SPECIMENS OF MORBID ANATOMY: A STUDY OF CONTEXT AND SORTING METHODS OF COMMINGLED HUMAN REMAINS FROM THE POINT SAN JOSE OSSUARY

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Heather MacInnes

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ABSTRACT

SPECIMENS OF MORBID ANATOMY: A STUDY OF CONTEXT AND SORTING METHODS OF COMMINGLED HUMAN REMAINS FROM THE POINT SAN JOSE OSSUARY

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The primary goal of bioarchaeology is to learn about the life histories of past populations from the information recorded on the skeleton. Commingled skeletal assemblages present a significant obstacle to this goal; hindering the assessment of the demographics of an assemblage, as well as making it difficult to ascertain trends necessary to make inferences about health in life, and potential cause and manners of death for individuals within the assemblage. This thesis examines a 19th century commingled assemblage of human remains discovered at Point San José Military Reservation, now known as Fort Mason, in San Francisco, California. In total, more than 4,000 commingled elements were discovered in a small yard at the rear of the old hospital located on the reservation. The hypothesized origin of this assemblage is that of a discarded anatomical collection, which would disproportionately target the poor and marginalized individuals. This thesis seeks to find the individuals among the many, and to evaluate the methods employed to sort commingled remains. For this both qualitative and quantitative methods for sorting commingled remains were applied individually and in varying orders. It was found, that of all methods visual pair matching performed best individually, as it provided the most segregation while leaving a small group of confidently matched pairs. When examining the application of the methods in varying orders, it was found that the quantitative methods served best as an initial sorting of the assemblage, and that the subsequent application of the qualitative methods provided significant refinement of the original sort. Although these methods showed differences in their efficacy, they were not able to generate meaningful impacts of the demographic profile of the assemblage. The sorting of these remains did not provide discrete enough results to accomplish this aim, but in addition there was no evidence provided to contradict the demographic profile assessed from the unsorted assemblage.

CHAPTER I

INTRODUCTION

The primary goal of bioarchaeology is to learn about the life histories of past populations, the structure of their society, their health, their demographics, how a population reacted to the wax and wane of prosperity, and much more, from the information recorded on the skeleton. These trends and effects can be determined through the information produced from the biological profile, as well as pathology, taphonomy, trauma, and bone chemistry analyses. Commingled skeletal assemblages present a significant obstacle to this goal, hindering the assessment of the demographics of an assemblage, as well as making it difficult ascertain trends necessary to make inferences about the health in life, and potential cause and manners of death (Byrd and LeGarde 2014; Byrd and LeGarde 2014; Ubelaker 2014; Vickers et al. 2015).

Sometimes, especially with historical collections, information can be gleaned from written documentation, and skeletal assemblages can support or refute this information. However, in absence of written documentation, the skeletal remains can be the only remaining source of information. Such is the case of the Point San José Ossuary. This collection of human remains was discovered during a renovation and lead abatement project being conducted on a Civil War era hospital at Fort Mason in 2010, previously named Point San José Military Reservation. More than 4,000 commingled elements were discovered in the small yard at the rear of the old hospital. The assemblage was thought to have originated around 1870 based on the discovery of several medicinal bottles associated with the skeletal elements; this is consistent with the time period of use of the hospital at Point San José (Fagan 2010).

During this time period it was a common for surgeons to use either "resurrected" bodies, or obtain cadavers through government sanctioned programs, to study anatomy and practice surgical skills through dissection (Sappol 2002; Richardson 2000). Bodies were often obtained from prisons, almshouses, or taken from potter's fields; thereby directly targeting the poor and marginalized within societies. (Nystrom 2011; Nystrom 2014; Sappol 2002). In fact many of the skeletal collections used as reference samples in this study were obtained through these practices (Muller et al. 2017).

Thus far, no documentation has been discovered concerning the specific origin of this collection, whether it was the result of a secondary deposits multiple burials, medical waste, or the remains of an anatomical collection retained for medical study and dissection. This will be one of the topics addressed in this thesis. However, the main goal of this thesis is to find the individuals among the many, and to evaluate the various methods for sorting commingled remains. Through this process, we hope to learn more about Civil War era San Francisco and Point San José, as well as how people lived in that era, and how medical practices were conducted at that time.

Research Questions

The first protocol for sorting commingled human remains was established in 1948, and relied heavily on the visual assessment of physical morphology to associate homologous pairs and joint articulation (Snow 1948). Since that time new methods for sorting commingled remains have been established, and how these methods are applied must be examined. In this study, the traditional qualitative methods of visual pair matching (VPM) and joint articulation (JA) will be compared to their counterparts from the newer method of osteometric sorting. While there had been one previous notable effort to assess the congruency of joint through osteometrics, the methods commonly referred to now as osteometric sorting was first introduced in Byrd and Adams (2003) and was further developed in Byrd (2008) and Byrd and LeGarde (2014), and brings a quantitative approach to examining pair matching and joint articulation.

To evaluate methods for the sorting of commingled human remains, qualitative and quantitative methods for sorting were applied, both individually and in varying orders, to the Point San José Ossuary assemblage. Only postcranial remains were examined in this study, including the scapula, clavicle, humerus, radius, ulna, os coxa, femur, tibia, fibula, calcaneus, and talus. The other seriated elements from the postcranial skeleton were excluded due the high degree of fragmentation in these elements, as well as the fact that they were not consistent with the statistical models developed for the quantitative analyses. Only adult remains (18 years or older) were examined in this study to remain consistent with the skeletal reference samples that were employed in the osteometric sorting methods (Byrd 2008; Byrd and LeGarde 2014; Thomas, Ubelaker, and Byrd 2013).

Through the process of sorting commingled elements, a deeper understanding about the origins of this assemblage can be obtained. In the absence of any supporting documentation about the creation of this collection, there are several possibilities for the creation of this ossuary. The main possibilities, given where the assemblage was interred, are that these remains are from medical waste resulting from surgical procedures conducted at Point San José, unclaimed individuals interred after autopsy, or an anatomical collection retained for medical study. Medical waste specimens would disproportionately consist of appendicular elements with medical interventions that would be associated with some form of trauma or pathology. Individuals who remained unclaimed after autopsy would show more representation from all elements in the body, and these elements would be fairly intact. Evidence of postmortem damage would be associated with cuts typically made in autopsy, consistent with the determination of cause of death (Chapman and Kostro 2017:68; Nystrom 2014:770). Remains of dissection, retained for an anatomical collection, would again show representation from all elements in the body. However, an assemblage of this nature would show a much higher degree of fragmentation (Nystrom 2014:770). Additionally, elements may also exhibit cut marks, closely placed together, and not associated with normal autopsy cuts (Chapman and Kostro 2017:68). Finally, remains of this nature may be associated with artifacts, or bear evidence on the remains, of long term retention and other medical refuse (Chapman and Kostro 2017:68; Nystrom 2014:770).

These methods will be used to address the main research hypothesis of this study, which asks, do the type of methods applied, and the order in which they are applied significantly influence how well an assemblage of commingled remains is sorted? This research aims to answer the following questions:

1. Is there a method of sorting that is the most effective for identifying associated elements from this assemblage? This question seeks to explore if there is a method that

can sufficiently stand alone as a method for sorting commingled human remains. Efficacy will be determined based on the degree of segregation achieved by each method independently.

a. *Hypothesis*: The more quantitative methods, such as osteometric sorting, will perform better than the more qualitative methods, and may prove to be sufficient for sorting commingled remains, especially when there is only a limited timeframe.

2. Is there an order to which methods of sorting should be applied to achieve a more effective sort? This question seeks to determine if methods are more, or less, statistically supported by their order of application. Do methods serve as a confirmation and enhancement of previous sorting methods? Or is the order in which methods are applied arbitrary, bearing no significant impact on analysis?

b. *Hypothesis*: The more quantitative methods will serve best for initially sorting from the much larger collection. The results for this will be further bolstered and refined by the application of the corresponding qualitative approaches.

