error	238	52.62731289	0.22112316		
Corrected Total	248	63.98995984			

Table 51: Zero-Inflated GLM for Entheseal Remodeling – Subscapularis (Ossification Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	7.58201381	3.79100691	17.14	<0.0001
Groups	2	0.71271744	0.35635872	1.61	0.2017
Sex	1	0.00003343	0.00003343	0.00	0.9902
Region	1	0.25402817	0.25402817	1.15	0.2849
Lower Limb	2	0.40886809	0.20443405	0.92	0.3981
Upper Limb	2	0.40935221	0.20467610	0.93	0.3977

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.6405
Post-Ottoman/Pre-Ottoman	0.4115
Pre-Ottoman/Vlach	0.1846
Post-Ottoman/Vlach	0.7671
Male/Female	0.9902
Adriatic/Continental	0.2849
Large lower limb/Medium lower limb	0.8196
Medium lower limb/Small lower limb	0.4160
Large lower limb/Small lower limb	0.8221
Large upper limb/Medium upper limb	0.6130
Medium upper limb/Small upper limb	0.6305
Large upper limb/Small upper limb	0.3633

Least Squares Means for Different Sources
OA (0.55) > MA (0.14) > YA (0.06)
Pre-Ottoman (0.33) > Post-Ottoman (0.23) > Vlach (0.18)
Male (0.246) > Female (0.245)
Adriatic (0.29) > Continental (0.20)
Small LL (0.31) > Large LL (0.24) > Small LL (0.19)
Large UL (0.37) > Medium UL (0.25) > Small UL (0.16)

Table 52: Model Summary – Supraspinatus (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	148.4950061	14.8495006	7.76	<0.0001
Error	232	444.0872984	1.9141694		
Corrected Total	242	592.5823045			

Table 53: Zero-Inflated GLM for Entheseal Remodeling – Supraspinatus (Robusticity & Stress Lesion Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	75.70163994	37.85081997	19.77	<0.0001
Groups	2	8.83726155	4.41863078	2.31	0.1017
Sex	1	15.33937379	15.33937379	8.01	0.0051
Region	1	0.05837082	0.05837082	0.03	0.8615
Lower Limb	2	1.38127385	0.69063693	0.36	0.6975
Upper Limb	2	75.70163994	37.85081997	19.77	<0.0001
Comparison			**P Value**		
Older adult/Middle-aged adult			<0.0001		
Young adult/Older adult			<0.0001		
Young adult/Middle-aged adult			0.3148		
Post-Ottoman/Pre-Ottoman			0.1258		
Pre-Ottoman/Vlach			0.1525		
Post-Ottoman/Vlach			0.9971		
Male/Female			0.0051		
Adriatic/Continental			0.8872		
Large lower limb/Medium lower limb			0.7820		
Medium lower limb/Small lower limb			0.6757		
Large lower limb/Small lower limb			0.7428		
Large upper limb/Medium upper limb			0.9780		
Medium upper limb/Small upper limb			0.2448		
Large upper limb/Small upper limb			0.5864		
Least Squares Means for Different Sources					
OA (1.64) > MA (0.38) > YA (0.01)					
Vlach (0.85) > Post-Ottoman (0.83) > Pre-Ottoman (0.35)					
Female (0.98) > Male (0.37)					
Continental (0.70) > Adriatic (0.65)					
Large LL (0.82) > Medium LL (0.70) > Small LL (0.51)					
Medium UL (0.85) > Large UL (0.79) > Small UL (0.40)					

Table 54: Model Summary – Supraspinatus (Ossification Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1.60426857	0.16042686	3.89	<.0001
Error	233	9.60372323	0.04121770		
Corrected Total	243	11.20799180			

Table 55: Zero-Inflated GLM for Entheseal Remodeling – Supraspinatus (Ossification Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.97570015	0.48785008	11.84	<0.0001
Groups	2	0.40303214	0.20151607	4.89	0.0083
Sex	1	0.00125299	0.00125299	0.03	0.8617
Region	1	0.00891947	0.00891947	0.22	0.6422
Lower Limb	2	0.01732992	0.00866496	0.21	0.8106
Upper Limb	2	0.08285893	0.04142947	1.01	0.3676

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	0.0009
Young adult/Middle-aged adult	1.0000
Post-Ottoman/Pre-Ottoman	0.0291
Pre-Ottoman/Vlach	0.9998
Post-Ottoman/Vlach	0.0237
Male/Female	0.8614
Adriatic/Continental	0.6422
Large lower limb/Medium lower limb	0.9938
Medium lower limb/Small lower limb	0.8046
Large lower limb/Small lower limb	0.8405
Large upper limb/Medium upper limb	0.3354
Medium upper limb/Small upper limb	0.9999
Large upper limb/Small upper limb	0.5296

Least Squares Means for Different Sources
OA (0.17) > MA (0.0155) > YA (0.0152)
Post-Ottoman (0.13) > Vlach (0.037) > Pre-Ottoman (0.036)
Male (0.07) > Female (0.065)
Continental (0.77) > Adriatic (0.6)
Large LL (0.079) > Medium LL (0.075) > Small LL (0.5)
Large UL (0.11) > Medium UL (0.047) > Small UL (0.046)

Table 56: Model Summary – Infraspinatus (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	189.1605186	18.9160519	7.33	<0.0001
Error	235	606.8394814	2.5822957		
Corrected Total	245	796.0000000			

Table 57: Zero-Inflated GLM for Entheseal Remodeling – Infraspinatus (Robusticity & Stress Lesion Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	67.35191915	33.67595958	13.04	<0.0001
Groups	2	14.38474728	7.19237364	2.79	0.0638
Sex	1	17.67211876	17.67211876	6.84	0.0095
Region	1	3.87750628	3.87750628	1.50	0.2217
Lower Limb	2	7.27814120	3.63907060	1.41	0.2464
Upper Limb	2	8.38267297	4.19133648	1.62	0.1995

Comparison	P Value
Older adult/Middle-aged adult	0.0004
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.0609
Post-Ottoman/Pre-Ottoman	0.1469
Pre-Ottoman/Vlach	0.0660
Post-Ottoman/Vlach	0.8228
Male/Female	0.0095
Adriatic/Continental	0.2217
Large lower limb/Medium lower limb	0.2216
Medium lower limb/Small lower limb	0.9938
Large lower limb/Small lower limb	0.4435
Large upper limb/Medium upper limb	0.7099
Medium upper limb/Small upper limb	0.2164
Large upper limb/Small upper limb	0.8083

Least Squares Means for Different Sources
OA (1.77) > MA (0.75) > YA (0.08)
Vlach (1.15) > Post-Ottoman (0.99) > Pre-Ottoman (0.46)
Female (1.18) > Male (0.55)
Adriatic (1.05) > Continental (0.68)
Large LL (1.21) > Medium LL (0.71) > Small LL (0.67)
Medium UL (1.14) > Large UL (0.87) > Small UL (0.59)

Table 58: Model Summary – Infraspinatus (Ossification Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.90784755	0.09078475	1.32	0.2223
Error	235	16.20698985	0.06896591		
Corrected Total	245	17.11483740			

Table 59: Zero-Inflated GLM for Entheseal Remodeling – Infraspinatus (Ossification Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.38295151	0.19147575	2.78	0.0643
Groups	2	0.11455140	0.05727570	0.83	0.4371
Sex	1	0.00036586	0.00036586	0.01	0.9420
Region	1	0.16935069	0.16935069	2.46	0.1185
Lower Limb	2	0.28666409	0.14333204	2.08	0.1274
Upper Limb	2	0.21371699	0.10685850	1.55	0.2145

Comparison	P Value
Older adult/Middle-aged adult	0.1498
Young adult/Older adult	0.0680
Young adult/Middle-aged adult	0.6140
Post-Ottoman/Pre-Ottoman	0.5099
Pre-Ottoman/Vlach	0.4710
Post-Ottoman/Vlach	0.9821
Male/Female	0.9420
Adriatic/Continental	0.1185
Large lower limb/Medium lower limb	0.1420
Medium lower limb/Small lower limb	0.6504
Large lower limb/Small lower limb	0.8193
Large upper limb/Medium upper limb	0.1853
Medium upper limb/Small upper limb	0.9891
Large upper limb/Small upper limb	0.4444

Least Squares Means for Different Sources
OA (0.14) > MA (0.06) > YA (0.01)
Vlach (0.09) > Post-Ottoman (0.085) > Pre-Ottoman (0.034)
Female (0.07) > Male (0.069)
Continental (0.11) > Adriatic (0.03)
Medium LL (0.19) > Small LL (0.07) > Large LL (0.03)
Large UL (0.13) > Small UL (0.043) > Medium UL (0.035)

Table 60: Model Summary – Teres Minor (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	7.85580904	0.78558090	2.65	0.0045
Error	216	63.93273721	0.29598489		
Corrected Total	226	71.78854626			

Table 61: Zero-Inflated GLM for Entheseal Remodeling – Teres Minor (Robusticity & Stress Lesion Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	3.71872885	1.85936443	6.28	0.0022
Groups	2	1.79622775	0.89811387	3.03	0.0502
Sex	1	0.00788402	0.00788402	0.03	0.8705
Region	1	0.38468233	0.38468233	1.30	0.2555
Lower Limb	2	0.54869572	0.27434786	0.93	0.3973
Upper Limb	2	0.88735125	0.44367562	1.50	0.2257

Comparison	P Value
Older adult/Middle-aged adult	0.0046
Young adult/Older adult	0.0076
Young adult/Middle-aged adult	0.7316
Post-Ottoman/Pre-Ottoman	0.4297
Pre-Ottoman/Vlach	0.0388
Post-Ottoman/Vlach	0.3262
Male/Female	0.8705
Adriatic/Continental	0.2555
Large lower limb/Medium lower limb	0.8618
Medium lower limb/Small lower limb	0.4416
Large lower limb/Small lower limb	0.3940
Large upper limb/Medium upper limb	0.5155
Medium upper limb/Small upper limb	0.4282
Large upper limb/Small upper limb	0.1984

Least Squares Means for Different Sources
OA (0.35) > MA (0.06) > YA (-0.02)
Vlach (0.027) > Post-Ottoman (0.13) > Pre-Ottoman (0.1)
Female (0.14) > Male (0.13)
Continental (0.19) > Adriatic (0.07)
Large LL (0.22) > Medium LL (0.17) > Small LL (0.02)
Small UL (0.27) > Medium UL (0.13) > Large UL (-0.01)

Table 62: Model Summary – Teres Minor (Ossification Variable)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	0.58375865	0.05837586	1.24	0.2677
Error	216	10.18055853	0.04713222		
Corrected Total	226	10.76431718			

Table 63: Zero-Inflated GLM for Entheseal Remodeling – Teres Minor (Ossification Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.35891152	0.17945576	3.81	0.0237
Groups	2	0.08084637	0.04042318	0.86	0.4256
Sex	1	0.04202855	0.04202855	0.89	0.3461
Region	1	0.03501666	0.03501666	0.74	0.3897
Lower Limb	2	0.01845399	0.00922699	0.20	0.8223
Upper Limb	2	0.00087516	0.00043758	0.01	0.9908

Comparison	P Value
Older adult/Middle-aged adult	0.0518
Young adult/Older adult	0.0352
Young adult/Middle-aged adult	0.6622
Post-Ottoman/Pre-Ottoman	0.5311
Pre-Ottoman/Vlach	0.4488
Post-Ottoman/Vlach	0.9678
Male/Female	0.3461
Adriatic/Continental	0.3897
Large lower limb/Medium lower limb	0.9287
Medium lower limb/Small lower limb	0.8798
Large lower limb/Small lower limb	0.8067
Large upper limb/Medium upper limb	0.9998
Medium upper limb/Small upper limb	0.9899
Large upper limb/Small upper limb	0.9962

Least Squares Means for Different Sources
OA (0.12) > MA (0.04) > YA (0.002)
Vlach (0.08) > Post-Ottoman (0.07) > Pre-Ottoman (0.02)
Female (0.07) > Male (0.04)
Continental (0.07) > Adriatic (0.04)
Large LL (0.07) > Medium LL (0.06) > Small LL (0.03)
Small UL (0.06) > Large UL (0.054) > Medium UL (0.053)

Table 64: Model Summary – Extensors (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1.10053132	0.11005313	1.76	0.0678
Error	252	15.73026716	0.06242170		
Corrected Total	262	16.83079848			

Table 65: Zero-Inflated GLM for Entheseal Remodeling – Extensors (Robusticity & Stress Lesion Variable)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	0.16402641	0.08201321	1.31	0.2706
Groups	2	0.08780500	0.04390250	0.70	0.4959
Sex	1	0.27590807	0.27590807	4.42	0.0365
Region	1	0.16586396	0.16586396	2.66	0.1043
Lower Limb	2	0.14756138	0.07378069	1.18	0.3084
Upper Limb	2	0.26483349	0.13241675	2.12	0.1220

Comparison	**P Value**
Older adult/Middle-aged adult	0.2930
Young adult/Older adult	0.4013
Young adult/Middle-aged adult	0.9788
Post-Ottoman/Pre-Ottoman	0.9973
Pre-Ottoman/Vlach	0.5994
Post-Ottoman/Vlach	0.5106
Male/Female	0.0365
Adriatic/Continental	0.1043
Large lower limb/Medium lower limb	0.3732
Medium lower limb/Small lower limb	0.8825
Large lower limb/Small lower limb	0.3607
Large upper limb/Medium upper limb	0.2021
Medium upper limb/Small upper limb	0.3397
Large upper limb/Small upper limb	0.9629

Least Squares Means for Different Sources
OA (0.05) > MA (-0.02) > YA (-0.01)
Post-Ottoman (0.02) > Pre-Ottoman (0.019) > Vlach (-0.02)
Female (0.04) > Male (-0.03)
Adriatic (-0.03) > Continental (0.04)
Large LL (0.05) > Small LL (-0.03) > Medium LL (-0.005)
Medium UL (0.06) > Large UL (-0.03) > Medium UL (-0.01)