3. Do these sorting methods have a meaningful impact on enhancing our ability to understand the demographics of the assemblage? Does this sorting aid in our ability to assess the origins of this assemblage?

c. *Hypothesis*: The sorting will enhance the assessment of demographic profile for the assemblage. Through this processes, it will be possible to make inferences about the origins of this assemblage.

Thesis Organization

Chapter II will address the historical background of this study. This chapter will first explore the history of 19th century medicine in the United States as it pertains to the practice of autopsy and dissection. This chapter will examine how these practices became more prevalent in the United States, and how society and governmental actions and reactions led to the development of the Anatomy Acts, which would function as a form of structural violence against the lower class. Secondly, this chapter will turn to the history of Point San José as a military installation to provide context for the location of this assemblage. Lastly, this chapter will address the history of assemblage itself, from its location on the reservation, its excavation, the nature of the remains and artifacts found within the pit feature, and a potential source for the creation of the assemblage.

Chapter III will explore both qualitative and quantitative methods for sorting commingled human remains, examining the development of these methods, as well as the theoretical foundations through which this assemblage will be interpreted. The first section of the chapter will examine the establishment of a baseline for the number of individuals represented in the assemblage through the determination of the minimum number of individuals (MNI), grand minimum total (GMT), and the most likely number of individuals (MLNI). Secondly, this chapter will cover the qualitative techniques, of visual pair matching and joint articulation, and the quantitative techniques, of pair matching and joint articulation through osteometric sorting. Finally, this chapter will cover how evidence of structural violence might be observed in this assemblage.

Chapter IV provides a summary of the methods employed in the analysis of this assemblage. First, exploring how each method will be applied individually.

Secondly, the chapter will outline the varying order of application of these methods, to examine how they perform in conjunction with one another.

Chapter V summarizes the results of the data analysis. The first section of this chapter examines the determination of MNI, GMT, and MLNI. The second section explores the results from each method of sorting performed individually. The third section of this chapter covers the results from applying the sorting methods in varying orders; first applying qualitative methods and then quantitative, and vice versa.

Chapter VI will discuss the implications of the research results, and how they addressed the research hypotheses. The first section of the chapter will discuss the results of the MNI, GMT, and MLNI analyses, as well as how each methods of sorting performed individually. The second section examines the impacts that the order of application of methods had on how well the assemblage was sorted. The third section will discuss what information the demographics of the assemblage provide regarding the origin of this assemblage. Finally, the chapter will turn to the limitations of this study, discuss directions for future avenues of research, and present the overall conclusions of this study.

CHAPTER II

THE EVOLUTION OF AN ASSEMBLAGE: THE HISTORY OF POINT SAN JOSÉ AND THE PRACTICE OF ANATOMY AND DISSECTION IN THE 19TH CENTURY

Introduction

In the 19th century, medical and surgical practice, as we understand it today, was still in its infancy. The development of medicine in this time faced the challenge of confronting many entrenched views of the dead. Many at this time felt touching the dead would “communicate a moral pollution”; that once dead, an individual’s everlasting rest had to not be disturbed for fear of negative repercussions on the living (Sappol 2002). These views were only further enforced when the act of dissection was added as an additional punishment to the sentences administered for some of the most severe crimes in society (Nystrom 2014; Muller, Pearlstein, and de la Cova 2017; Richardson 2000; Sappol 2002). Over time the marginalized within society would suffer severe structural violence at the hands of government passed legislation regarding the procurement of cadavers for anatomical study (Nystrom 2014; Nystrom 2011; Sappol 2002). Understanding the historical context of this time aids in understanding the origins of this assemblage.

This chapter will address the historical background of this study. First, this chapter will discusses the history of 19th century medicine in the United States as it pertains to the practice of autopsy and dissection. Following how these practices originated in Europe, how they were brought to the New World by the colonists, and how societal and governmental actions, and reactions, led to the development of the Anatomy Acts the would serve to oppress the lower class. Secondly, this chapter will then turn to the history of the Point San José, as a military installation, to provide context for the location of this assemblage. This chapter will briefly outline Point San José's use and role as a military reservation, from its founding in 1797 to when it officially became a National Park in 1977, renamed Fort Mason by that point in time. Lastly, this chapter will address the history of assemblage itself, from its location on the reservation, its excavation, the nature of the remains and artifacts found within the pit feature, as well as a potential source for the creation of the assemblage. Understanding the historical context of this collection will aid in the interpretation of the results, allowing for more insight to be gained into the origins of this assemblage, and how the practice of medicine and the development of surgery in the 19th century may have played a role in this.

History of Autopsy and Dissection in 19th Century United States

The Birth of Autopsy and Dissection in the Americas

Humans have always been curious about their own body, eager to know and understand the mechanisms that drive this remarkable machine. From ancient times physicians have explored the human form. Greek physicians preformed the first human dissections in Alexandria in the 3rd century B.C. External examinations for the human body was at times used for legal purposes in ancient Rome (Charlier et al. 2014:371). In medieval Europe, beginning in the 13th century, practices of human dissection became common place; often controlled by the Catholic church this practice flourished and waned based on the religious climates of the time and the sensibilities of the current Pope (Charlier et al. 2014:371; Crist and Sorg 2017:29-30). The earliest physical evidence of autopsy came from a mummified torso, sold by a medical arts dealer in Paris in 2003. This torso, which was radiocarbon dated from 1200-1280 A.D., exhibited clear anatomical cuts (Charlier et al. 2014:366-7). By 16th century autopsies and dissections were common parts of medical education and practice in Europe (Crist and Sorg 2017:30). In 1543 the Flemish author, Andres Vesalius, published *De Corporis Humani Fabrica*, which was the first text to portray realistic and accurate depictions of human anatomy. In France, the barber-surgeon Ambroise Paré published many texts on surgical technics, and is often thought of as the father of forensic pathology (Crist and Sorg 2017:27,30; Richardson 2000:32). The European colonists brought the seeds of these medical practices with them to the New World.

The first definitively documented autopsies in the Americas were performed in 1533 in Santo Doming, modern day Dominican Republic; the first autopsy in the continental North America was performed in 1536 near what is modern day Québec City (Crist and Sorg 2017:34). However, the earliest physical evidence (skeletal remains) of autopsy in the Americas was discovered originally in 1969, and then re-excavated in 2003, on Saint Croix Island, Maine (Crist and Sorg 2017:32). The autopsy was documented in Samuel de Champlain's book *Les Voyages*, which described how over the course of a hard winter between 1604 and 1605, 35 men died of illness in Champlain's settlement (Crist and Sorg 2017:25-6). In an effort to determine the cause of what at the time was referred to "*mal de le terre*" the men were autopsied. Unfortunately, this disease was likely the result of severe nutritional deficiencies, and no clear cause was able to be determined through the examination (Crist and Sorg 2017:26). In the excavation of this site only one of these individuals was discovered, a male colonist between the ages of 18-20. His remains exhibited evidence of an active systemic infection, sinusitis, and scurvy, for which the anterior portion of his palate and maxillary dentition were removed antemortem. Postmortem evidence of autopsy was signified by a craniotomy cut; further evidence of autopsy could not be determined due to the significant deterioration of the post-cranial skeleton (Crist and Sorg 2017:32). This example of the types of postmortem damage that is associated with the practice of autopsy, serves as one of the first of many to come in the Americas and the future United States.

In Europe, the ecclesiastical debate over the sacred state of the dead's remains was settled, feeling that the soul and the body were separated at death. Additionally, beliefs articulated by Saint Augustine declared that no matter what happened to the body after death, upon resurrection all dispersed elements would be instantaneously reunited, no matter their corporeal state or location (Brown 1990:803-4). This assurance lent itself to alleviating any concerns facing the treatment of remains after death, and dismemberment after death became a common practice even among elites. However, there was distinct differences placed on dismemberment as a burial preparation and autopsy, thought to be reasonable practices preformed in private, compared to the distasteful practice of dissection for anatomical study (Crist and Sorg 2017:36). These sentiments would be reflected in the American colonies, and a fervent debate over the correct treatment of the dead would follow the development of medical practice in this country into the 20th century.

The Explosion of Medical Education and Practice in 19th Century United States

In the 18th century United States medicine was still an evolving and growing profession. Prior to this time many communities received their health care from local midwives and folk healers, however, by midcentury, diplomaed physicians were replacing these individuals as the primary care providers (Sappol 2002:47-8). Moving into the 19th Century, the country was undergoing industrialization and urbanization, so much so that urban populations increased nearly one thousand percent between 1800 and 1850. This developed a job crisis that often required people travel around the country seeking the more abundant labor-based jobs (Nystrom 2014:767). In this rapidly expanding economy, work and wealth could not be guaranteed, and often fluctuated greatly. The medical profession provided a unique avenue by which gentlemen were able to not only gain a more reliable and secure profession, but also help them ascend to the upper, “bourgeois” class of society (Sappol 2002). From 1760 to 1860 the medical profession exploded in the country. Medical schools, private institutions, and publications grew dramatically during this time. At the start of the century, in 1810, there were 5 medical schools in the country, this expanded to 65 by 1860, and reached over 160 by 1900 (Sappol 2002).

As the medical profession grew so did the demands on the content and rigor of medical education. Within the profession there was a pervasive sentiment that medical professionals who had only been educated via texts, and had not had the opportunity to perform dissections of cadavers, were inferior to those who had attended institutions where these resources were available (Sappol 2002). This placed great pressure on medical schools to provide cadavers. Those who possessed the means, would go to Paris where cadavers to practice on were particularly abundant (Sappol 2002:52). Within the United States medical schools maintained fierce competition for students based on their claims of the availability of cadavers, creating heated rivalries between schools (Sappol 2002:60).

Anatomy Laws

As a direct result of increased interest into the study of anatomy by the medical profession, many students and professors would seek to obtain cadavers by any means possible. To address this several acts of anatomy legislation were passed. The earliest anatomy act was passed in Great Britain by James IV of Scotland. This act allotted one body of an executed criminal to the Edinburgh Guild of Surgeons and Barbers in 1506 (Muller et al. 2017:186; Richardson 2000:32; Sappol 2002). From this point on dissection of human body was inextricably correlated to legal punishments meant to be more severe than execution alone (Nystrom 2014:767; Richardson 2000; Sappol 2002).

Over time the number of criminal cadavers would be increased, but these increases would never meet the demand made by surgeons, and body snatching continued unabated. People referred to as “resurrectionists” would steal bodies from cemeteries and sell them to anatomists for a profit (Nystrom 2011:165; Richardson 2000; Sappol 2002:3). This culminated in Great Britain with William Burke and William Hare. In 1829 the duo murdered 16 individuals that were subsequently sold to a professor of anatomy at the University of Edinburgh (Muller et al. 2017:186; Richardson 2000:32; Sappol 2002:5). This resulted in the passage of the Anatomy Act in 1832 in Great Britain that allotted all "unclaimed" bodies to medical education. While this act did greatly help to meet the demands of medical education, the ambiguity of the term "unclaimed" became synonymous for the poor, socially marginalized portions of society (Muller et al. 2017:187; Nystrom 2014:775; Richardson 2000; Sappol 2002). These sentiments would be carried to the United States with the practice of medicine, and would color the perception of autopsy and dissection by the public into the 20th century.

Just as in Great Britain, potter's fields were disproportionally targeted as the families of robbed graves had less political clout for which to create meaningful social repercussions (Humphrey 1973:820; Sappol 2002). African American families repeatedly petitioned the New York State government to prohibit the sale of human bodies, or to confine medical dissections to the bodies of criminals convicted of capital crimes. However, these petitions were ignored and the African American Burial ground in New York continued to be looted (Nystrom 2011:166; Sappol 2002). It was not until a white woman was "resurrected" that the citizens of New York began to mobilize. What resulted was the Doctor's Mob in April of 1788, which lasted for three days and resulted in the death of 6 people (Humphrey 1973:821; Nystrom 2014:768; Sappol 2002:108-9). This however is simply an example of the many anatomy riots, 17 in total, as well as several additional mob gatherings, that occurred in the United States from 1765-1884 (Sappol 2002).

The first legal efforts made concerning the use of cadavers in the United States, began with allowing judges to impose dissection as an additional punishment for murder cases, and allocating the bodies of executed prisoners to medical schools for the purpose of dissection (Sappol 2002). However, these measures proved to be ineffective and insufficient to meet medical schools demands for cadavers, and the theft of bodies from graveyards continued, with body snatchers disturbing 600-700 graves annually in New York (Humphrey 1973:821). The first anatomy act was passed in Massachusetts 1831, which legalized the transfer of unclaimed bodies in Boston to medical schools (Muller et al. 2017:187; Sappol 2002). A similar act was shortly passed in New York in 1854. The bill was called the Act to promote Medical Science and Protect Burial Grounds, or more commonly known as the Bone Bill, and required cities of more than 30,000 in New York to donate the bodies of the "unclaimed" to medical institutions. (Muller et al. 2017:187; Sappol 2002).

Much of the anatomy legislation of the 19th century arose from the utilitarian philosopher Jeremy Bentham. He felt that the human body should be viewed as a commodity. The indigent living in almshouse would work for their food and shelter in life. Should they die and need to be buried with government funds, their bodies would be given to anatomists for dissection, thereby repaying their debt to society (Nystrom 2011:165; Nystrom 2014:767; Sappol 2002). In Bentham's view, this philosophy would serve not only to provide economic balance, but also function as a deterrent to becoming indigent. Bentham, and many of the time, felt that the indigent simply lacked the "moral discipline" to be contributing members of a capitalistic society, reeducation was required to make them into hard working individuals, and valuable members of society (Sappol 2002:118). Bentham's protégé, Dr. Thomas Southwood Smith would write a polemic in 1824 titled "The Use of the Dead to the Living", this work would serve as the basis from which many anatomy acts would be crafted into the 1890's (Sappol 2002:119).

Several states would follow the example of Massachusetts in the years to come, always signing away the "unclaimed." Through these channels cadavers were supplied primarily by almshouses, which were established to house the indigent, and hospitals, where the majority of patients suffered from tuberculosis, a disease that most affected blacks and poor whites (Humphrey 1973:824). One testimony of a doctor from New York stated that he had met with hundreds of relatives that had no recourse to save their deceased family members from dissection (Muller et al. 2017:187). This legislation ensured that only the most marginalized and voiceless section of the population would be targeted, making the distasteful process of dissection a distant issue for middle and upper classes of society (Humphrey 1973; Muller et al. 2017; Richardson 2000; Sappol 2002).

A Brief History of Point San José/Fort Mason

When considering the history of Point San José Military Reservation there is a paucity of information available. As will be seen, major use of the area as a point of defense was almost exclusively during the Civil War, after which the use of the fort continually decreased. Therefore, here is brief accounting of the Point San José Military Reservation, and its role as a military installation in California.

Point San José was originally constructed as the Batería San José in 1797 when five 8-pounder cannons were placed at the site (Hart 2009). However, no troops were stationed there and by 1806 the battery was abandoned and fell into disrepair (Sebby 2009). By 1822 the area was often referred to as Black Point, due to all the dark underbrush that had overtaken the site (Roberts 1988:77; Hart 2009). In 1848, the discovery of gold was made in California. Subsequently, there was a massive influx of people to the region in 1849, these people were referred to as the 49ers. It became difficult to find a place to live, thus many people took up residence at the point as squatters. The military found it difficult to secure these sites, but not many resources were deployed for this effort. Often the military would evict people just to have them return later. (Hart 2009; Sebby 2009). However, by the 1850s the U.S. Army was again recognizing the need for Point San José, and President Fillmore signed a Presidential Order reclaiming the fort for the military along with four other parcels of land in the area. In 1851, the President further acted to separate the point from the Presidio, and established Point San José Military Reservation as a separate entity. Despite President Fillmore's declaration, many people continued to take up residence there with little opposition during the following years (Sebby 2009).