Table 66: Model Summary – Extensors (Ossification Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	32.5272318	3.2527232	11.57	<0.0001
Error	256	71.9914948	0.2812168		
Corrected Total	266	104.5187266			

Table 67: Zero-Inflated GLM for Entheseal Remodeling – Extensors (Ossification Variable)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	22.95532958	11.47766479	40.81	<0.0001
Groups	2	2.14337678	1.07168839	3.81	0.0234
Sex	1	0.14280225	0.14280225	0.51	0.4767
Region	1	0.32096799	0.32096799	1.14	0.2864
Lower Limb	2	0.12743846	0.06371923	0.23	0.7974
Upper Limb	2	0.44203439	0.22101720	0.79	0.4568

Comparison	**P Value**
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.1492
Post-Ottoman/Pre-Ottoman	0.0172
Pre-Ottoman/Vlach	0.2481
Post-Ottoman/Vlach	0.5752
Male/Female	0.4767
Adriatic/Continental	0.2864
Large lower limb/Medium lower limb	0.8162
Medium lower limb/Small lower limb	0.9844
Large lower limb/Small lower limb	0.8332
Large upper limb/Medium upper limb	0.8174
Medium upper limb/Small upper limb	0.5865
Large upper limb/Small upper limb	0.4388

Least Squares Means for Different Sources
OA (0.85) > MA (0.22) > YA (0.05)
Pre-Ottoman (0.51) > Vlach (0.35) > Post-Ottoman (0.27)
Female (0.40) > Male (0.35)
Adriatic (0.42) > Continental (0.33)
Small LL (0.41) > Medium LL (0.39) > Large LL (0.33)
Large UL (0.45) > Medium UL (0.39) > Small UL (0.29)

Table 68: Model Summary – Flexors (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	2.71190354	0.27119035	1.01	0.4327
Error	257	68.79835765	0.26769789		
Corrected Total	267	71.51026119			

Table 69: Zero-Inflated GLM for Entheseal Remodeling – Flexors (Robusticity & Stress Lesion Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.92727103	0.46363552	1.73	0.1790
Groups	2	0.29847062	0.14923531	0.56	0.5733
Sex	1	0.52520396	0.52520396	1.96	0.1625
Region	1	0.01819123	0.01819123	0.07	0.7945
Lower Limb	2	0.64772591	0.32386296	1.21	0.2999
Upper Limb	2	0.60141593	0.30070797	1.12	0.3268

Comparison	P Value
Older adult/Middle-aged adult	0.2080
Young adult/Older adult	0.2673
Young adult/Middle-aged adult	0.9480
Post-Ottoman/Pre-Ottoman	0.6457
Pre-Ottoman/Vlach	0.9992
Post-Ottoman/Vlach	0.6511
Male/Female	0.1625
Adriatic/Continental	0.7945
Large lower limb/Medium lower limb	0.2855
Medium lower limb/Small lower limb	0.8216
Large lower limb/Small lower limb	0.8321
Large upper limb/Medium upper limb	0.4059
Medium upper limb/Small upper limb	0.6009
Large upper limb/Small upper limb	0.9584

Least Squares Means for Different Sources
OA (0.20) > MA (0.04) > YA (0.02)
Post-Ottoman (0.13) > Pre-Ottoman (0.06) > Vlach (0.05)
Female (0.13) > Male (0.03)
Adriatic (0.09) > Continental (0.07)
Large LL (0.15) > Small LL (0.08) > Medium LL (0.01)
Medium UL (0.15) > Small UL (0.06) > Large UL (0.02)

Table 70: Model Summary – Flexors (Ossification Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	9.02446066	0.90244607	6.03	<0.0001
Error	261	39.07756140	0.14972246		
Corrected Total	271	48.10202206			

Table 71: Zero-Inflated GLM for Entheseal Remodeling – Flexors (Ossification Variable)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	5.37773765	2.68886882	17.96	<0.0001
Groups	2	0.19402578	0.09701289	0.65	0.5240
Sex	1	0.62241938	0.62241938	4.16	0.0425
Region	1	0.14599640	0.14599640	0.98	0.3243
Lower Limb	2	0.47159604	0.23579802	1.57	0.2090
Upper Limb	2	0.95771223	0.47885612	3.20	0.0424

Comparison	**P Value**
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.5900
Post-Ottoman/Pre-Ottoman	0.7468
Pre-Ottoman/Vlach	0.9208
Post-Ottoman/Vlach	0.5162
Male/Female	0.0425
Adriatic/Continental	0.3243
Large lower limb/Medium lower limb	0.9434
Medium lower limb/Small lower limb	0.1802
Large lower limb/Small lower limb	0.4286
Large upper limb/Medium upper limb	0.8578
Medium upper limb/Small upper limb	0.0325
Large upper limb/Small upper limb	0.3018

Least Squares Means for Different Sources
OA (0.40) > MA (0.08) > YA (0.02)
Post-Ottoman (0.21) > Pre-Ottoman (0.16) > Vlach (0.13)
Female (0.22) > Male (0.11)
Adriatic (0.20) > Continental (0.13)
Small LL (0.25) > Large LL (0.13) > Medium LL (0.11)
Medium UL (0.24) > Large UL (0.20) > Small UL (0.06)

Table 72: Model Summary – Triceps Brachii (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	10.8570499	1.0857050	2.11	0.0240
Error	246	126.2966466	0.5134010		
Corrected Total	256	137.1536965			

Table 73: Zero-Inflated GLM for Entheseal Remodeling – Triceps Brachii (Robusticity & Stress Lesion Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	3.52462119	1.76231060	3.43	0.0339
Groups	2	4.19111708	2.09555854	4.08	0.0180
Sex	1	1.97865137	1.97865137	3.85	0.0508
Region	1	0.25361109	0.25361109	0.49	0.4828
Lower Limb	2	1.39939084	0.69969542	1.36	0.2579
Upper Limb	2	0.58909198	0.29454599	0.57	0.5642

Comparison	P Value
Older adult/Middle-aged adult	0.2229
Young adult/Older adult	0.0263
Young adult/Middle-aged adult	0.2906
Post-Ottoman/Pre-Ottoman	0.0295
Pre-Ottoman/Vlach	0.9515
Post-Ottoman/Vlach	0.0806
Male/Female	0.0508
Adriatic/Continental	0.4828
Large lower limb/Medium lower limb	0.2355
Medium lower limb/Small lower limb	0.9976
Large lower limb/Small lower limb	0.4683
Large upper limb/Medium upper limb	0.9998
Medium upper limb/Small upper limb	0.5389
Large upper limb/Small upper limb	0.6922

Least Squares Means for Different Sources
OA (0.41) > MA (0.22) > YA (0.03)
Post-Ottoman (0.41) > Vlach (0.15) > Pre-Ottoman (0.10)
Female (0.32) > Male (0.12)
Continental (0.26) > Adriatic (0.18)
Large LL (0.36) > Medium LL (0.15) > Small LL (0.14)
Medium UL (0.270) > Large UL (0.267) > Small UL (0.12)

Table 74: Model Summary – Triceps Brachii (Ossification Variable)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	8.76996116	0.87699612	3.05	0.0012
Error	246	70.82731511	0.28791592		
Corrected Total	256	79.59727626			

Table 75: Zero-Inflated GLM for Entheseal Remodeling – Triceps Brachii (Ossification Variable)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	4.95758979	2.47879490	8.61	0.0002
Groups	2	0.24073323	0.12036661	0.42	0.6588
Sex	1	0.07963283	0.07963283	0.28	0.5994
Region	1	0.12632969	0.12632969	0.44	0.5083
Lower Limb	2	0.27886777	0.13943389	0.48	0.6167
Upper Limb	2	0.27517047	0.13758523	0.48	0.6207

Comparison	**P Value**
Older adult/Middle-aged adult	0.0128
Young adult/Older adult	0.0002
Young adult/Middle-aged adult	0.0856
Post-Ottoman/Pre-Ottoman	0.9903
Pre-Ottoman/Vlach	0.7694
Post-Ottoman/Vlach	0.6491
Male/Female	0.5994
Adriatic/Continental	0.5083
Large lower limb/Medium lower limb	0.5880
Medium lower limb/Small lower limb	0.9956
Large lower limb/Small lower limb	0.8176
Large upper limb/Medium upper limb	0.9252
Medium upper limb/Small upper limb	0.6106
Large upper limb/Small upper limb	0.8924

Least Squares Means for Different Sources
OA (0.51) > MA (0.27) > YA (0.06)
Vlach (0.33) > Pre-Ottoman (0.26) > Post Ottoman (0.25)
Female (0.30) > Male (0.26)
Adriatic (0.31) > Continental (0.25)
Large LL (0.34) > Small LL (0.25) > Medium LL (0.24)
Medium UL (0.33) > Large UL (0.29) > Small UL (0.23)

Table 76: Model Summary – Brachialis (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	29.7624532	2.9762453	5.04	<0.0001
Error	285	168.3963306	0.5908643		
Corrected Total	295	198.1587838			

Table 77: Zero-Inflated GLM for Entheseal Remodeling – Brachialis (Robusticity & Stress Lesion Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	8.18673637	4.09336819	6.93	0.0012
Groups	2	12.68835840	6.34417920	10.74	<0.0001
Sex	1	0.11978891	0.11978891	0.20	0.6529
Region	1	3.23391286	3.23391286	5.47	0.0200
Lower Limb	2	1.75758709	0.87879355	1.49	0.2277
Upper Limb	2	0.08874935	0.04437467	0.08	0.9277

Comparison	P Value
Older adult/Middle-aged adult	0.2949
Young adult/Older adult	0.0008
Young adult/Middle-aged adult	0.0112
Post-Ottoman/Pre-Ottoman	0.0968
Pre-Ottoman/Vlach	0.0560
Post-Ottoman/Vlach	<0.0001
Male/Female	0.6529
Adriatic/Continental	0.0200
Large lower limb/Medium lower limb	0.2466
Medium lower limb/Small lower limb	0.6858
Large lower limb/Small lower limb	0.8962
Large upper limb/Medium upper limb	0.9262
Medium upper limb/Small upper limb	0.9981
Large upper limb/Small upper limb	0.9449

Least Squares Means for Different Sources
OA (0.90) > MA (0.74) > YA (0.36)
Vlach (0.96) > Pre-Ottoman (0.65) > Post-Ottoman (0.40)
Female (0.69) > Male (0.64)
Continental (0.81) > Adriatic (0.52)
Medium LL (0.77) > Small LL (0.64) > Large LL (0.57)
Large UL (0.70) > Medium UL (0.65) > Small UL (0.65)

Table 78: Model Summary – Brachialis (Ossification Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	8.33642164	0.83364216	3.59	0.0002
Error	286	66.33697903	0.23194748		
Corrected Total	296	74.67340067			

Table 79: Zero-Inflated GLM for Entheseal Remodeling – Brachialis (Ossification Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.54682239	0.27341119	1.18	0.3091
Groups	2	2.53302627	1.26651313	5.46	0.0047
Sex	1	0.00534313	0.00534313	0.02	0.8795
Region	1	7.17205148	7.17205148	30.92	<0.0001
Lower Limb	2	0.07264820	0.03632410	0.16	0.8551
Upper Limb	2	0.18876765	0.09438383	0.41	0.6661

Comparison	P Value
Older adult/Middle-aged adult	0.8546
Young adult/Older adult	0.2920
Young adult/Middle-aged adult	0.4263
Post-Ottoman/Pre-Ottoman	0.1924
Pre-Ottoman/Vlach	0.0031
Post-Ottoman/Vlach	0.1222
Male/Female	0.8795
Adriatic/Continental	<0.0001
Large lower limb/Medium lower limb	0.9752
Medium lower limb/Small lower limb	0.8520
Large lower limb/Small lower limb	0.9551
Large upper limb/Medium upper limb	0.9823
Medium upper limb/Small upper limb	0.6690
Large upper limb/Small upper limb	0.7070

Least Squares Means for Different Sources
OA (0.44) > MA (0.40) > YA (0.30)
Vlach (0.53) > Post-Ottoman (0.38) > Pre-Ottoman (0.25)
Male (0.39) > Female (0.38)
Continental (0.60) > Adriatic (0.17)
Small LL (0.41) > Large LL (0.36) > Medium LL (0.36)
Large UL (0.42) > Medium UL (0.40) > Small UL (0.33)

Table 80: Model Summary –Biceps Brachii (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	66.8319863	6.6831986	4.74	<0.0001
Error	269	379.1671209	1.4095432		
Corrected Total	279	445.9991071			

Table 81: Zero-Inflated GLM for Entheseal Remodeling – Biceps Brachii (Robusticity & Stress Lesion Variable)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	38.66193834	19.33096917	13.71	<0.0001
Groups	2	3.04393353	1.52196677	1.08	0.3411
Sex	1	0.04977003	0.04977003	0.04	0.8511
Region	1	0.81577456	0.81577456	0.58	0.4475
Lower Limb	2	4.78541999	2.39270999	1.70	0.1851
Upper Limb	2	0.08168725	0.04084362	0.03	0.9714

Comparison	**P Value**
Older adult/Middle-aged adult	0.0002
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.0989
Post-Ottoman/Pre-Ottoman	0.3495
Pre-Ottoman/Vlach	0.9401
Post-Ottoman/Vlach	0.5824
Male/Female	0.8511
Adriatic/Continental	0.4475
Large lower limb/Medium lower limb	0.3736
Medium lower limb/Small lower limb	0.5067
Large lower limb/Small lower limb	0.1686
Large upper limb/Medium upper limb	0.9784
Medium upper limb/Small upper limb	0.9865
Large upper limb/Small upper limb	0.9988

Least Squares Means for Different Sources
OA (1.28) > MA (0.55) > YA (0.18)
Post-Ottoman (0.80) > Vlach (0.61) > Pre-Ottoman (0.53)
Female (0.66) > Male (0.63)
Adriatic (0.72) > Continental (0.57)
Large LL (0.91) > Medium LL (0.65) > Small LL (0.38)
Medium UL (0.67) > Small UL (0.636) > Large UL (0.630)

Table 82: Model Summary – Biceps Brachii (Ossification Variable)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	30.3070558	3.0307056	9.14	<0.0001
Error	272	90.1841103	0.3315592		
Corrected Total	282	120.4911661			

Table 83: Zero-Inflated GLM for Entheseal Remodeling – Biceps Brachii (Ossification Variable)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	24.43352339	12.21676169	36.85	<0.0001
Groups	2	0.19537856	0.09768928	0.29	0.7450
Sex	1	0.50363590	0.50363590	1.52	0.2188
Region	1	0.06574579	0.06574579	0.20	0.6565
Lower Limb	2	0.32352600	0.16176300	0.49	0.6145
Upper Limb	2	0.17755127	0.08877563	0.27	0.7653

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.0145
Post-Ottoman/Pre-Ottoman	0.8850
Pre-Ottoman/Vlach	0.9641
Post-Ottoman/Vlach	0.7381
Male/Female	0.2188
Adriatic/Continental	0.6565
Large lower limb/Medium lower limb	0.7190
Medium lower limb/Small lower limb	0.8611
Large lower limb/Small lower limb	0.6087
Large upper limb/Medium upper limb	0.8731
Medium upper limb/Small upper limb	0.8813
Large upper limb/Small upper limb	0.7459

Least Squares Means for Different Sources
OA (0.95) > MA (0.34) > YA (0.06)
Vlach (0.48) > Pre-Ottoman (0.45) > Post-Ottoman (0.41)
Male (0.50) > Female (0.40)
Continental (0.47) > Adriatic (0.43)
Small LL (0.51) > Medium LL (0.45) > Large LL (0.38)
Large UL (0.50) > Medium UL (0.45) > Small UL (0.40)

Table 84: Model Summary –Brachioradialis (Robusticity & Stress Lesion Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1.00609641	0.10060964	0.95	0.4926
Error	186	19.78578176	0.10637517		
Corrected Total	196	20.79187817			

Table 85: Zero-Inflated GLM for Entheseal Remodeling – Brachioradialis (Robusticity & Stress Lesion Variable)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	0.10290560	0.05145280	0.48	0.6173
Groups	2	0.09615463	0.04807732	0.45	0.6371
Sex	1	0.02112228	0.02112228	0.20	0.6564
Region	1	0.01187241	0.01187241	0.11	0.7387
Lower Limb	2	0.39741476	0.19870738	1.87	0.1573
Upper Limb	2	0.51112649	0.25556324	2.40	0.0933

Comparison	**P Value**
Older adult/Middle-aged adult	0.7749
Young adult/Older adult	0.9757
Young adult/Middle-aged adult	0.6603
Post-Ottoman/Pre-Ottoman	0.9262
Pre-Ottoman/Vlach	0.6224
Post-Ottoman/Vlach	0.7982
Male/Female	0.6564
Adriatic/Continental	0.7387
Large lower limb/Medium lower limb	0.1356
Medium lower limb/Small lower limb	0.9987
Large lower limb/Small lower limb	0.3714
Large upper limb/Medium upper limb	0.0772
Medium upper limb/Small upper limb	0.8446
Large upper limb/Small upper limb	0.4211

Least Squares Means for Different Sources
MA (0.05) > OA (0.01) > YA (-0.002)
Vlach (0.06) > Post-Ottoman (0.02) > Pre-Ottoman (-0.009)
Male (0.03) > Female (0.009)
Continental (0.03) > Adriatic (0.01)
Large LL (0.11) > Medium LL (-0.02) > Small LL (-0.01)
Medium UL (0.09) > Small UL (0.05) > Large UL (-0.07)

Table 86: Model Summary –Brachioradialis (Ossification Variable)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	3.95039418	0.39503942	1.97	0.0391
Error	186	37.36178856	0.20086983		
Corrected Total	196	41.31218274			

Table 87: Zero-Inflated GLM for Entheseal Remodeling – Brachioradialis (Ossification Variable)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	0.06399262	0.03199631	0.16	0.8529
Groups	2	0.91396707	0.45698354	2.28	0.1056
Sex	1	0.38313736	0.38313736	1.91	0.1689
Region	1	0.65895673	0.65895673	3.28	0.0717
Lower Limb	2	1.83382909	0.91691454	4.56	0.0116
Upper Limb	2	0.32190035	0.16095017	0.80	0.4503

Comparison	**P Value**
Older adult/Middle-aged adult	0.8443
Young adult/Older adult	0.9179
Young adult/Middle-aged adult	0.9986
Post-Ottoman/Pre-Ottoman	0.3296
Pre-Ottoman/Vlach	0.0889
Post-Ottoman/Vlach	0.6716
Male/Female	0.1689
Adriatic/Continental	0.0717
Large lower limb/Medium lower limb	0.0610
Medium lower limb/Small lower limb	0.0656
Large lower limb/Small lower limb	0.9760
Large upper limb/Medium upper limb	0.4742
Medium upper limb/Small upper limb	0.9513
Large upper limb/Small upper limb	0.4969

Least Squares Means for Different Sources
OA (0.30) > YA (0.260) > MA (0.56)
Vlach (0.37) > Post-Ottoman (0.29) > Pre-Ottoman (0.16)
Female (0.33) > Male (0.22)
Continental (0.36) > Adriatic (0.19)
Medium LL (0.42) > Large LL (0.21) > Small LL (0.19)
Large UL (0.36) > Medium UL (0.24) > Small UL (0.21)

Summary Statistics – Osteoarthritis (Upper Limb)

Table 88: Summary Statistics – Osteoarthritis (Shoulder Joint Composite)

Variable	N	Mean	Std Dev	Min	Max
Shoulder Lipping	215	0.38255	0.62220	0	2.75
Shoulder Eburnation	222	0.01914	0.11368	0	1.00
Shoulder Porosity	222	0.09797	0.34005	0	2.50
Elbow Lipping	262	0.13577	0.29802	0	1.75
Elbow Eburnation	262	0.01262	0.05619	0	0.50
Elbow Porosity	262	0.02884	0.11918	0	1.00
Wrist Lipping	183	0.17826	0.36567	0	2.00
Wrist Eburnation	179	0.01536	0.08753	0	1.00
Wrist Porosity	179	0.04329	0.18890	0	1.50

Pearson Correlation Results – Osteoarthritis (Upper Limb)

Table 89: Pearson Correlation Results – Osteoarthritis (Shoulder Joint Composite)

Variable	Variable	Pearson's R	P Value
Left Humeral Head Lipping	Right Humeral Head Lipping	0.62434	<0.0001
Left Glenoid Lipping	Right Glenoid Lipping	0.68159	<0.0001
Left Humeral Head Eburnation	Right Humeral Head Eburnation	0.18519	0.0191
Left Glenoid Eburnation	Right Glenoid Eburnation	0.57105	<0.0001
Left Humeral Head Porosity	Right Humeral Head Porosity	0.60084	<0.0001
Left Glenoid Porosity	Right Glenoid Porosity	0.46195	<0.0001

Table 90: Pearson Correlation Results – Osteoarthritis (Elbow Joint Composite)

Variable	Variable	Pearson's R	P Value
Left Capitulum Lipping	Right Capitulum Lipping	0.47209	<0.0001
Left Trochlea Lipping	Right Trochlear Lipping	0.51997	<0.0001
Left Radial Head (Humeral Art.) Lipping	Right Radial Head (Humeral Art.) Lipping	0.12357	0.1172
Left Radial Head (Ulnar Art.) Lipping	Right Radial Head (Ulnar Art.) Lipping	0.60288	<0.0001
Left Trochlear Notch Lipping	Right Trochlear Notch Lipping	0.57628	<0.0001
Left Radial Notch Lipping	Right Radial Notch Lipping	0.53439	<0.0001
Left Capitulum Eburnation	Right Capitulum Eburnation	0.18734	0.0125
Left Trochlea Eburnation	Right Trochlear Eburnation	-0.01039	0.8854
Left Radial Head (Humeral Art.) Eburnation	Right Radial Head (Humeral Art.) Eburnation	0.79904	<0.0001
Left Radial Head (Ulnar Art.) Eburnation	Right Radial Head (Ulnar Art.) Eburnation	Non est.	Non est.
Left Trochlear Notch Eburnation	Right Trochlear Notch Eburnation	Non est.	Non est.
Left Radial Notch Eburnation	Right Radial Notch Eburnation	Non est.	Non est.
Left Capitulum Porosity	Right Capitulum Porosity	0.60873	<0.0001
Left Trochlea Porosity	Right Trochlear Porosity	0.28019	<0.0001
Left Radial Head (Humeral Art.) Porosity	Right Radial Head (Humeral Art.) Porosity	0.48012	<0.0001
Left Radial Head (Ulnar Art.) Porosity	Right Radial Head (Ulnar Art.) Porosity	Non est.	Non est.
Left Trochlear Notch Porosity	Right Trochlear Notch Porosity	-0.02200	0.7650
Left Radial Notch Porosity	Right Radial Notch Porosity	0.77038	<0.0001

Table 91: Pearson Correlation Results – Wrist Joint Composite (Osteoarthritis)

Variable	**Variable**	**Pearson's R**	**P Value**
Left Ulnar Notch Lipping	Right Ulnar Notch Lipping	0.20104	0.0153
Left Scaphoid Articulation Lipping	Right Scaphoid Articulation Lipping	0.37606	<0.0001
Left Lunate Articulation Lipping	Right Lunate Articulation Lipping	0.36562	<0.0001
Left Ulnar Head Lipping	Right Ulnar Head Lipping	0.62154	<0.0001
Left Ulnar Notch Eburnation	Right Ulnar Notch Eburnation	Non est.	Non est.
Left Scaphoid Articulation Eburnation	Right Scaphoid Articulation Eburnation	Non est.	Non est.
Left Lunate Articulation Eburnation	Right Lunate Articulation Eburnation	Non est.	Non est.
Left Ulnar Head Eburnation	Right Ulnar Head Eburnation	0.39114	0.0002
Left Ulnar Notch Porosity	Right Ulnar Notch Porosity	-0.01052	0.9001
Left Scaphoid Articulation Porosity	Right Scaphoid Articulation Porosity	0.09998	0.2315
Left Lunate Articulation Porosity	Right Lunate Articulation Porosity	-0.02105	0.7995
Left Ulnar Head Porosity	Right Ulnar Head Porosity	0.19914	0.0660

Zero-Inflated GLM Results – Osteoarthritis (Upper Limb)

Table 92: Model Summary –Osteoarthritis (Shoulder Joint Lipping)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	30.32185130	3.03218513	11.78	<0.0001
Error	204	52.52524173	0.25747668		
Corrected Total	214	82.84709302			

Table 93: Zero-Inflated GLM Results – Osteoarthritis (Shoulder Joint Lipping)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	17.96036581	8.98018291	34.88	<0.0001
Groups	2	1.12318662	0.56159331	2.18	0.1155
Sex	1	0.01475502	0.01475502	0.06	0.8110
Region	1	0.44942770	0.44942770	1.75	0.1879
Lower Limb	2	0.19141121	0.09570560	0.37	0.6900
Upper Limb	2	1.35124549	0.67562274	2.62	0.0750

Comparison	**P Value**
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.2994
Post-Ottoman/Pre-Ottoman	0.1650
Pre-Ottoman/Vlach	0.1544
Post-Ottoman/Vlach	0.9948
Male/Female	0.8110
Adriatic/Continental	0.1879
Large lower limb/Medium lower limb	0.6650
Medium lower limb/Small lower limb	0.9994
Large lower limb/Small lower limb	0.8581
Large upper limb/Medium upper limb	0.1104
Medium upper limb/Small upper limb	0.6449
Large upper limb/Small upper limb	0.0846

Least Squares Means for Different Sources
OA (0.86) > MA (0.20) > YA (0.06)
Pre-Ottoman (0.50) > Post-Ottoman (0.32) > Vlach (0.31)
Male (0.38) > Female (0.36)
Adriatic (0.44) > Continental (0.30)
Large LL (0.43) > Small LL (0.35) > Medium LL (0.34)
Large UL (0.56) > Medium UL (0.33) > Small UL (0.23)

Table 94: Model Summary –Osteoarthritis (Shoulder Joint Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.14474261	0.01447426	1.13	0.3437
Error	211	2.71139478	0.01285021		
Corrected Total	221	2.85613739			

Table 95: Zero-Inflated GLM Results – Osteoarthritis (Shoulder Joint Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.06625921	0.03312960	2.58	0.0783
Groups	2	0.01327335	0.00663668	0.52	0.5974
Sex	1	0.01558191	0.01558191	1.21	0.2721
Region	1	0.00265609	0.00265609	0.21	0.6498
Lower Limb	2	0.00103273	0.00051637	0.04	0.9606
Upper Limb	2	0.02253134	0.01126567	0.88	0.4177

Comparison	P Value
Older adult/Middle-aged adult	0.0669
Young adult/Older adult	0.2863
Young adult/Middle-aged adult	0.9722
Post-Ottoman/Pre-Ottoman	0.9429
Pre-Ottoman/Vlach	0.5912
Post-Ottoman/Vlach	0.7434
Male/Female	0.2721
Adriatic/Continental	0.6498
Large lower limb/Medium lower limb	0.9893
Medium lower limb/Small lower limb	0.9647
Large lower limb/Small lower limb	0.9917
Large upper limb/Medium upper limb	0.3840
Medium upper limb/Small upper limb	0.9971
Large upper limb/Small upper limb	0.6547

Least Squares Means for Different Sources
OA (0.06) > YA (0.018) > MA (0.013)
Pre-Ottoman (0.039) > Post-Ottoman (0.032) > Vlach (0.017)
Male (0.04) > Female (0.02)
Continental (0.05) > Adriatic (0.02)
Small LL (0.03) > Large LL (0.029) > Medium LL (0.026)
Large UL (0.05) > Small UL (0.020) > Medium UL (0.018)

Table 96: Model Summary – Osteoarthritis (Shoulder Joint Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1.56942658	0.15694266	1.38	0.1909
Error	211	23.98716126	0.11368323		
Corrected Total	221	25.55658784			