With the start of the Civil War the use of Point San José would radically shift. In 1863 with the threat of Confederates organizing in San Francisco, as well as raiding by Confederate privateers of the Pacific Fleet, active fortification of the point began. At this time all residents or squatters had been evicted, with some houses razed, repurposed, or moved entirely (Hart 2009; Sebby 2009). Figure 1 shows a painting of the point shortly after that time, in 1865. Many of the displaced residents would file lawsuits against the

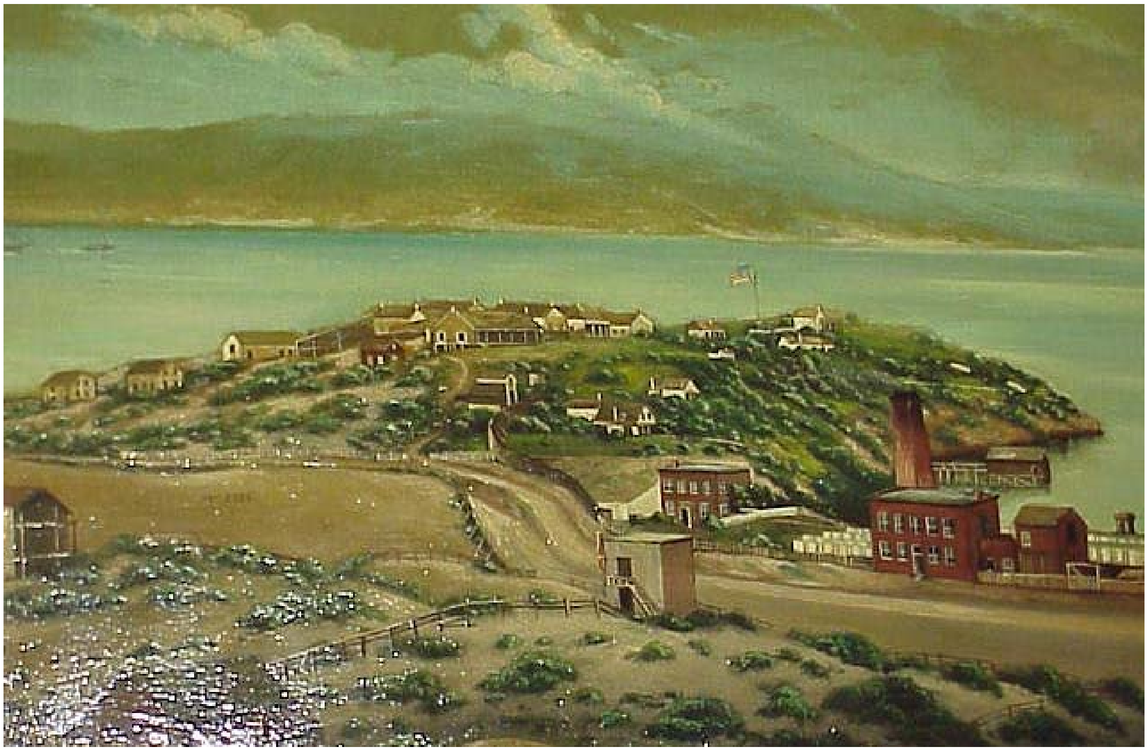

Figure 1. 1865 painting of Point San José Military Base. (Hart 2009)

government after the Civil War, but all failed to succeed in gaining reparations for their lost property (Sebby 2009). During the years of the Civil War, troops were permanently stationed at the fort, and multiple gun batteries were constructed, creating intersecting fire with defenses placed at Alcatraz Island, to protect the harbor (Hart 2009; Sebby 2009). However, during the years of the Civil War troops stationed at Point San José, as well those stationed at the other Bay Area forts, dealt more with local civil issues than harbor defense (Hart 2009).

After the Civil War, Point San José's role in military conflicts was much reduced, having little to no involvement in the Spanish-American War and the Philippine Insurrection. In 1870, the reservation was reduced to its present-day boundaries. In 1882, the point was renamed Fort Mason in honor of Brevet Brigadier General Richard Barnes

Mason who was the commanding officer of the 1st Regiment of Dragoons and the 5th military governor of California. Despite of its lack on involvement in war time efforts, the fort served as a base of operations for security and relief after the San Francisco earthquake in 1906. In 1909, the fort ceased to serve as harbor protection., and throughout the first half of the 20th century, during World Wars I and II and the Korean War, Fort Mason's role was to serve as a point of embarkation and transportation of troops and supplies to the U.S. Army's Pacific Division (Sebby 2009).

In the late 1950s and early 1960s, Fort Mason's roles in embarkation and transportation were transferred to Oakland Army Terminal, and the fort ceased to be used (Sebby 2009). In 1972, President Nixon signed the Golden Gate National Recreation Area Act, which called for all unused military facilities to be transferred to the control of the National Parks Service (NPS); Fort Mason was transferred in 1973 (Sebby 2009). By 1977, Fort Mason opened its doors to serve as a non-profit community center where free or low-cost activities to support education and the arts were offered to the public (Roberts 1988:77). It continues in this role to the present day.

The History and Excavation of the Point San José Ossuary Pit

While there is not much information available about the excavation, as its formal report for the National Parks Service (NPS) is still pending, what is available will be provided here. Most of the following information and images were provided to me by NPS Archaeologist, Peter Gavette, who along with now retired, NPS Archaeologist Leo Barker, created a presentation about the excavation of the assemblage for an informal symposium about the Point San José Ossuary Pit, which was held in September of 2016.

The Point San José Ossuary Pit was located behind what was formally the hospital of the base. The hospital had only four beds and served more as an infirmary from 1863-1903.

The ossuary pit was discovered in the yard directly behind the hospital during a renovation and lead abatement project being conducted in 2010 (Fagan 2010). The pit was intact, and had not been disturbed by the later construction on the surrounding structures, or the placement of utility lines. Approximately one foot above the pit feature was a thin layer of crushed sandstone. The purpose of this is not clear, but the excavating archaeologists speculated that it could have been a hygienic seal. This stratigraphic layer extends below the adjacent Steward's Quarters, which was constructed in 1891, thus indicating the pit feature had been made prior to that time. Figure 2 shows a photo of the hospital from 1892, with the steward's quarters to the left of the main building.

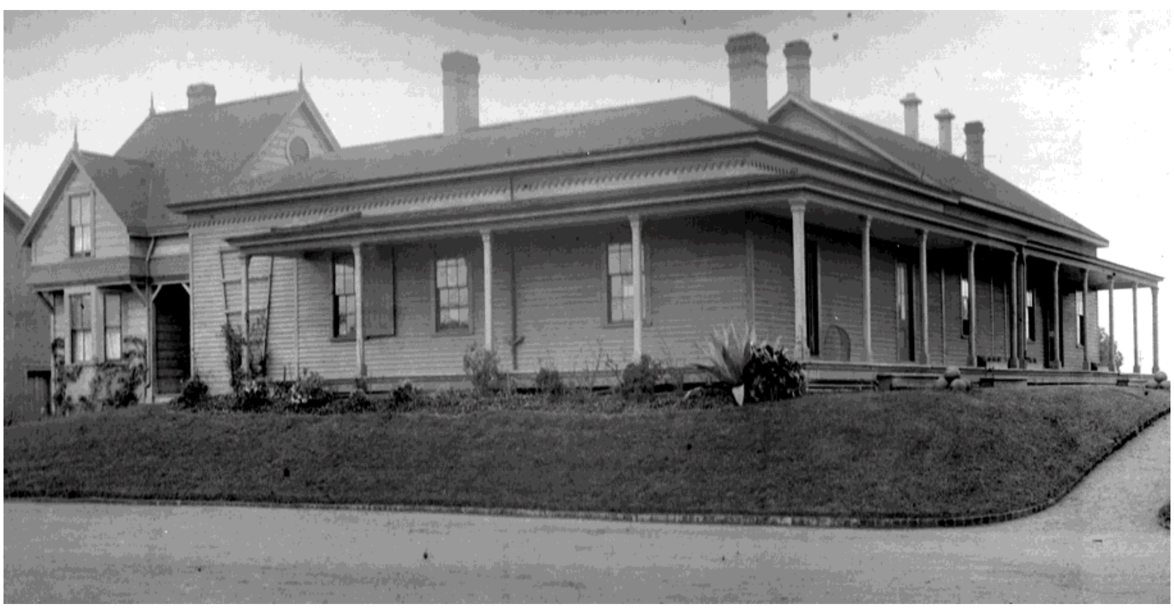

Figure 2. Point San José Hospital and Steward's Quarters (left) in 1892. (Barker 2016)