Table 97: Zero-Inflated GLM Results – Osteoarthritis (Shoulder Joint Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.76269996	0.38134998	3.35	0.0368
Groups	2	0.02813677	0.01406838	0.12	0.8837
Sex	1	0.00009900	0.00009900	0.00	0.9765
Region	1	0.01952135	0.01952135	0.17	0.6790
Lower Limb	2	0.01356415	0.00678207	0.06	0.9421
Upper Limb	2	0.08086593	0.04043296	0.36	0.7011

Comparison	P Value
Older adult/Middle-aged adult	0.0590
Young adult/Older adult	0.0659
Young adult/Middle-aged adult	0.8387
Post-Ottoman/Pre-Ottoman	0.9999
Pre-Ottoman/Vlach	0.9089
Post-Ottoman/Vlach	0.8961
Male/Female	0.9765
Adriatic/Continental	0.6790
Large lower limb/Medium lower limb	0.9523
Medium lower limb/Small lower limb	0.9793
Large lower limb/Small lower limb	0.9996
Large upper limb/Medium upper limb	0.9653
Medium upper limb/Small upper limb	0.7182
Large upper limb/Small upper limb	0.7132

Least Squares Means for Different Sources
OA (0.19) > MA (0.05) > YA (0.02)
Vlach (0.10) > Post-Ottoman (0.76) > Pre-Ottoman (0.75)
Male (0.086) > Female (0.084)
Adriatic (0.09) > Continental (0.07)
Medium LL (0.10) > Small LL (0.081) > Large LL (0.080)
Large UL (0.11) > Small UL (0.10) > Medium UL (0.04)

Table 98: Model Summary – Osteoarthritis (Elbow Joint Lipping)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	4.15028712	0.41502871	5.47	<0.0001
Error	251	19.03207060	0.07582498		
Corrected Total	261	23.18235771			

Table 99: Zero-Inflated GLM Results – Osteoarthritis (Elbow Joint Lipping)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	2.26665771	1.13332886	14.95	<0.0001
Groups	2	0.41900519	0.20950259	2.76	0.0650
Sex	1	0.00273693	0.00273693	0.04	0.8495
Region	1	0.27125747	0.27125747	3.58	0.0597
Lower Limb	2	0.02871705	0.01435853	0.19	0.8276
Upper Limb	2	0.13864459	0.06932230	0.91	0.4022
Comparison			**P Value**		
Older adult/Middle-aged adult			<0.0001		
Young adult/Older adult			<0.0001		
Young adult/Middle-aged adult			0.8975		
Post-Ottoman/Pre-Ottoman			0.1070		
Pre-Ottoman/Vlach			0.0869		
Post-Ottoman/Vlach			0.9489		
Male/Female			0.8495		
Adriatic/Continental			0.0597		
Large lower limb/Medium lower limb			0.9854		
Medium lower limb/Small lower limb			0.8138		
Large lower limb/Small lower limb			0.9105		
Large upper limb/Medium upper limb			0.9981		
Medium upper limb/Small upper limb			0.3856		
Large upper limb/Small upper limb			0.5047		
Least Squares Means for Different Sources					
OA (0.26) > MA (0.04) > YA (0.01)					
Pre-Ottoman (0.17) > Post-Ottoman (0.08) > Vlach (0.06)					
Male (0.11) > Female (0.10)					
Adriatic (0.15) > Continental (0.05)					
Medium LL (0.12) > Large LL (0.11) > Small LL (0.09)					
Large UL (0.13) > Medium UL (0.12) > Small UL (0.06)					

Table 100: Model Summary – Osteoarthritis (Elbow Joint Eburnation)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	0.06281708	0.00628171	2.07	0.0273
Error	251	0.76145651	0.00303369		
Corrected Total	261	0.82427359			

Table 101: Zero-Inflated GLM Results – Osteoarthritis (Elbow Joint Eburnation)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	0.01260428	0.00630214	2.08	0.1274
Groups	2	0.00179658	0.00089829	0.30	0.7440
Sex	1	0.01405123	0.01405123	4.63	0.0323
Region	1	0.00073796	0.00073796	0.24	0.6223
Lower Limb	2	0.00166092	0.00083046	0.27	0.7608
Upper Limb	2	0.02121975	0.01060987	3.50	0.0318

Comparison	**P Value**
Older adult/Middle-aged adult	0.1235
Young adult/Older adult	0.8012
Young adult/Middle-aged adult	0.5718
Post-Ottoman/Pre-Ottoman	0.9646
Pre-Ottoman/Vlach	0.8926
Post-Ottoman/Vlach	0.7228
Male/Female	0.0323
Adriatic/Continental	0.6223
Large lower limb/Medium lower limb	0.7811
Medium lower limb/Small lower limb	0.9088
Large lower limb/Small lower limb	0.9950
Large upper limb/Medium upper limb	0.6148
Medium upper limb/Small upper limb	0.0267
Large upper limb/Small upper limb	0.3350

Least Squares Means for Different Sources
OA (0.02) > YA (0.01) > MA (0.003)
Vlach (0.016) > Pre-Ottoman (0.01) > Post-Ottoman (0.009)
Female (0.02) > Male (0.004)
Adriatic (0.02) > Continental (0.01)
Large LL (0.02) > Small LL (0.013) > Medium LL (0.008)
Medium UL (0.02) > Large UL (0.015) > Small UL (-0.004)

Table 102: Model Summary – Osteoarthritis (Elbow Joint Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.39153760	0.03915376	2.96	0.0015
Error	251	3.31601629	0.01321122		
Corrected Total	261	3.70755389			

Table 103: Zero-Inflated GLM Results – Osteoarthritis (Elbow Joint Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.12552647	0.06276324	4.75	0.0094
Groups	2	0.03795376	0.01897688	1.44	0.2397
Sex	1	0.02666161	0.02666161	2.02	0.1567
Region	1	0.02961645	0.02961645	2.24	0.1356
Lower Limb	2	0.00976666	0.00488333	0.37	0.6914
Upper Limb	2	0.01958125	0.00979063	0.74	0.4776

Comparison	P Value
Older adult/Middle-aged adult	0.0067
Young adult/Older adult	0.1268
Young adult/Middle-aged adult	0.8909
Post-Ottoman/Pre-Ottoman	0.2497
Pre-Ottoman/Vlach	0.9038
Post-Ottoman/Vlach	0.4876
Male/Female	0.1567
Adriatic/Continental	0.1356
Large lower limb/Medium lower limb	0.8794
Medium lower limb/Small lower limb	0.8064
Large lower limb/Small lower limb	0.6663
Large upper limb/Medium upper limb	0.9954
Medium upper limb/Small upper limb	0.4668
Large upper limb/Small upper limb	0.5609

Least Squares Means for Different Sources
OA (0.06) > YA (0.01) > MA (0.002)
Pre-Ottoman (0.4) > Vlach (0.03) > Post-Ottoman (0.005)
Female (0.04) > Male (0.01)
Adriatic (0.04) > Continental (0.007)
Large LL (0.03) > Medium LL (0.02) > Small LL (0.01)
Large UL (0.034) > Medium UL (0.032) > Small UL (0.004)

Table 104: Model Summary –Osteoarthritis (Wrist Joint Lipping)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	5.63673122	0.56367312	5.18	<0.0001
Error	172	18.70021066	0.10872216		
Corrected Total	182	24.33694188			

Table 105: Zero-Inflated GLM Results – Osteoarthritis (Wrist Joint Lipping)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	1.97843821	0.98921911	9.10	0.0002
Groups	2	0.37832134	0.18916067	1.74	0.1786
Sex	1	0.02739986	0.02739986	0.25	0.6163
Region	1	0.67909794	0.67909794	6.25	0.0134
Lower Limb	2	0.09552591	0.04776295	0.44	0.6452
Upper Limb	2	1.19637432	0.59818716	5.50	0.0048
Comparison			**P Value**		
Older adult/Middle-aged adult			0.0002		
Young adult/Older adult			0.0056		
Young adult/Middle-aged adult			0.9945		
Post-Ottoman/Pre-Ottoman			0.3326		
Pre-Ottoman/Vlach			0.1708		
Post-Ottoman/Vlach			0.8402		
Male/Female			0.6163		
Adriatic/Continental			0.0134		
Large lower limb/Medium lower limb			0.9976		
Medium lower limb/Small lower limb			0.6186		
Large lower limb/Small lower limb			0.7366		
Large upper limb/Medium upper limb			0.0374		
Medium upper limb/Small upper limb			0.1988		
Large upper limb/Small upper limb			0.0039		
Least Squares Means for Different Sources					
OA (0.33) > MA (0.08) > YA (0.07)					
Pre-Ottoman (0.24) > Post-Ottoman (0.14) > Vlach (0.11)					
Male (0.18) > Female (0.15)					
Adriatic (0.26) > Continental (0.07)					
Small LL (0.22) > Large LL (0.14) > Medium LL (0.13)					
Large UL (0.34) > Medium UL (0.15) > Small UL (0.01)					

Table 106: Model Summary – Osteoarthritis (Wrist Joint Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.15034582	0.01503458	2.08	0.0285
Error	168	1.21365557	0.00722414		
Corrected Total	178	1.36400140			

Table 107: Zero-Inflated GLM Results – Osteoarthritis (Wrist Joint Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.04940527	0.02470263	3.42	0.0350
Groups	2	0.02416356	0.01208178	1.67	0.1909
Sex	1	0.00031831	0.00031831	0.04	0.8340
Region	1	0.01246544	0.01246544	1.73	0.1908
Lower Limb	2	0.06161992	0.03080996	4.26	0.0156
Upper Limb	2	0.03734693	0.01867346	2.58	0.0784

Comparison	P Value
Older adult/Middle-aged adult	0.0327
Young adult/Older adult	0.1532
Young adult/Middle-aged adult	0.9994
Post-Ottoman/Pre-Ottoman	0.8295
Pre-Ottoman/Vlach	0.5179
Post-Ottoman/Vlach	0.1656
Male/Female	0.8340
Adriatic/Continental	0.1908
Large lower limb/Medium lower limb	0.9586
Medium lower limb/Small lower limb	0.0138
Large lower limb/Small lower limb	0.0285
Large upper limb/Medium upper limb	1.0000
Medium upper limb/Small upper limb	0.0682
Large upper limb/Small upper limb	0.1651

Least Squares Means for Different Sources
OA (0.04) > YA (0.003) > MA (0.002)
Post-Ottoman (0.03) > Pre-Ottoman (0.02) > Vlach (-0.002)
Male (0.02) > Female (0.01)
Adriatic (0.03) > Continental (0.002)
Small LL (0.06) > Medium LL (-0.004) > Large LL (-0.009)
Large UL (0.0314) > Medium UL (0.0313) > Small UL (-0.02)

Table 108: Model Summary – Osteoarthritis (Wrist Joint Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.61797880	0.06179788	1.81	0.0621
Error	168	5.73397650	0.03413081		
Corrected Total	178	6.35195531			

Table 109: Zero-Inflated GLM Results – Osteoarthritis (Wrist Joint Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.24899302	0.12449651	3.65	0.0281
Groups	2	0.09933520	0.04966760	1.46	0.2363
Sex	1	0.01799298	0.01799298	0.53	0.4688
Region	1	0.04337902	0.04337902	1.27	0.2612
Lower Limb	2	0.05868053	0.02934026	0.86	0.4252
Upper Limb	2	0.07946680	0.03973340	1.16	0.3147

Comparison	P Value
Older adult/Middle-aged adult	0.0253
Young adult/Older adult	0.1466
Young adult/Middle-aged adult	0.9959
Post-Ottoman/Pre-Ottoman	0.8302
Pre-Ottoman/Vlach	0.2276
Post-Ottoman/Vlach	0.4340
Male/Female	0.4688
Adriatic/Continental	0.2612
Large lower limb/Medium lower limb	0.7634
Medium lower limb/Small lower limb	0.4592
Large lower limb/Small lower limb	0.8502
Large upper limb/Medium upper limb	0.7088
Medium upper limb/Small upper limb	0.4903
Large upper limb/Small upper limb	0.2848

Least Squares Means for Different Sources
OA (0.10) > YA (0.014) > MA (0.011)
Pre-Ottoman (0.07) > Post-Ottoman (0.05) > Vlach (0.003)
Male (0.05) > Female (0.03)
Adriatic (0.06) > Continental (0.02)
Small LL (0.07) > Large LL (0.04) > Medium LL (0.01)
Large UL (0.08) > Medium UL (0.05) > Small UL (-0.005)

Summary Statistics – Osteoarthritis (Vertebral Articular Facets)

Table 110: Summary Statistics – Osteoarthritis (Vertebral Articular Facets)

Variable	N	Mean	Std Dev	Min	Max
Zone 1 Lipping	187	0.18272	0.35286	0	2.00
Zone 1 Porosity	187	0.10481	0.26307	0	1.60
Zone 1 Eburnation	187	0.47823	6.10809	0	0.50
Zone 2 Lipping	186	0.22694	0.37351	0	1.70
Zone 2 Porosity	186	0.18677	0.36374	0	2.10
Zone 2 Eburnation	186	0.01326	0.04886	0	0.30
Zone 3 Lipping	188	0.30243	0.40915	0	2.60
Zone 3 Porosity	188	0.07694	0.18198	0	1.40
Zone 3 Eburnation	188	0.01623	0.06656	0	0.60
Zone 4 Lipping	183	0.71132	0.77615	0	3.00
Zone 4 Porosity	184	0.14808	0.38858	0	2.60
Zone 4 Eburnation	183	0.01705	0.05388	0	0.30

Zero-Inflated GLM Results – Osteoarthritis (Vertebral Articular Facets)

Table 111: Model Summary – Osteoarthritis (Articular Facet Zone 1 Lipping)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	5.51525147	0.55152515	5.50	<0.0001
Error	176	17.64381162	0.10024893		
Corrected Total	186	23.15906309			

Table 112: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 1 Lipping)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	2.90759735	1.45379867	14.50	<0.0001
Groups	2	0.12796733	0.06398366	0.64	0.5294
Sex	1	0.00439364	0.00439364	0.04	0.8344
Region	1	0.05280117	0.05280117	0.53	0.4690
Lower Limb	2	0.12832158	0.06416079	0.64	0.5285
Upper Limb	2	0.46948592	0.23474296	2.34	0.0992

Comparison	**P Value**
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.8878
Post-Ottoman/Pre-Ottoman	0.8188
Pre-Ottoman/Vlach	0.8698
Post-Ottoman/Vlach	0.5013
Male/Female	0.8344
Adriatic/Continental	0.4690
Large lower limb/Medium lower limb	0.7049
Medium lower limb/Small lower limb	0.7413
Large lower limb/Small lower limb	0.4985
Large upper limb/Medium upper limb	0.0804
Medium upper limb/Small upper limb	0.9889
Large upper limb/Small upper limb	0.3191

Least Squares Means for Different Sources
OA (0.42) > MA (0.12) > YA (0.09)
Post-Ottoman (0.25) > Pre-Ottoman (0.21) > Vlach (0.18)
Male (0.22) > Female (0.21)
Adriatic (0.23) > Continental (0.19)
Large LL (0.27) > Medium LL (0.21) > Small LL (0.15)
Large UL (0.31) > Medium UL (0.16) > Small UL (0.15)

Table 113: Model Summary – Osteoarthritis (Articular Facet Zone 1 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	2.22057675	0.22205768	3.67	0.0002
Error	176	10.65212843	0.06052346		
Corrected Total	186	12.87270518			

Table 114: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 1 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	1.23916915	0.61958457	10.24	<0.0001
Groups	2	0.14226795	0.07113398	1.18	0.3111
Sex	1	0.02260607	0.02260607	0.37	0.5419
Region	1	0.01343163	0.01343163	0.22	0.6382
Lower Limb	2	0.01470577	0.00735288	0.12	0.8857
Upper Limb	2	0.10701130	0.05350565	0.88	0.4149

Comparison	P Value
Older adult/Middle-aged adult	0.0002
Young adult/Older adult	0.0003
Young adult/Middle-aged adult	0.7236
Post-Ottoman/Pre-Ottoman	0.3049
Pre-Ottoman/Vlach	0.9105
Post-Ottoman/Vlach	0.5674
Male/Female	0.5419
Adriatic/Continental	0.6382
Large lower limb/Medium lower limb	0.9720
Medium lower limb/Small lower limb	0.9080
Large lower limb/Small lower limb	0.8804
Large upper limb/Medium upper limb	0.3994
Medium upper limb/Small upper limb	0.9802
Large upper limb/Small upper limb	0.5306

Least Squares Means for Different Sources
OA (0.26) > MA (0.07) > YA (0.03)
Post-Ottoman (0.16) > Vlach (0.11) > Pre-Ottoman (0.09)
Female (0.13) > Male (0.11)
Adriatic (0.13) > Continental (0.11)
Large LL (0.14) > Medium LL (0.12) > Small LL (0.10)
Large UL (0.17) > Medium UL (0.10) > Small UL (0.09)

Table 115: Model Summary – Osteoarthritis (Articular Facet Zone 1 Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	580.544640	58.054464	1.61	0.1079
Error	176	6358.891432	36.130065		
Corrected Total	186	6939.436073			

Table 116: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 1 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	27.1075187	13.5537593	0.38	0.6877
Groups	2	82.5390140	41.2695070	1.14	0.3215
Sex	1	16.8093105	16.8093105	0.47	0.4961
Region	1	12.8306526	12.8306526	0.36	0.5520
Lower Limb	2	386.9170558	193.4585279	5.35	0.0055
Upper Limb	2	209.7785950	104.8892975	2.90	0.0575
Comparison			**P Value**		
Older adult/Middle-aged adult			0.9042		
Young adult/Older adult			0.9251		
Young adult/Middle-aged adult			0.6759		
Post-Ottoman/Pre-Ottoman			0.3837		
Pre-Ottoman/Vlach			0.9976		
Post-Ottoman/Vlach			0.4353		
Male/Female			0.4961		
Adriatic/Continental			0.5520		
Large lower limb/Medium lower limb			0.9305		
Medium lower limb/Small lower limb			0.0044		
Large lower limb/Small lower limb			0.0194		
Large upper limb/Medium upper limb			0.9113		
Medium upper limb/Small upper limb			0.0457		
Large upper limb/Small upper limb			0.2829		
Least Squares Means for Different Sources					
MA (0.91) > OA (0.42) > MA (-0.10)					
Post-Ottoman (1.44) > Vlach (-0.06) > Pre-Ottoman (-0.14)					
Male (0.79) > Female (0.03)					
Adriatic (0.78) > Continental (0.04)					
Small LL (3.77) > Medium LL (-1.02) > Medium LL (-1.51)					
Medium UL (1.80) > Large UL (1.22) > Small UL (-1.78)					

Table 117: Model Summary – Osteoarthritis (Articular Facet Zone 2 Lipping)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	5.19777172	0.51977717	4.41	<0.0001
Error	175	20.61198229	0.11778276		
Corrected Total	185	25.80975401			

Table 118: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 2 Lipping)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	1.46863783	0.73431891	6.23	0.0024
Groups	2	0.48472613	0.24236306	2.06	0.1308
Sex	1	0.21543513	0.21543513	1.83	0.1780
Region	1	0.24899267	0.24899267	2.11	0.1477
Lower Limb	2	0.08649802	0.04324901	0.37	0.6932
Upper Limb	2	1.03774800	0.51887400	4.41	0.0136
Comparison			**P Value**		
Older adult/Middle-aged adult			0.0053		
Young adult/Older adult			0.0077		
Young adult/Middle-aged adult			0.8377		
Post-Ottoman/Pre-Ottoman			0.9472		
Pre-Ottoman/Vlach			0.3071		
Post-Ottoman/Vlach			0.1307		
Male/Female			0.1780		
Adriatic/Continental			0.1477		
Large lower limb/Medium lower limb			0.6764		
Medium lower limb/Small lower limb			0.9672		
Large lower limb/Small lower limb			0.9167		
Large upper limb/Medium upper limb			0.0361		
Medium upper limb/Small upper limb			0.3862		
Large upper limb/Small upper limb			0.0144		
Least Squares Means for Different Sources					
OA (0.36) > MA (0.16) > YA (0.12)					
Post-Ottoman (0.27) > Pre-Ottoman (0.24) > Vlach (0.14)					
Male (0.26) > Female (0.17)					
Adriatic (0.27) > Continental (0.16)					
Medium LL (0.24) > Small LL (0.22) > Large LL (0.18)					
Large UL (0.39) > Medium UL (0.19) > Small UL (0.07)					

Table 119: Model Summary – Osteoarthritis (Articular Facet Zone 2 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	4.41745894	0.44174589	3.85	<0.0001
Error	175	20.05951682	0.11462581		
Corrected Total	185	24.47697576			

Table 120: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 2 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	1.74564278	0.87282139	7.61	0.0007
Groups	2	0.60530539	0.30265270	2.64	0.0742
Sex	1	0.08628265	0.08628265	0.75	0.3868
Region	1	0.15438561	0.15438561	1.35	0.2474
Lower Limb	2	0.10265604	0.05132802	0.45	0.6398
Upper Limb	2	0.87503794	0.43751897	3.82	0.0238

Comparison	P Value
Older adult/Middle-aged adult	0.0028
Young adult/Older adult	0.0017
Young adult/Middle-aged adult	0.6379
Post-Ottoman/Pre-Ottoman	0.5742
Pre-Ottoman/Vlach	0.4972
Post-Ottoman/Vlach	0.0587
Male/Female	0.3868
Adriatic/Continental	0.2474
Large lower limb/Medium lower limb	0.6350
Medium lower limb/Small lower limb	0.9298
Large lower limb/Small lower limb	0.9347
Large upper limb/Medium upper limb	0.0597
Medium upper limb/Small upper limb	0.4106
Large upper limb/Small upper limb	0.0239

Least Squares Means for Different Sources
OA (0.34) > YA (0.13) > MA (0.07)
Post-Ottoman (0.26) > Vlach (0.10) > Pre-Ottoman (0.19)
Female (0.21) > Male (0.16)
Adriatic (0.23) > Continental (0.14)
Medium LL (0.22) > Small LL (0.18) > Large LL (0.15)
Large UL (0.35) > Medium UL (0.16) > Small UL (0.05)

Table 121: Model Summary – Osteoarthritis (Articular Facet Zone 2 Eburnation)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	0.04186278	0.00418628	1.83	0.0581
Error	175	0.39982062	0.00228469		
Corrected Total	185	0.44168339			

Table 122: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 2 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.01558991	0.00779495	3.41	0.0352
Groups	2	0.00834799	0.00417400	1.83	0.1640
Sex	1	0.00767642	0.00767642	3.36	0.0685
Region	1	0.00243149	0.00243149	1.06	0.3037
Lower Limb	2	0.00160576	0.00080288	0.35	0.7042
Upper Limb	2	0.00164925	0.00082463	0.36	0.6975

Comparison	P Value
Older adult/Middle-aged adult	0.0518
Young adult/Older adult	0.0687
Young adult/Middle-aged adult	0.9201
Post-Ottoman/Pre-Ottoman	0.5329
Pre-Ottoman/Vlach	0.7672
Post-Ottoman/Vlach	0.1440
Male/Female	0.0685
Adriatic/Continental	0.3037
Large lower limb/Medium lower limb	0.7508
Medium lower limb/Small lower limb	0.9381
Large lower limb/Small lower limb	0.7166
Large upper limb/Medium upper limb	0.6842
Medium upper limb/Small upper limb	0.9964
Large upper limb/Small upper limb	0.7850

Least Squares Means for Different Sources
OA (0.03) > YA (0.007) > MA (0.003)
Post-Ottoman (0.02) > Pre-Ottoman (0.01) > Vlach (0.004)
Male (0.02) > Female (0.004)
Adriatic (0.02) > Continental (0.007)
Small LL (0.02) > Medium LL (0.01) > Large LL (0.006)
Large UL (0.02) > Medium UL (0.0098) > Small UL (0.0089)

Table 123: Model Summary – Osteoarthritis (Articular Facet Zone 3 Lipping)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	6.15219513	0.61521951	4.33	<0.0001
Error	177	25.15352379	0.14211030		
Corrected Total	187	31.30571893			

Table 124: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 3 Lipping)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	3.07288959	1.53644479	10.81	<0.0001
Groups	2	0.72259509	0.36129754	2.54	0.0815
Sex	1	0.18104626	0.18104626	1.27	0.2605
Region	1	0.01699228	0.01699228	0.12	0.7299
Lower Limb	2	0.31219371	0.15609685	1.10	0.3357
Upper Limb	2	0.77853429	0.38926715	2.74	0.0674
Comparison			**P Value**		
Older adult/Middle-aged adult			0.0003		
Young adult/Older adult			0.0001		
Young adult/Middle-aged adult			0.4346		
Post-Ottoman/Pre-Ottoman			0.8108		
Pre-Ottoman/Vlach			0.2957		
Post-Ottoman/Vlach			0.0703		
Male/Female			0.2605		
Adriatic/Continental			0.7299		
Large lower limb/Medium lower limb			0.3619		
Medium lower limb/Small lower limb			0.7539		
Large lower limb/Small lower limb			0.9101		
Large upper limb/Medium upper limb			0.0927		
Medium upper limb/Small upper limb			0.7030		
Large upper limb/Small upper limb			0.0822		
Least Squares Means for Different Sources					
OA (0.51) > MA (0.24) > YA (0.15)					
Post-Ottoman (0.37) > Pre-Ottoman (0.33) > Vlach (0.21)					
Male (0.34) > Female (0.26)					
Adriatic (0.31) > Continental (0.29)					
Medium LL (0.36) > Small LL (0.30) > Large LL (0.25)					
Large UL (0.45) > Medium UL (0.26) > Small UL (0.19)					

Table 125: Model Summary – Osteoarthritis (Articular Facet Zone 3 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.81002119	0.08100212	2.66	0.0047
Error	177	5.38348510	0.03041517		
Corrected Total	187	6.19350628			

Table 126: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 3 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.34703983	0.17351992	5.71	0.0040
Groups	2	0.33850977	0.16925489	5.56	0.0045
Sex	1	0.01480788	0.01480788	0.49	0.4862
Region	1	0.01863192	0.01863192	0.61	0.4349
Lower Limb	2	0.01203539	0.00601770	0.20	0.8207
Upper Limb	2	0.02444748	0.01222374	0.40	0.6697

Comparison	P Value
Older adult/Middle-aged adult	0.0075
Young adult/Older adult	0.0112
Young adult/Middle-aged adult	0.8552
Post-Ottoman/Pre-Ottoman	0.0922
Pre-Ottoman/Vlach	0.5461
Post-Ottoman/Vlach	0.0040
Male/Female	0.4862
Adriatic/Continental	0.4349
Large lower limb/Medium lower limb	0.9262
Medium lower limb/Small lower limb	0.8506
Large lower limb/Small lower limb	0.9866
Large upper limb/Medium upper limb	0.9504
Medium upper limb/Small upper limb	0.6999
Large upper limb/Small upper limb	0.6804

Least Squares Means for Different Sources
OA (0.15) > MA (0.05) > YA (0.03)
Post-Ottoman (0.14) > Pre-Ottoman (0.06) > Vlach (0.02)
Female (0.0) > Male (0.06)
Continental (0.09) > Adriatic (0.06)
Medium LL (0.09) > Large LL (0.07) > Small LL (0.06)
Large UL (0.09) > Medium UL (0.08) > Small UL (0.05)

Table 127: Model Summary – Osteoarthritis (Articular Facet Zone 3 Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.09857235	0.00985724	2.39	0.0111
Error	177	0.73008487	0.00412477		
Corrected Total	187	0.82865722			