More than 4,000 commingled elements were discovered in the pit (Fagan 2010). Figure 3 shows the ossuary pit at the start of it excavation. There was clear non-random deposition within the feature. While there was significant commingling there was

Figure 3. The Point San José Ossuary Pit at the start of the excavation (Baker 2016).

some clear groupings by element type, and some articulated elements, such as a complete vertebral column towards the bottom of the pit. Associated with the skeletal elements were several U.S. Army Hospital Medical Bottles that were issued between 1862-1865. In conjunction with other associated bottles and artifacts the date range for the creation of the ossuary pit was likely around 1870. Thus far, no documentation has been discovered concerning the specific origin of this collection, whether it was the result of a mass burial, medical waste, or the remains of an anatomical collection for dissection and medical study. The determination of the origins of this collection is the objective of one of the research questions of this thesis.

While there were many surgeons stationed at Point San José throughout the 19th century, one stands out among the others, as a possible creator of the ossuary pit. Edwin Bentley held the longest tenure at the base during this time, which overlaps with the suggested period of creation of the pit, from 1869-1875. He held a distinguished career in the Army having enlisted at the start of the Civil War in 1861, and served until 1888. During this time, Dr. Bentley served as a Professor of Anatomy and the Medical College of the Pacific. He would later be one of the founders of the Arkansas Medical School, and after his retirement from the military, he continued to practice medicine in Arkansas privately (Powell and Shippen 1892:35; Watson 1896:531-2).

In 1862, shortly after Dr. Bentley enlisted in the army as a surgeon, William A. Hammond, the Surgeon General, issued a directive to all military physicians outlining the specific details that should be collected in their monthly reports. Within this directive was the following request

> As it is proposed to establish in Washington, an *Army Medical Museum*, Medical officers are directed diligently to collect, and forward to the office of the Surgeon General, all specimens of morbid anatomy, surgical or medical, which may be regarded as valuable; together with projectiles and foreign bodies removed, and such other matters as may prove of interest in the study of military medicine or surgery. (Hammond 1862)

Given this directive, and the common practice of the time for surgeons to acquire and maintain anatomical collections for surgical practice and educational purposes, Dr. Bentley very likely could be the progenitor of this assemblage.

Summary

The development of medical practice in the 19th century held many significant impacts on society. Both the fear of, and fervor for, anatomical dissection drove many of the social dynamics of the time. Many who held power protected themselves and their loved ones from these practices on the backs of those less fortunate. This chapter discussed the history of 19th century medicine and the practices of autopsy and dissection; the subsequent impacts on society and the resulting legislative measures in response to these impacts. This chapter also discussed the history of Point San José Military Reservation, and the location and excavation of this assemblage to provide regional context. Finally, potential historical information regarding the creation of this assemblage was explored. While, this research aims to sort a commingled assemblage that alone does not provide the true information that a bioarchaeologist seeks. Understanding the historical and social context of practice of medicine in the 19th century aids in understanding of who is potentially represented within this assemblage, and what the origin of this assemblage may be.

CHAPTER III

APPROACHES TO COMMINGLING AND THE BIOARCHAEOLOGICAL CONTEXT OF STRUCTURAL VIOLENCE

Introduction

When examining archaeological skeletal assemblages, it is possible to gain great insights into not only the demographics of the individuals that make up the assemblage, but also to learn much about behaviors and practices of past cultures (Harrington and Blakely 1995:105). It is through bioarchaeological analysis that these interpretations can be made and we can build a more in depth understanding of the past. With commingled assemblages, these interpretations can be obscured, therefore it is only through methods of sorting commingled human remains that we are able to gain a deeper understanding of such assemblages. However, every commingled assemblage is different, presenting its own unique questions and the methods chosen to address these questions have to be determined on case by case basis (Ubelaker 2014:1).

While just over a decade ago forensic and physical anthropologists were citing a general lack of attention brought to the study of commingling, this has changed within the last 14 years and the breadth of literature has increased significantly (Ubelaker 2014:1). This chapter will explore both qualitative and quantitative methods for sorting commingled human remains, and how these methods will be employed to determine the most effective means to sort this assemblage. The following discussion will explore the development of these methods, as well as the theoretical foundations through which this assemblage will be interpreted.

Methods for Sorting Commingled Human Remains

Minimum Number of Individuals, Grand Minimum Total, and Most Likely Number of Individuals

The study of minimum number of individuals (MNI) was originally developed in zooarchaeological studies, to make inferences about past human behavior with regard to diet. The first use of this method being attributed to T.E. White (1953) (Konigsberg and Adams 2014:193). Archaeologists would use this approach in the study of commingled assemblages of animal remains to gain insights into the types of animals, and the frequency in which these animals were represented, to understand the food sources being most exploited by past human populations. These methods have since been adapted to be used in both bioarchaeological and forensic contexts. Their application to commingled assemblages of human remains aids in gaining a better understanding of the demographic profile of an assemblage, which is necessary for understanding what portion of a population is represented; as well as mortuary behaviors surrounding creation of an assemblage (Nikita and Lahr 2011:629).

MNI represents the minimum number of individuals that contribute to an assemblage, and is most often defined as the most frequently occurring taxon or element within the assemblage (Nikita and Lahr 2011:629). However, there are a few variations in the way one may calculate MNI. The equations in the following discussion will use “L” to denote the number of lefts elements, “R” to denote the number of right elements, and “P” to denote the number of paired elements.

First, the traditional calculation of MNI, established by White (1953), is the simple sorting of left and right elements and taking the largest number as the MNI count.

$$MNI=Max\ (L,R) \qquad [1]$$

However this method holds the assumption that all less frequently observed bones within the assemblage are paired with those that are observed in greater frequency (Adams and Konigsberg 2004:139).

Another more conservative method for calculating MNI takes the average of the number of left and rights of an elements.

$$MNI=(L+R)/2 \qquad [2]$$

Both this and equation 1 have been show to dramatically underestimate the true number of individuals within an assemblage by as much as 30% at a recovery probability of 0.7 (Adams and Konigsberg 2004:139).

A final method for calculating MNI, also sometimes referred to as the grand minimum total (GMT), takes the sum of left and right elements present minus the number of paired elements (Adams and Konigsberg 2004:139; Horton 1984:259-260).

$$GMT=L+R-P \qquad [3]$$

This method has been shown to more accurately estimate the number of individuals, only underestimating by 9%, and assumes that the unpaired bones from different sides for an element originate from different individuals (Adams and Konigsberg 2004:139). This method does rely on the observer’s ability to make accurate pair matches between left and right elements, and incorrect matches could potentially bias the results.

While both MNI and GMT are informative base measures of the number of individuals that are represented in an assemblage, these measures will always underestimate the true population in instances when the recovery rates are less than 100% (Konigsberg and Adams 2014:197; Nikita and Lahr 2011:629).