Table 128: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 3 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.04843828	0.02421914	5.87	0.0034
Groups	2	0.02903059	0.01451530	3.52	0.0317
Sex	1	0.00222886	0.00222886	0.54	0.4633
Region	1	0.00252434	0.00252434	0.61	0.4351
Lower Limb	2	0.01139365	0.00569682	1.38	0.2540
Upper Limb	2	0.01257203	0.00628602	1.52	0.2207

Comparison	P Value
Older adult/Middle-aged adult	0.0028
Young adult/Older adult	0.0381
Young adult/Middle-aged adult	0.9629
Post-Ottoman/Pre-Ottoman	0.6272
Pre-Ottoman/Vlach	0.2484
Post-Ottoman/Vlach	0.0243
Male/Female	0.4633
Adriatic/Continental	0.4351
Large lower limb/Medium lower limb	0.2328
Medium lower limb/Small lower limb	0.8929
Large lower limb/Small lower limb	0.6955
Large upper limb/Medium upper limb	0.2167
Medium upper limb/Small upper limb	0.9516
Large upper limb/Small upper limb	0.3119

Least Squares Means for Different Sources
OA (0.04) > YA (0.006) > MA (0.003)
Post-Ottoman (0.03) > Pre-Ottoman (0.02) > Vlach (-0.001)
Male (0.02) > Female (0.01)
Adriatic (0.02) > Continental (0.01)
Medium LL (0.03) > Small LL (0.02) > Large LL (0.004)
Large UL (0.04) > Medium UL (0.01) > Small UL (0.006)

Table 129: Model Summary – Osteoarthritis (Articular Facet Zone 4 Lipping)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	30.2314383	3.0231438	6.55	<0.0001
Error	172	79.4073601	0.4616707		
Corrected Total	182	109.6387984			

Table 130: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 4 Lipping)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	19.77740374	9.88870187	21.42	<0.0001
Groups	2	3.22489886	1.61244943	3.49	0.0326
Sex	1	0.26640933	0.26640933	0.58	0.4485
Region	1	0.32907698	0.32907698	0.71	0.3997
Lower Limb	2	0.90867480	0.45433740	0.98	0.3759
Upper Limb	2	1.55805676	0.77902838	1.69	0.1880

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.1455
Post-Ottoman/Pre-Ottoman	0.9081
Pre-Ottoman/Vlach	0.1193
Post-Ottoman/Vlach	0.0328
Male/Female	0.4482
Adriatic/Continental	0.3997
Large lower limb/Medium lower limb	0.6100
Medium lower limb/Small lower limb	0.4964
Large lower limb/Small lower limb	0.9710
Large upper limb/Medium upper limb	0.1607
Medium upper limb/Small upper limb	0.9799
Large upper limb/Small upper limb	0.4676

Least Squares Means for Different Sources
OA (1.26) > MA (0.55) > YA (0.29)
Post-Ottoman (0.83) > Pre-Ottoman (0.78) > Vlach (0.48)
Male (0.74) > Female (0.65)
Adriatic (0.76) > Continental (0.64)
Medium LL (0.81) > Large LL (0.67) > Small LL (0.62)
Large UL (0.88) > Small UL (0.62) > Medium UL (0.59)

Table 131: Model Summary – Osteoarthritis (Articular Facet Zone 4 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	4.75294221	0.47529422	3.59	0.0002
Error	173	22.87932167	0.13225041		
Corrected Total	183	27.63226388			

Table 132: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 4 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	2.21454940	1.10727470	8.37	0.0003
Groups	2	0.57000315	0.28500157	2.16	0.1190
Sex	1	0.09495279	0.09495279	0.72	0.3980
Region	1	0.06457617	0.06457617	0.49	0.4856
Lower Limb	2	0.46835581	0.23417791	1.77	0.1733
Upper Limb	2	0.14279019	0.07139509	0.54	0.5838

Comparison	P Value
Older adult/Middle-aged adult	0.0006
Young adult/Older adult	0.0023
Young adult/Middle-aged adult	0.9159
Post-Ottoman/Pre-Ottoman	0.1344
Pre-Ottoman/Vlach	0.9262
Post-Ottoman/Vlach	0.2754
Male/Female	0.3980
Adriatic/Continental	0.4856
Large lower limb/Medium lower limb	0.8353
Medium lower limb/Small lower limb	0.2013
Large lower limb/Small lower limb	0.1845
Large upper limb/Medium upper limb	0.6626
Medium upper limb/Small upper limb	0.8806
Large upper limb/Small upper limb	0.8503

Least Squares Means for Different Sources
OA (0.32) > MA (0.06) > YA (0.03)
Post-Ottoman (0.22) > Vlach (0.11) > Pre-Ottoman (0.08)
Female (0.17) > Male (0.11)
Adriatic (0.16) > Continental (0.11)
Large LL (0.22) > Medium LL (0.17) > Small LL (0.02)
Small UL (0.19) > Medium UL (0.15) > Large UL (0.07)

Table 133: Model Summary – Osteoarthritis (Articular Facet Zone 4 Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.06092450	0.00609245	2.24	0.0176
Error	172	0.46753472	0.00271823		
Corrected Total	182	0.52845922			

Table 134: Zero-Inflated GLM Results – Osteoarthritis (Articular Facet Zone 4 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.03853791	0.01926896	7.09	0.0011
Groups	2	0.01806488	0.00903244	3.32	0.0384
Sex	1	0.00042200	0.00042200	0.16	0.6941
Region	1	0.00006413	0.00006413	0.02	0.8781
Lower Limb	2	0.00063706	0.00031853	0.12	0.8895
Upper Limb	2	0.00359371	0.00179685	0.66	0.5176

Comparison	P Value
Older adult/Middle-aged adult	0.0015
Young adult/Older adult	0.0076
Young adult/Middle-aged adult	0.9767
Post-Ottoman/Pre-Ottoman	0.1457
Pre-Ottoman/Vlach	0.8811
Post-Ottoman/Vlach	0.0451
Male/Female	0.6941
Adriatic/Continental	0.8781
Large lower limb/Medium lower limb	0.9983
Medium lower limb/Small lower limb	0.8789
Large lower limb/Small lower limb	0.9367
Large upper limb/Medium upper limb	0.4908
Medium upper limb/Small upper limb	0.9996
Large upper limb/Small upper limb	0.6760

Least Squares Means for Different Sources
OA (0.04) > MA (0.005) > YA (0.003)
Post-Ottoman (0.03) > Pre-Ottoman (0.01) > Vlach (0.006)
Male (0.018) > Female (0.015)
Adriatic (0.17) > Continental (0.016)
Medium LL (0.0188) > Large LL (0.0181) > Small LL (0.013)
Small UL (0.0213) > Medium UL (0.0209) > Large UL (0.007)

Summary Statistics – Vertebral Osteophytosis

Table 135: Summary Statistics for Vertebral Osteophytosis Zones

Variable	N	Mean	Std Dev	Min	Max
Zone 1 Lipping	196	0.3141	0.51828	0	2.73
Zone 1 Eburnation	196	0.01305	0.06431	0	0.50
Zone 1 Porosity	196	0.20011	0.46246	0	2.67
Zone 2 Lipping	198	0.48613	0.57158	0	2.44
Zone 2 Eburnation	198	0.00036	0.00507	0	0.07
Zone 2 Porosity	198	0.03520	0.19051	0	1.93
Zone 3 Lipping	200	0.65984	0.74120	0	3.00
Zone 3 Eburnation	200	0.00458	0.05920	0	0.83
Zone 3 Porosity	200	0.03133	0.21845	0	2.78
Zone 4 Lipping	207	0.61909	0.70057	0	2.53
Zone 4 Eburnation	207	0	0	0	0.00
Zone 4 Porosity	207	0.09066	0.33132	0	2.40

Zero-Inflated GLM Results – Vertebral Osteophytosis

Table 136: Model Summary – Vertebral Osteophytosis (Zone 1 Lipping)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	14.99677203	1.49967720	7.42	<0.0001
Error	185	37.38434020	0.20207751		
Corrected Total	195	52.38111223			

Table 137: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 1 Lipping)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	8.43176203	4.21588102	20.86	<0.0001
Groups	2	0.66133857	0.33066928	1.64	0.1975
Sex	1	0.04399683	0.04399683	0.22	0.6413
Region	1	0.84504118	0.84504118	4.18	0.0423
Lower Limb	2	0.45086496	0.22543248	1.12	0.3299
Upper Limb	2	0.48649706	0.24324853	1.20	0.3024

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.3048
Post-Ottoman/Pre-Ottoman	0.8371
Pre-Ottoman/Vlach	0.4904
Post-Ottoman/Vlach	0.1722
Male/Female	0.6413
Adriatic/Continental	0.0423
Large lower limb/Medium lower limb	0.3069
Medium lower limb/Small lower limb	0.9118
Large lower limb/Small lower limb	0.7816
Large upper limb/Medium upper limb	0.7785
Medium upper limb/Small upper limb	0.3698
Large upper limb/Small upper limb	0.2935

Least Squares Means for Different Sources
OA (0.64) > YA (0.19) > MA (0.05)
Post-Ottoman (0.36) > Pre-Ottoman (0.31) > Vlach (0.20)
Female (0.31) > Male (0.27)
Adriatic (0.38) > Continental (0.20)
Large LL (0.37) > Small LL (0.28) > Medium LL (0.23)
Large UL (0.39) > Medium UL (0.32) > Small UL (0.17)

Table 138: Model Summary – Vertebral Osteophytosis (Zone 1 Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.10205145	0.01020515	2.68	0.0044
Error	185	0.70443428	0.00380775		
Corrected Total	195	0.80648573			

Table 139: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 1 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.06302352	0.03151176	8.28	0.0004
Groups	2	0.00741115	0.00370558	0.97	0.3798
Sex	1	0.00087546	0.00087546	0.23	0.6322
Region	1	0.00160065	0.00160065	0.42	0.5176
Lower Limb	2	0.00030570	0.00015285	0.04	0.9607
Upper Limb	2	0.01769669	0.00884835	2.32	0.1008

Comparison	P Value
Older adult/Middle-aged adult	0.0002
Young adult/Older adult	0.0237
Young adult/Middle-aged adult	0.8420
Post-Ottoman/Pre-Ottoman	0.5530
Pre-Ottoman/Vlach	0.3727
Post-Ottoman/Vlach	0.9025
Male/Female	0.6322
Adriatic/Continental	0.5176
Large lower limb/Medium lower limb	0.9980
Medium lower limb/Small lower limb	0.9572
Large lower limb/Small lower limb	0.9809
Large upper limb/Medium upper limb	0.0817
Medium upper limb/Small upper limb	0.9891
Large upper limb/Small upper limb	0.3401

Least Squares Means for Different Sources
OA (0.05) > MA (0.002) > YA (0.009)
Pre-Ottoman (0.03) > Post-Ottoman (0.02) > Vlach (0.01)
Female (0.021) > Male (0.016)
Adriatic (0.023) > Continental (0.015)
Small LL (0.022) > Large LL (0.018) > Medium LL (0.017)
Large UL (0.04) > Small UL (0.01) > Medium UL (0.008)

Table 140: Model Summary – Vertebral Osteophytosis (Zone 1 Porosity)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	9.91139287	0.99113929	5.77	<0.0001
Error	185	31.79392720	0.17185907		
Corrected Total	195	41.70532007			

Table 141: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 1 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	6.51220917	3.25610459	18.95	<0.0001
Groups	2	0.21401532	0.10700766	0.62	0.5376
Sex	1	0.03729118	0.03729118	0.22	0.6419
Region	1	0.04305399	0.04305399	0.25	0.6173
Lower Limb	2	0.41311129	0.20655564	1.20	0.3030
Upper Limb	2	0.00253219	0.00126610	0.01	0.9927

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.7958
Post-Ottoman/Pre-Ottoman	0.5197
Pre-Ottoman/Vlach	0.9163
Post-Ottoman/Vlach	0.7936
Male/Female	0.6419
Adriatic/Continental	0.6173
Large lower limb/Medium lower limb	0.3922
Medium lower limb/Small lower limb	0.7702
Large lower limb/Small lower limb	0.3193
Large upper limb/Medium upper limb	0.9998
Medium upper limb/Small upper limb	0.9923
Large upper limb/Small upper limb	0.9942

Least Squares Means for Different Sources
OA (0.51) > MA (0.08) > YA (0.03)
Post-Ottoman (0.25) > Vlach (0.20) > Pre-Ottoman (0.17)
Female (0.22) > Male (0.19)
Adriatic (0.27) > Continental (0.19)
Large LL (0.31) > Medium LL (0.19) > Small LL (0.12)
Large UL (0.21) > Medium UL (0.209) > Small UL (0.197)

Table 142: Model Summary – Vertebral Osteophytosis (Zone 2 Lipping)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	16.48715804	1.64871580	6.44	<0.0001
Error	187	47.87346982	0.25600786		
Corrected Total	197	64.36062785			

Table 143: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 2 Lipping)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	9.73776554	4.86888277	19.02	<0.0001
Groups	2	0.99660283	0.49830142	1.95	0.1457
Sex	1	0.01738466	0.01738466	0.07	0.7947
Region	1	0.73439243	0.73439243	2.87	0.0920
Lower Limb	2	0.11640916	0.05820458	0.23	0.7969
Upper Limb	2	0.41550813	0.20775406	0.81	0.4457

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.0144
Post-Ottoman/Pre-Ottoman	0.6202
Pre-Ottoman/Vlach	0.6332
Post-Ottoman/Vlach	0.1225
Male/Female	0.7947
Adriatic/Continental	0.0920
Large lower limb/Medium lower limb	0.8861
Medium lower limb/Small lower limb	0.8940
Large lower limb/Small lower limb	0.7810
Large upper limb/Medium upper limb	0.4132
Medium upper limb/Small upper limb	0.9999
Large upper limb/Small upper limb	0.6481

Least Squares Means for Different Sources
OA (0.82) > MA (0.41) > YA (0.12)
Post-Ottoman (0.55) > Pre-Ottoman (0.45) > Vlach (0.35)
Female (0.46) > Male (0.44)
Adriatic (0.54) > Continental (0.36)
Large LL (0.50) > Medium LL (0.45) > Small LL (0.39)
Large UL (0.56) > Medium UL (0.399) > Small UL (0.397)