To address the issue of underestimation the measure Most Likely Number of Individuals (MLNI) was developed in Adams and Konigsberg (2004). This equation is as an adaptation of the Lincoln Index (LI), designed from capture and release zooarchaeological studies, and has been shown to be a more accurate estimator of true population size (Adams and Konigsberg 2004; Nikita and Lahr 2011:630). However, the LI was found to produce a negative bias when the number of pairs recovered was low and was modified by Chapman (1951).

$$N = \left\lfloor \frac{(L+1)(R+1)}{P+1} - 1 \right\rfloor \qquad [4]$$

The Chapman Index, equation 4, is what is used to determine the MLNI (Adams and Konigsberg 2004:141). As with GMT, this method relies on the ability to make accurate pair matches between elements. Good preservation among elements is required, and MLNI should not be applied to highly fragmented collections (Konigsberg and Adams 2014:200). When determining pairs of elements, general morphology, robusticity, age, sex, size, and taphonomy should all be considered. Additionally, extensive osteological experience naturally enhances the efficacy of this method (Konigsberg and Adams 2014:200-201). MLNI can be applied to both single and multiple elements using equations and Excel spreadsheets provided in Adams and Konigsberg (2004). Note, that with the application of this method to multiple elements, it is not necessary to have previously determined matches between element types, and therefore can be applied to otherwise unsorted commingled assemblages. However, there is also an assumption of independent recovery, that is assessed in this calculation (Adams and Konigsberg 2004:145).

In addition to the calculation of MNI, GMT, and MLNI it is important to document recovery probabilities for each element type. This is simply determining the likelihood that an element will make it into the assemblage analyzed, and is an important factor when attempting to determine any significant sample bias that may have resulted from poor recovery rates (Adams and Konigsberg 2004:143). True recovery rates can never be perfectly calculated for archaeological or forensic assemblages, especially for open assemblages consisting of unknown numbers of expected individuals. However, high correlations between MNI and MLNI do suggest a high degree of recovery was achieved, and thus these measures should always be reported together (Adams and Konigsberg 2004:149).

Visual Pair Matching

Visual Pair Matching (VPM) is one of the original methods used for sorting commingled human remains. The protocol outlined in Snow (1948) is often considered the first clear method proposed for sorting commingled remains; visual pair matching is the second step of this protocol. However, while this method has long been recognized as an effective means for sorting remains, it has had little to no validation studies conducted on it. This process associates homologous (left-right) elements based on similarities in their general morphology, including markers or their age, sex, and stature, as well as distinct aspects of their taphonomy and/or pathology (Adams and Byrd 2006:64). VPM of non-homologous elements is not appropriate due to the high likelihood of a significant degree of subjectivity that could bias the results, exceptions to this would be distinct anomalies in skeletal variation, such as matching fracture patterns, which may allow for inter-element association (Adams and Byrd 2006:64). Pair matching is the basis for the calculation of both GMT and MLNI; it is imperative that accurate pair matches are made in this process (Konigsberg and Adams 2014:200). VPM has been shown to be most effective when performed by an experienced osteologist with some elements being more easily matched than others, depending on the preservation and distinct morphological differences (Adams and Byrd 2006:65; Konigsberg and Adams 2014:200-201).

Joint Articulation

Joint articulation is again a long-accepted method for sorting commingled human remains, and is part of several of the steps in the protocol outlined in Snow (1948). This method examines the degree of congruency between two articulating elements. Again, there have not been many validation studies conducted concerning this method. The most notable of these is the exploration of congruence between cervical vertebrae articulation conducted by Buikstra et al. (1984), and is an excellent example of the efficacy of the application of this method of sorting, as the osteometric findings were consistent with those of physical joint articulation. Another notable study employing this method was conducted on a small commingled assemblage of Vietnam war dead by Adams and Byrd (2006). In this study they found that the strength of associations between elements is highly dependent on the joints examined, the closeness of the fit, and the amount of contact area between these elements (Adams and Byrd 2006:65). As with all methods of sorting, this application is strongest as a means of excluding associations between elements, possible matches only suggest that two elements may be associated rather than definitively confirming an association. However, Adams and Byrd felt that, depending on the joint examined, this method can be a one of the most reliable and accurate means to establish association between elements (Adams and Byrd 2006:65).

Osteometric Sorting

It has long been accepted that elements from a single individual are of similar size and robusticity, barring anomalous variation. Osteometric sorting is a quantitative means by which to determine if two elements are outside the range of normal human variation, and thus not likely to originate from a single individual (Byrd and Adams 2003:1). The study conducted by Buikstra et al. (1984) discussed in the previous section was one of only a few previous studies that made use of a method of osteometric sorting to quantitatively test the congruence between joints, in this case the cervical vertebrae. This study found that while this quantitative method confirmed results found by the more traditional methods of joint articulation, they did not find this method to be more efficient or effective at sorting commingled humans remains (Byrd and Adams 2003:2).

Byrd and Adams (2003) first proposed that bivariate correlations of summed measurements made from a single element could be used to effectively sort remains (Byrd and Adams 2003:4). Additionally, they showed that a multivariate analysis could be used to generate a single variable from measurements from multiple elements. This variable could then be used as a means of corroborating associations between elements associated by other methods of sorting. However, this method did not show significant enough benefits to justify the additional complexity introduced by this analysis (Byrd and Adams 2003:4). Osteometric sorting was further developed in Byrd (2008) and Byrd and

LeGarde (2014), where methods for comparison between homologous elements, congruence of articulating bone proportions, and inter-elements associations were expanded upon, producing statistical models which can be employed in these analyses.

Thomas et al. (2013) further developed methods for sorting homologous elements, by employing the use of an M statistic, which serves to capture size variation that may occur between left and right elements. However rather than using the sum of multiple measurements as seen the statistical models of Byrd (2008) and Byrd and LeGarde (2014), this method examines each measure independently. Therefore, this method may be exceptionally useful for evaluating highly fragmented assemblages, as well as understanding nuances of bilateral variation. While this method is cited as being easier to apply to commingled assemblages, it is also considered statistically weaker than the previously discussed osteometric pair matching method (Byrd and LeGarde 2014:174).

However, Vickers et al. (2015) conducted a validation of the method proposed in Byrd and LeGarde (2014). They found that the potential for false rejection of homologous pairs could range from 7-36% (Vickers et al. 2014:103). They suggest that this impact can be diminished through the use of ranges for the amount of size variation between homologous elements (Vickers et al. 2015:104). The, impact of this has not been tested on the alternative method proposed in Thomas (2013), but one must be cognizant of the possibility that this aspect of osteometric sorting may underestimate the number of individuals paired, and is best supported by additional sorting methods.

The main benefit of osteometric sorting is that these methods provide a means to quantitatively compare elements, when many of the sorting procedures for commingled humans remains are qualitative and can be significantly biased by osteological experience level and subjectivity. The majority of measurements collected for osteometric sorting are those outlined in both Buikstra and Ubelaker (1994) and Moore-Jansen et al. (1994). However, Adams and Byrd (2003) and Thomas et al. (2013) developed additional measures that facilitate the use of more fragmented remains. They have found that while measures of maximum length of elements have the highest correlations, elements where only breadth measurements were able to be collected showed no significant decline in the strength of the statistical models used (Byrd and Adams 2003:4). It is stressed that the efficacy on this model relies heavily on the breadth and comparability of a reference data collections (Byrd and Adams 2003:3; Byrd 2008:200; Byrd and LeGarde 2014:170). In this study reference data provided in Byrd and Adams (2003) originates from CIL, Hammond-Todd Collection, the Terry Collection, the Bass Collection, and data from the Forensic Data Bank; Byrd (2008) and Byrd and LeGarde (2014) added additional reference data from the International Commission of Missing Persons, and the Harvard Peabody Museum (Byrd 2008:201; Byrd and LeGarde 2014:171). It should be noted that the robusticity of the reference sample serves to bolster the strength of this method. In this form of analysis, the reference samples should be examined for significant temporal similarities as well as represent diverse populations and genders, as often much of the details of the biological profile are unknown prior to the sorting of commingled remains (Byrd 2008:201; Byrd and LeGarde 2014:170).