Table 144: Model Summary – Vertebral Osteophytosis (Zone 2 Eburnation)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	10	0.00030160	0.00003016	1.18	0.3064
Error	187	0.00477771	0.00002555		
Corrected Total	197	0.00507932			

Table 145: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 2 Eburnation)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	0.00007900	0.00003950	1.55	0.2158
Groups	2	0.00007286	0.00003643	1.43	0.2429
Sex	1	0.00000165	0.00000165	0.06	0.7997
Region	1	0.00000502	0.00000502	0.20	0.6582
Lower Limb	2	0.00011410	0.00005705	2.23	0.1101
Upper Limb	2	0.00007589	0.00003795	1.49	0.2291

Comparison	**P Value**
Older adult/Middle-aged adult	0.2095
Young adult/Older adult	0.3944
Young adult/Middle-aged adult	1.0000
Post-Ottoman/Pre-Ottoman	0.4895
Pre-Ottoman/Vlach	0.9213
Post-Ottoman/Vlach	0.2437
Male/Female	0.7997
Adriatic/Continental	0.6582
Large lower limb/Medium lower limb	0.0914
Medium lower limb/Small lower limb	0.9445
Large lower limb/Small lower limb	0.4830
Large upper limb/Medium upper limb	0.1994
Medium upper limb/Small upper limb	0.9991
Large upper limb/Small upper limb	0.4796

Least Squares Means for Different Sources
OA (0.001) > MA (-0.0002) > YA (-0.0002)
Post-Ottoman (0.001) > Pre-Ottoman (0.00) > Vlach (-0.0004)
Male (0.0003) > Female (0.0001)
Adriatic (0.0005) > Continental (0.00002)
Large LL (0.002) > Small LL (-0.0002) > Medium LL (-0.0006)
Medium UL (0.0009) > Small UL (0.0008) > Large UL (-0.001)

Table 146: Model Summary – Vertebral Osteophytosis (Zone 2 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.54471261	0.05447126	1.54	0.1274
Error	187	6.60549010	0.03532348		
Corrected Total	197	7.15020271			

Table 147: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 2 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.16001982	0.08000991	2.27	0.1067
Groups	2	0.01183370	0.00591685	0.17	0.8459
Sex	1	0.13724804	0.13724804	3.89	0.0502
Region	1	0.01076293	0.01076293	0.30	0.5816
Lower Limb	2	0.05369247	0.02684623	0.76	0.4691
Upper Limb	2	0.04532986	0.02266493	0.64	0.5276

Comparison	P Value
Older adult/Middle-aged adult	0.1210
Young adult/Older adult	0.1968
Young adult/Middle-aged adult	0.9670
Post-Ottoman/Pre-Ottoman	0.8655
Pre-Ottoman/Vlach	0.9976
Post-Ottoman/Vlach	0.8896
Male/Female	0.0502
Adriatic/Continental	0.5816
Large lower limb/Medium lower limb	0.4528
Medium lower limb/Small lower limb	0.9814
Large lower limb/Small lower limb	0.6092
Large upper limb/Medium upper limb	0.8106
Medium upper limb/Small upper limb	0.6315
Large upper limb/Small upper limb	0.5009

Least Squares Means for Different Sources
OA (0.07) > MA (0.02) > YA (0.01)
Post-Ottoman (0.05) > Vlach (0.04) > Pre-Ottoman (0.03)
Female (0.07) > Male (0.005)
Adriatic (0.05) > Continental (0.03)
Large LL (0.07) > Medium LL (0.03) > Small LL (0.02)
Large UL (0.07) > Medium UL (0.05) > Small UL (0.002)

Table 148: Model Summary – Vertebral Osteophytosis (Zone 3 Lipping))

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	38.1602164	3.8160216	10.13	<0.0001
Error	189	71.1663219	0.3765414		
Corrected Total	199	109.3265383			

Table 149: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 3 Lipping)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	17.82924809	8.91462404	23.68	<0.0001
Groups	2	4.69549328	2.34774664	6.24	0.0024
Sex	1	0.53948115	0.53948115	1.43	0.2328
Region	1	2.66502557	2.66502557	7.08	0.0085
Lower Limb	2	0.11716405	0.05858202	0.16	0.8560
Upper Limb	2	3.85005972	1.92502986	5.11	0.0069

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.0133
Post-Ottoman/Pre-Ottoman	0.9957
Pre-Ottoman/Vlach	0.0083
Post-Ottoman/Vlach	0.0051
Male/Female	0.2328
Adriatic/Continental	0.0085
Large lower limb/Medium lower limb	0.8457
Medium lower limb/Small lower limb	0.9991
Large lower limb/Small lower limb	0.9144
Large upper limb/Medium upper limb	0.0050
Medium upper limb/Small upper limb	0.8557
Large upper limb/Small upper limb	0.1756

Least Squares Means for Different Sources
OA (1.13) > MA (0.56) > YA (0.21)
Pre-Ottoman (0.76) > Post-Ottoman (0.75) > Vlach (0.38)
Male (0.70) > Female (0.56)
Adriatic (0.79) > Continental (0.47)
Large LL (0.68) > Medium LL (0.61) > Small LL (0.60)
Large UL (0.90) > Small UL (0.54) > Medium UL (0.46)

Table 150: Model Summary – Vertebral Osteophytosis (Zone 3 Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.03868713	0.00386871	1.11	0.3567
Error	189	0.65880292	0.00348573		
Corrected Total	199	0.69749006			

Table 151: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 3 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.01059649	0.00529825	1.52	0.2214
Groups	2	0.01107460	0.00553730	1.59	0.2069
Sex	1	0.00016192	0.00016192	0.05	0.8296
Region	1	0.00000056	0.00000056	0.00	0.9899
Lower Limb	2	0.00035717	0.00017859	0.05	0.9501
Upper Limb	2	0.01087252	0.00543626	1.56	0.2129

Comparison	P Value
Older adult/Middle-aged adult	0.2042
Young adult/Older adult	0.4472
Young adult/Middle-aged adult	0.9914
Post-Ottoman/Pre-Ottoman	0.4789
Pre-Ottoman/Vlach	0.8693
Post-Ottoman/Vlach	0.2017
Male/Female	0.8296
Adriatic/Continental	0.9899
Large lower limb/Medium lower limb	0.9728
Medium lower limb/Small lower limb	0.9676
Large lower limb/Small lower limb	0.9989
Large upper limb/Medium upper limb	0.1841
Medium upper limb/Small upper limb	0.9901
Large upper limb/Small upper limb	0.5043

Least Squares Means for Different Sources
OA (0.02) > YA (0.005) > MA (0.004)
Post-Ottoman (0.02) > Pre-Ottoman (0.008) > Vlach (0.002)
Male (0.01) > Female (0.009)
Adriatic (0.0105) > Continental (0.0103)
Small LL (0.012) > Large LL (0.011) > Medium LL (0.008)
Large UL (0.03) > Small UL (0.004) > Large UL (0.002)

Table 152: Model Summary – Vertebral Osteophytosis (Zone 3 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.53324907	0.05332491	1.12	0.3459
Error	189	8.96341706	0.04742549		
Corrected Total	199	9.49666614			

Table 153: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 3 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.06886759	0.03443379	0.73	0.4852
Groups	2	0.13684996	0.06842498	1.44	0.2389
Sex	1	0.00002786	0.00002786	0.00	0.9807
Region	1	0.00065034	0.00065034	0.01	0.9069
Lower Limb	2	0.02792515	0.01396258	0.29	0.7453
Upper Limb	2	0.09613131	0.04806566	1.01	0.3649

Comparison	P Value
Older adult/Middle-aged adult	0.5932
Young adult/Older adult	0.5013
Young adult/Middle-aged adult	0.9064
Post-Ottoman/Pre-Ottoman	0.2836
Pre-Ottoman/Vlach	0.9798
Post-Ottoman/Vlach	0.3815
Male/Female	0.9807
Adriatic/Continental	0.9069
Large lower limb/Medium lower limb	0.7345
Medium lower limb/Small lower limb	0.9737
Large lower limb/Small lower limb	0.9424
Large upper limb/Medium upper limb	0.3463
Medium upper limb/Small upper limb	0.9727
Large upper limb/Small upper limb	0.4955

Least Squares Means for Different Sources
OA (0.08) > MA (0.04) > YA (0.02)
Post-Ottoman (0.09) > Vlach (0.03) > Pre-Ottoman (0.02)
Female (0.047) > Male (0.046)
Adriatic (0.049) > Continental (0.044)
Large LL (0.07) > Small LL (0.04) > Medium LL (0.03)
Large UL (0.10) > Medium UL (0.03) > Small UL (0.02)

Table 154: Model Summary – Vertebral Osteophytosis (Zone 4 Lipping)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	21.6940969	2.1694097	5.35	<0.0001
Error	196	79.4131397	0.4051691		
Corrected Total	206	101.1072366			

Table 155: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 4 Lipping)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	11.54158689	5.77079344	14.24	<0.0001
Groups	2	0.94395137	0.47197569	1.16	0.3141
Sex	1	0.07090503	0.07090503	0.18	0.6762
Region	1	0.88655920	0.88655920	2.19	0.1407
Lower Limb	2	0.40018500	0.20009250	0.49	0.6110
Upper Limb	2	0.64236037	0.32118019	0.79	0.4541

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.0227
Post-Ottoman/Pre-Ottoman	0.6217
Pre-Ottoman/Vlach	0.2829
Post-Ottoman/Vlach	0.7479
Male/Female	0.6762
Adriatic/Continental	0.1407
Large lower limb/Medium lower limb	0.6215
Medium lower limb/Small lower limb	0.9640
Large lower limb/Small lower limb	0.6792
Large upper limb/Medium upper limb	0.9306
Medium upper limb/Small upper limb	0.4679
Large upper limb/Small upper limb	0.4877

Least Squares Means for Different Sources
OA (0.93) > MA (0.52) > YA (0.19)
Pre-Ottoman (0.65) > Post-Ottoman (0.54) > Vlach (0.45)
Female (0.57) > Male (0.52)
Adriatic (0.64) > Continental (0.45)
Large LL (0.64) > Medium LL (0.52) > Small LL (0.48)
Large UL (0.64) > Medium UL (0.59) > Small UL (0.41)

Table 156: Model Summary – Vertebral Osteophytosis (Zone 4 Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0	0	Non est.	Non est.
Error	196	0	0		
Corrected Total	206	0			

Table 157: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 4 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0	0	Non est.	Non est.
Groups	2	0	0	Non est.	Non est.
Sex	1	0	0	Non est.	Non est.
Region	1	0	0	Non est.	Non est.
Lower Limb	2	0	0	Non est.	Non est.
Upper Limb	2	0	0	Non est.	Non est.

Comparison	P Value
Older adult/Middle-aged adult	Non est.
Young adult/Older adult	Non est.
Young adult/Middle-aged adult	Non est.
Post-Ottoman/Pre-Ottoman	Non est.
Pre-Ottoman/Vlach	Non est.
Post-Ottoman/Vlach	Non est.
Male/Female	Non est.
Adriatic/Continental	Non est.
Large lower limb/Medium lower limb	Non est.
Medium lower limb/Small lower limb	Non est.
Large lower limb/Small lower limb	Non est.
Large upper limb/Medium upper limb	Non est.
Medium upper limb/Small upper limb	Non est.
Large upper limb/Small upper limb	Non est.

Least Squares Means for Different Sources
All least squares means for age are 0
All least squares means for group are 0
All least squares means for sex are 0
All least squares means for region are 0
All least squares means for body size (lower limb) are 0
All least squares means for body size (upper limb) are 0

Table 158: Model Summary – Vertebral Osteophytosis (Zone 4 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1.48803441	0.14880344	1.38	0.1915
Error	196	21.12585060	0.10778495		
Corrected Total	206	22.61388501			

Table 159: Zero-Inflated GLM Results – Vertebral Osteophytosis (Zone 4 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.36004625	0.18002313	1.67	0.1909
Groups	2	0.16295921	0.08147961	0.76	0.4709
Sex	1	0.03885611	0.03885611	0.36	0.5489
Region	1	0.10263851	0.10263851	0.95	0.3303
Lower Limb	2	0.30098998	0.15049499	1.40	0.2500
Upper Limb	2	0.12046524	0.06023262	0.56	0.5728

Comparison	P Value
Older adult/Middle-aged adult	0.3830
Young adult/Older adult	0.1803
Young adult/Middle-aged adult	0.6659
Post-Ottoman/Pre-Ottoman	0.5354
Pre-Ottoman/Vlach	0.9970
Post-Ottoman/Vlach	0.5830
Male/Female	0.5489
Adriatic/Continental	0.3303
Large lower limb/Medium lower limb	0.2357
Medium lower limb/Small lower limb	0.9590
Large lower limb/Small lower limb	0.7721
Large upper limb/Medium upper limb	0.3306
Medium upper limb/Small upper limb	0.5428
Large upper limb/Small upper limb	0.7626

Least Squares Means for Different Sources
OA (0.15) > MA (0.08) > YA (0.02)
Post-Ottoman (0.13) > Vlach (0.064) > Pre-Ottoman (0.059)
Female (0.10) > Male (0.07)
Adriatic (0.11) > Continental (0.05)
Large LL (0.14) > Small LL (0.07) > Medium LL (0.03)
Medium UL (0.11) > Large UL (0.10) > Small UL (0.03)

Summary Statistics – Osteoarthritis (Costal Articulations)

Table 160: Summary Statistics – Osteoarthritis (Costal Articulations)