Understanding Demography: Bioarchaeological Context of Structural Violence

Structural violence is defined as harm done to a group of people through the normalization of social inequalities embedded within a sociopolitical and socioeconomic institutions (Nystrom 2014:765). Many previous studies of commingled disarticulated remains from the 19th century have shown to be portions of discarded anatomical collections. As discussed in the previous chapter, marginalized groups were often disproportionately represented in these assemblages. These individuals' bodies were obtained either through illegal grave robbing or through government policies that specifically targeted people of lower socio-economic status (Davidson 2007; Nystrom 2011; Nystrom 2014; Sappol 2002). After the application of methods for sorting the commingled assemblage, the demographics must be examined to determine the nature of this assemblage. Considering the possible for the origins of this assemblage differing patterns that either reflect practices of structural violence, or lack these indicators are expected to be present. For example, an assemblage that is composed of medical waste from surgical procedures performed in a military capacity would likely reflect a significant skew towards young adults, predominately of the male sex, and majority of white ancestry, in general lacking evidence of structural violence (Willey et al. 2016). However, an assemblage of remains from an anatomical collection would exhibit less age and gender disparities. Differences in ancestral origins are also likely to be present, skewing towards ancestry groups of minority or commonly low-socioeconomic status. Such ancestral groups as African American, Native Americans or Asians are more likely to be represented, as they were less likely to be able to afford the form of burial protection that many individuals of middle to upper class Europeans ancestry were able to provide for their deceased (Nystrom 2011 165; Nystrom 2014:769). Additionally, those of lower socioeconomic status would also reflect pathologies of chronic stress, poor dental health, and degenerative diseases (Willey et al. 2016). As mentioned in the previous chapter, often deceased tuberculosis patients were given to medical schools for the purposes of dissection; thereby targeting those of low socioeconomic status as they were more susceptible to this pathogen (Humphrey 1973:842). Therefore, through the examination of the demographic profile of the assemblage it is possible to determine if trends that reflect patterns of structural violence of the 19th century are present or absent, aiding in the determination of the origins of this assemblage.

Summary

This chapter examines both qualitative and quantitative methods for sorting commingled human remains. These methods cover first, the establishment of a baseline for the number of individuals represented in the assemblage through the determination MNI and MLNI. Secondly, this chapter explores the qualitative techniques of visual pair matching and joint articulation. While these methods require less time, and are typically easier to preform, they are also subject to inter-observer variation due to osteological experience. Thirdly, chapter examined the quantitative method of osteometric sorting which can be applied to matching homologous pairs, joint articulation, and inter-element associations. While these methods are often more time consuming and require some calculations, they serve as more objective analogs to the qualitative methods. Each of these methods individually has been found to be affective in sorting commingled human remains, however most studies have found that their application in conjunction with one another provides optimum results. Finally, this chapter examined how, through the social theory of structural violence, the demographics profile created after the application of the above methods could be used to determine the origins of this assemblage.

CHAPTER IV

METHODS

This study examined the commingled postcranial adult elements of the Point San José Ossuary collection. For the sake of consistency among sorting methods, the ribs, vertebrae, and the elements of the hands and feet except for the calcaneus and talus were excluded from analysis. This chapter will first discuss all the methods that were employed in the sorting of this commingled assemblage. Secondly, this chapter will outline the differing way in which methods of sorting were implemented to explore the second research question, pertaining to any significant benefit to the order in which these methods are applied.

The Point San José Ossuary collection is a commingled assemblage of approximately 4000 elements and fragments of human remains. Physical anthropology graduate students and professors of California State University, Chico, inventoried the assemblage in full. Methods defined by Buikstra and Ubelaker (1994) and National Park Service protocols were employed to examine minimum number of individuals, demography, stature, pathology, and taphonomy (Willey et al. 2016). All elements were sorted by element type, removing any non-osseous and non-human material from further study, sided when possible, and finally all possible associating fragments were either rearticulated and glued, or matched to all possible larger element portions. The details of the specific methodologies and materials used in this analysis are documented in Willey et al. (2016). The data obtained from this initial cataloguing and inventory were used to inform this thesis, and to explore if any changes occur in the demography of the assemblage after sorting the remains. Table 1 provides a summary of the elements used in this study, the number of elements used in each method, and sex demographic for each element.

Table 1: Summary of the n for each element used in the study, the number of elements used in each method, the sex demographic for each element.

		Tests					Sex		
Element	n	MNI	Visual Pair Matching	Joint articulation	OSM: Pair Matching	OSM: Joint Articulation	Male	Female	Unknown
Clavicle	20	20	18	0	9	0	6	4	10
Scapula	55	55	18	19	15	15	0	1	54
Humerus	30	30	29	24	28	18	18	7	5
Radius	35	35	30	25	30	16	10	4	21
Ulna	37	37	29	28	31	21	20	11	6
Os Coxa	64	64	40	25	27	23	15	14	34
Femur	30	30	23	18	23	17	16	7	7
Tibia	33	33	24	14	22	9	12	6	15
Fibula	30	30	28	5	15	0	2	6	22
Talus	38	38	38	35	0	34	0	0	38
Calcaneus	38	38	31	0	22	0	4	20	14
Totals	410	410	308	193	222	153	103	80	226

MNI, GMT, MLNI

To calculate minimum number of individuals (MNI), elements were first sorted by element type, as well as left and right sides. The traditional calculation of MNI=Max (L, R) equation was used (Adams and Konigsberg 2004:139; Konigsberg and Adams 2014:197; White 1953:397). As only adult remains are considered in this study no further refinement of age categories were conducted. However, an additional MNI refined by sex difference was also calculated. Sex estimations based on relatively intact os coxa are reliable; in addition to this, there is also evidence that sex estimations from other postcranial elements, even on single elements, can be close or even more accurate than estimations established from the skull, a widely accepted method for determining the sex of remains (Spradley and Jantz 2011). Difference between these MNI calculations provide additional insight into the demographics of the assemblage.

As discussed in Chapter III, the assumption made with the calculation of MNI is that all elements that occur in less frequency are paired with those that occur in greater frequency (Adams and Konigsberg 2004:139). However, given the nature of the assemblage this assumption may be violated. To address this, the calculation of the grand minimum total (GMT), which assumes unpaired elements originate from different individuals, was also made (Adams and Konigsberg 2004:139). GMT was be calculated using the equation GMT=L+R-P (Adams and Konigsberg 2004:139; Horton 1984:259-260). Only visual pair matching, to be discussed on more detail below, will be used to establish the number of pairs for this calculation to remains consistent with the previous applications of this method.

As both the calculations of MNI and GMT are shown to consistently underestimate the true number of individuals that may have contributed to an assemblage, the most likely number of individuals (MLNI) was also calculated (Adams and Konigsberg 2004). The calculations for MLNI was calculated using the links to the Excel spreadsheets provided in Adams and Konigsberg (2004). Only visual pair matching was used in determining pairs to, again, remain consistent with the previous applications of this method. The MLNI was calculated for each individual element, as well as for the elements with the four highest recovery probabilities. No more than four elements were considered in the calculation of the multiple element MLNI, as increased numbers violated the assumption of independent recovery (Adams and Konigsberg 2004:145). To gain insight in the accuracy of these estimations recovery probability (*r*) and standard error (*s.e.(r)*) were also calculated using equation 5 and 6 respectively:

$$r = \frac{2P}{L + \mathrm{R}} \qquad [5]$$

$$s.e(r) = \left[\frac{(r-1)^2(r-2)^2r^2}{r^2(L+R)(3-2r)+2P(2-6r+3r^2)}\right]^{1/2} \qquad [6]$$

High correlations between MNI and MLNI will further inform recovery rates and the accuracy of these estimations (Adams and Konigsberg 2004:149).