Variable	N	Mean	Std Dev	Min	Max
Zone 2 Left Lipping	179	0.21885	0.25498	0	1.25
Zone 2 Left Eburnation	179	0.00096	0.00910	0	0.08
Zone 2 Left Porosity	179	0.13372	0.21003	0	1.25
Zone 2 Right Lipping	179	0.21966	0.25041	0	1.06
Zone 2 Right Eburnation	179	0.00390	0.02814	0	0.33
Zone 2 Right Porosity	179	0.13709	0.22231	0	1.73
Zone 3 Left Lipping	175	0.53524	0.55012	0	2.33
Zone 3 Left Eburnation	175	0.00786	0.06449	0	0.75
Zone 3 Left Porosity	175	0.36476	0.50834	0	2.33
Zone 3 Right Lipping	175	0.51881	0.54211	0	2.00
Zone 3 Right Eburnation	175	0.01000	0.06625	0	0.50
Zone 3 Right Porosity	175	0.35309	0.48726	0	2.00
Zone 2 Lipping	179	0.21925	0.24866	0	1.16
Zone 2 Eburnation	179	0.00243	0.0164	0	0.17
Zone 2 Porosity	179	0.1354	0.21017	0	1.49
Zone 3 Lipping	175	0.52702	0.52249	0	2.13
Zone 3 Eburnation	175	0.00892	0.05982	0	0.63
Zone 3 Porosity	175	0.35892	0.46893	0	2.00

Pearson Correlation Results – Osteoarthritis (Costal Articulations)

Table 161: Pearson Correlation Results – Osteoarthritis (Costal Articulations)

Variable	**Variable**	**Pearson's R**	**P Value**
Zone 2 Lipping (Left)	Zone 2 Lipping (Right)	0.93669	<0.0001
Zone 2 Eburnation (Left)	Zone 2 Eburnation (Right)	0.40377	<0.0001
Zone 2 Porosity (Left)	Zone 2 Porosity (Right)	0.89059	<0.0001
Zone 3 Lipping (Left)	Zone 3 Lipping (Right)	0.83076	<0.0001
Zone 3 Eburnation (Left)	Zone 3 Eburnation (Right)	0.67512	<0.0001
Zone 3 Porosity (Left)	Zone 3 Porosity (Right)	0.77465	<0.0001

Zero-Inflated GLM Results – Osteoarthritis (Costal Articulations)

Table 162: Model Summary – Costal Osteoarthritis (Zone 1 Lipping)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	14.99677203	1.49967720	7.42	<0.0001
Error	185	37.38434020	0.20207751		
Corrected Total	195	52.38111223			

Table 163: Zero-Inflated GLM Results – Costal Osteoarthritis (Zone 2 Lipping)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	8.43176203	4.21588102	20.86	<0.0001
Groups	2	0.66133857	0.33066928	1.64	0.1975
Sex	1	0.04399683	0.04399683	0.22	0.6413
Region	1	0.84504118	0.84504118	4.18	0.0423
Lower Limb	2	0.45086496	0.22543248	1.12	0.3299
Upper Limb	2	0.48649706	0.24324853	1.20	0.3024

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.3048
Post-Ottoman/Pre-Ottoman	0.6057
Pre-Ottoman/Vlach	0.5875
Post-Ottoman/Vlach	0.0947
Male/Female	0.8221
Adriatic/Continental	0.1745
Large lower limb/Medium lower limb	0.9898
Medium lower limb/Small lower limb	0.7311
Large lower limb/Small lower limb	0.8639
Large upper limb/Medium upper limb	0.1140
Medium upper limb/Small upper limb	0.9999
Large upper limb/Small upper limb	0.3609

Least Squares Means for Different Sources
OA (0.36) > MA (0.17) > YA (0.10)
Post-Ottoman (0.26) > Pre-Ottoman (0.21) > Vlach (0.17)
Female (0.22) > Male (0.21)
Adriatic (0.25) > Continental (0.18)
Medium LL (0.23) > Large LL (0.22) > Small LL (0.19)
Large UL (0.29) > Medium UL (0.1788) > Small UL (0.1782)

Table 164: Model Summary – Costal Osteoarthritis (Zone 2 Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.00327602	0.00032760	1.23	0.0044
Error	168	0.04485471	0.00026699		
Corrected Total	178	0.04813073			

Table 165: Zero-Inflated GLM Results – Costal Osteoarthritis (Zone 2 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.00062716	0.00031358	1.17	0.3115
Groups	2	0.00045538	0.00022769	0.85	0.4281
Sex	1	0.00018711	0.00018711	0.70	0.4037
Region	1	0.00003897	0.00003897	0.15	0.7029
Lower Limb	2	0.00112614	0.00056307	2.11	0.1246
Upper Limb	2	0.00139004	0.00069502	2.60	0.0770

Comparison	P Value
Older adult/Middle-aged adult	0.4638
Young adult/Older adult	0.3232
Young adult/Middle-aged adult	0.8138
Post-Ottoman/Pre-Ottoman	0.4136
Pre-Ottoman/Vlach	0.8910
Post-Ottoman/Vlach	0.6633
Male/Female	0.4037
Adriatic/Continental	0.7029
Large lower limb/Medium lower limb	0.9612
Medium lower limb/Small lower limb	0.1120
Large lower limb/Small lower limb	0.1766
Large upper limb/Medium upper limb	0.6618
Medium upper limb/Small upper limb	0.0830
Large upper limb/Small upper limb	0.5493

Least Squares Means for Different Sources
OA (0.006) > MA (0.002) > YA (0.0007)
Post-Ottoman (0.006) > Vlach (0.003) > Pre-Ottoman (0.001)
Female (0.005) > Male (0.002)
Continental (0.004) > Adriatic (0.003)
Large LL (0.007) > Medium LL (0.006) > Small LL (-0.003)
Small UL (0.008) > Large UL (0.002) > Medium UL (-0.0009)

Table 166: Model Summary – Costal Osteoarthritis (Zone 2 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1.46870570	0.14687057	3.86	0.0001
Error	168	6.39432388	0.03806145		
Corrected Total	178	7.86302958			

Table 167: Zero-Inflated GLM Results – Costal Osteoarthritis (Zone 2 Porosity)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.54294714	0.27147357	7.13	0.0011
Groups	2	0.09840218	0.04920109	1.29	0.2773
Sex	1	0.04813751	0.04813751	1.26	0.2624
Region	1	0.01328300	0.01328300	0.35	0.5555
Lower Limb	2	0.04379591	0.02189795	0.58	0.5636
Upper Limb	2	0.12987537	0.06493769	1.71	0.1847
Comparison			**P Value**		
Older adult/Middle-aged adult			0.0126		
Young adult/Older adult			0.0013		
Young adult/Middle-aged adult			0.2601		
Post-Ottoman/Pre-Ottoman			0.2746		
Pre-Ottoman/Vlach			0.8716		
Post-Ottoman/Vlach			0.5065		
Male/Female			0.2624		
Adriatic/Continental			0.5555		
Large lower limb/Medium lower limb			0.8790		
Medium lower limb/Small lower limb			0.5857		
Large lower limb/Small lower limb			0.8836		
Large upper limb/Medium upper limb			0.1944		
Medium upper limb/Small upper limb			0.8504		
Large upper limb/Small upper limb			0.2468		
Least Squares Means for Different Sources					
OA (0.22) > MA (0.12) > YA (0.05)					
Post-Ottoman (0.17) > Vlach (0.13) > Pre-Ottoman (0.10)					
Female (0.15) > Male (0.11)					
Adriatic (0.15) > Continental (0.12)					
Medium LL (0.16) > Large LL (0.14) > Small LL (0.11)					
Large UL (0.20) > Medium UL (0.0.12) > Small UL (0.09)					

Table 168: Model Summary – Costal Osteoarthritis (Zone 3 Lipping)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	12.73246357	1.27324636	6.01	<0.0001
Error	164	34.77047397	0.21201509		
Corrected Total	174	47.50293754			

Table 169: Zero-Inflated GLM Results – Costal Osteoarthritis (Zone 3 Lipping)

Source	**DF**	**Type III Sum of Squares**	**Mean Square**	**F Value**	**P Value**
Age	2	8.23117570	4.11558785	19.41	<0.0001
Groups	2	0.12252745	0.06126373	0.29	0.7494
Sex	1	0.03024715	0.03024715	0.14	0.7061
Region	1	0.00008413	0.00008413	0.00	0.9841
Lower Limb	2	0.45928186	0.22964093	1.08	0.3409
Upper Limb	2	0.11225870	0.05612935	0.26	0.7677

Comparison	**P Value**
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.1536
Post-Ottoman/Pre-Ottoman	0.8583
Pre-Ottoman/Vlach	0.7332
Post-Ottoman/Vlach	0.9713
Male/Female	0.7061
Adriatic/Continental	0.9841
Large lower limb/Medium lower limb	0.8884
Medium lower limb/Small lower limb	0.3321
Large lower limb/Small lower limb	0.6847
Large upper limb/Medium upper limb	0.8719
Medium upper limb/Small upper limb	0.8467
Large upper limb/Small upper limb	0.9967

Least Squares Means for Different Sources
OA (0.85) > MA (0.41) > YA (0.22)
Vlach (0.53) > Post-Ottoman (0.51) > Pre-Ottoman (0.45)
Male (0.51) > Female (0.50)
Adriatic (0.497) > Continental (0.495)
Medium LL (0.57) > Large LL (0.52) > Small LL (0.39)
Small UL (0.52) > Large UL (0.51) > Medium UL (0.45)

Table 170: Model Summary – Osteoarthritis (Zone 3 Eburnation)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.05357485	0.00535748	1.54	0.1282
Error	164	0.56919301	0.00347069		
Corrected Total	174	0.62276786			

Table 171: Zero-Inflated GLM Results – Costal Osteoarthritis (Zone 3 Eburnation)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	0.01067627	0.00533814	1.54	0.2179
Groups	2	0.01889555	0.00944778	2.72	0.0687
Sex	1	0.00003694	0.00003694	0.01	0.9180
Region	1	0.00086738	0.00086738	0.25	0.6178
Lower Limb	2	0.01460216	0.00730108	2.10	0.1253
Upper Limb	2	0.01745807	0.00872903	2.52	0.0840
Comparison			**P Value**		
Older adult/Middle-aged adult			0.2034		
Young adult/Older adult			0.4661		
Young adult/Middle-aged adult			0.9930		
Post-Ottoman/Pre-Ottoman			0.4581		
Pre-Ottoman/Vlach			0.6089		
Post-Ottoman/Vlach			0.0543		
Male/Female			0.9180		
Adriatic/Continental			0.6178		
Large lower limb/Medium lower limb			0.1035		
Medium lower limb/Small lower limb			0.9959		
Large lower limb/Small lower limb			0.4144		
Large upper limb/Medium upper limb			0.0964		
Medium upper limb/Small upper limb			0.7380		
Large upper limb/Small upper limb			0.1187		
Least Squares Means for Different Sources					
OA (0.021) > YA (0.006) > MA (0.004)					
Post-Ottoman (0.03) > Pre-Ottoman (0.01) > Vlach (-0.003)					
Female (0.011) > Male (0.010)					
Adriatic (0.015) > Continental (0.008)					
Medium LL (0.021) > Small LL (0.019) > Large LL (-0.007)					
Large UL (0.04) > Medium UL (0.005) > Small UL (-0.007)					

Table 172: Model Summary – Costal Osteoarthritis (Zone 3 Porosity)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	13.05107125	1.30510712	8.49	<0.0001
Error	164	25.21161636	0.15372937		
Corrected Total	174	38.26268761			

Table 173: Zero-Inflated GLM Results – Zone 3 Porosity (Costal Osteoarthritis)

Source	DF	Type III Sum of Squares	Mean Square	F Value	P Value
Age	2	7.77831110	3.88915555	25.30	<0.0001
Groups	2	0.34221853	0.17110926	1.11	0.3310
Sex	1	0.19431662	0.19431662	1.26	0.2625
Region	1	0.03369740	0.03369740	0.22	0.6403
Lower Limb	2	0.21218317	0.10609158	0.69	0.5030
Upper Limb	2	0.14800316	0.07400158	0.48	0.6188

Comparison	P Value
Older adult/Middle-aged adult	<0.0001
Young adult/Older adult	<0.0001
Young adult/Middle-aged adult	0.1012
Post-Ottoman/Pre-Ottoman	0.3139
Pre-Ottoman/Vlach	0.5162
Post-Ottoman/Vlach	0.9084
Male/Female	0.2625
Adriatic/Continental	0.6403
Large lower limb/Medium lower limb	0.7028
Medium lower limb/Small lower limb	0.6380
Large lower limb/Small lower limb	0.9786
Large upper limb/Medium upper limb	0.6876
Medium upper limb/Small upper limb	0.8395
Large upper limb/Small upper limb	0.9899

Least Squares Means for Different Sources
OA (0.66) > MA (0.23) > YA (0.05)
Post-Ottoman (0.37) > Vlach (0.34) > Pre-Ottoman (0.24)
Female (0.36) > Male (0.27)
Continental (0.34) > Adriatic (0.29)
Medium LL (0.37) > Large LL (0.30) > Small LL (0.27)
Medium UL (0.36) > Small UL (0.30) > Large UL (0.28)

Coimbra Method and Hawkey & Merbs Comparison

Table 174: Summary Statistics – Coimbra and Hawkey & Merbs Comparison

Variable	N	Mean	Std Dev	Min	Max
Coimbra Composite Variable Left	2206	0.91024	1.45534	0	9.00000
Coimbra Composite Variable Right	2325	1.02495	1.52948	0	10.00000
Hawkey & Merbs Composite Left	2216	0.66426	1.38945	0	9.00000
Hawkey & Merbs Composite Right	2315	0.75853	1.49474	0	9.00000

Table 175: Pearson Correlation Results – Coimbra and Hawkey & Merbs Comparison

Variable	**Variable**	**Pearson's R**	**P Value**
Coimbra Composite Left	Coimbra Composite Right	0.63459	<0.0001
Hawkey & Merbs Composite Left	Hawkey & Merbs Composite Right	0.56227	<0.0001
Coimbra Composite Left	Hawkey & Merbs Composite Left	0.63924	<0.0001
Coimbra Composite Right	Hawkey & Merbs Composite Right	0.64314	<0.0001