Visual Pair Matching

Visual pair matching was conducted through the examination of general morphology and any significant and bilateral skeletal anomalies on homologous elements (Adams and Byrd 2006:64-65). Due the size, high of degree of commingling, and the potential for selective curation in this assemblage, matches were made on an ordinal scale of good, moderate, poor, and no match. These categories are meant to allow for more discrimination between possible matches that may exhibit some bilateral asymmetry, or variability in taphonomy, and provide informative data when secondary methods are applied. An additional category of confident matches was also made in this analysis. These matches are made when the similarity between homologous pairs excludes all other possible matches. Only confident matches were used in the calculation of GMT and

MLNI. While past studies have shown that matches can be made successfully between humeri, femora, and tibiae with experienced osteologists and good preservation; matches in this study were made between the clavicle, scapula, humeri, radii, ulnae, os coxa, femora, tibiae, calcanei, and tali. (Adams and Byrd 2006:65).

Joint Articulation

Joint articulation was examined in groupings of high, moderate, and low confidence articulations as defined in Adams and Byrd (2006). High confidence articulations include associations between the humerus and the ulna, ulna and radius, and tibia and talus. Moderate confidence articulations include articulations between the os coxa and the femur, femur and tibia, and tibia and fibula. Finally, low confidence articulation is between the humerus and the scapula (Adams and Byrd 2006). There are additional joint articulations for the postcranial skeleton that were excluded from this list, as the elements involved either had significantly poor preservation or underrepresentation within the assemblage, and/or could not be examine through the other methods of sorting employed in this study.

To examine these articulations, again, an ordinal scale was employed using the categories of positive, moderate, poor, and no articulation. Confident matches, or joint articulations, were also made for this method for comparison to VPM. As with all the methods described in this chapter the strength of this method lies with its ability to exclude elements as possible matches (Adams and Byrd 2006:65). Therefore, the significance between a positive and no match was considered with more weight, while the moderate and poor matches were employed more as potential support to matches made by other methods.

Osteometric Sorting

All the following methods described in this section use the reference sample employed in Byrd (2008) and Byrd and LeGarde (2014). This sample consists of a total of 376 documented remains from the Joint POW/MIA Accounting Command Central Identification Laboratory (JPAC/CIL), Hammond-Todd Collection at the Cleveland Museum of Natural History, the Terry Collection at the Smithsonian Institution, Bass Collection and Forensic Data Bank Collection at the University of Tennessee, International Commission on Missing Persons, and the Peabody Museum at Harvard University (Byrd 2008; Byrd and LeGarde 2014). All calculations and comparisons to the *t*-distribution, to be described with each following method, were made using Microsoft Excel 2011.

Osteometric sorting was conducted using the osteometric measurements outlined in Buikstra and Ubelaker (1994) and Moore-Jansen et al. (1994), the methods for their collection are outlined in Willey et al. (2016). For each of these measurements, 10 randomly selected measurements were rechecked to ensure consistency between previous observers and the author. Measurement were randomly selected using the randomize function on Excel 2011, assigning a randomized number between 0 and 1 to each of the elements for which a measurement could be collected, sorting these values from smallest to largest and selecting the first 10. In cases where there were less than 10 elements for which a measurement could be collected, all measurements were re-measured.

To assess correlation between observers intra-class correlation coefficient (ICC) was calculated in SPSS v.24. For this calculation, a two-way mixed model was used to assess absolute agreement between observers. Results will be assessed based on the threshold defined in Cicchetti (1994). Table2 provides a summary of these thresholds.

Table 2. Summary of IIC coefficient values and associated correlation fit (Cicchetti 1994).

ICC Coefficient	Correlation
1.0-0.75	Excellent
0.74-0.60	Good
0.59-0.40	Fair
<0.40	Poor

All elements were re-measured for any measurement that produced ICC coefficients less than 0.75, or lower bounds ICC coefficient of the 95% confidence interval less than 0.60. All measures that yielded ICC coefficients of 0.75-1.0, show no significant variation between observers, and were not recollected. Additional osteometric measurements outlined in Adams and Byrd (2003), Byrd (2008), Byrd and LeGarde (2014), and Thomas et al. (2013), that enhance the ability to sort more fragmented remains, were collected by the author.

Osteometric comparisons made between homologous elements was done by two separate methods. First, the method described in Thomas et al. (2013) (abbreviated as OSPM for the remained of the study), which made comparisons between elements on individual measurements using the M-statistic, equation 7:

$$M = |L - R| / (L+R)/2) \qquad [7]$$

where L and R are the measurements for left and right elements respectively (Thomas et al. 2013:954). The measurements of M were then compared to the 90th percentile values provided from the reference sample used in Thomas et al. (2013). Differences between males and female assessments for individual elements were found to be significant in only three measurements by Thomas et al. (2013). These were examined to determine if sex had any impact on the result of the sorting.

Secondly, osteometric sorting between homologous pairs was examined by method described in Byrd (2008) and Byrd and LeGarde (2014) (abbreviated as OSPD for the remainder of the study), which examines homologous pair through the summation of multiple measurements. This method calculates a value D, equation 8:

$$D = \Sigma\ (a_i - b_i) \qquad [8]$$

where a and b are the measurements i for the right and lefts elements, respectively (Byrd 2008:202; Byrd and LeGarde 2014:172) The null hypothesis of no difference between elements was tested through equation 9 providing a *t* score: $t = |D - 0|/\mathit{standard\ deviation}$

$$t = |D - 0|/\mathit{standard\ deviation} \qquad [9]$$

where the standard deviation is provided from the reference sample used by Byrd (2008) and Byrd and LeGarde (2014). The *t* value was compared to a *t* distribution as a two-tailed *t*-test with n-1 degrees of freedom (Byrd 2008:203; Byrd and LeGarde 2014:186).

Osteometric sorting for joint articulations was done using the methods described in Byrd (2008) and Byrd and LeGarde (2014) (abbreviated as OSJA for the remainder of the study) using equation 10:

$$d = c_i - d_j \qquad [10]$$

where i is the measurement of bone c and j is the measurement of bone d (Byrd 2008:204; Byrd and LeGarde 2014:174-175). The null hypothesis of no difference between the dimensions of each aspect of the articulating joint was tested by equation 11:

$$t = |D - \text{mean}|/(\textit{standard deviation}) \qquad [11]$$

where the mean and standard deviation are provided by the reference sample in Byrd (2008) and Byrd and LeGarde (2014). The *t* score was compared to a two-tailed *t*-distribution with n-1 degrees of freedom (Byrd 2008:204; Byrd and LeGarde 2014:186).

Assessment of the Application of Methods

Initially each individual method of sorting was conducted separately, on the entire assemblage, and without bias from the other methods. The results of each method were examined in isolation to generate a final sort. These final sorts determined if one method is more effective at sorting the remains than others.

In order to examine how well the methods perform in conjunction with one another, each method was assessed and then modified by subsequent methods in varying orders of application. This was done by first conducting the qualitative methods of VPM and JA, then further sorting the possible matches through the application of the quantitative methods of OSPM/OSPD and OSJA. Then secondly, by sorting the assemblage first by the quantitative methods, generating a set of possible matches, then further refining this through the application of the qualitative counterparts VPM and JA.

Summary

The assemblage of postcranial remains (n=410 elements) from the Point San José Ossuary collection was examined by several methods for sorting commingled human remains. First, the remains were examined for MNI both with and without the consideration of sex, GMT, and MLNI. This was done to gain a baseline for the number of individuals expected to have contributed to the formation of the assemblage, and evaluate any skews in sex to inform the demographic profile. The assemblage was then sorted through both qualitative methods of visual pair matching, and joint articulation, as well as quantitative methods of osteometric sorting for pair matching and joint articulation. Each method was performed individually, and in varying orders to address the first and second research questions of this thesis.

CHAPTER V

RESULTS

Introduction

This chapter details the results of the various methods employed to sort this commingled assemblage. First, this chapter will review the outcomes of each of the methods of sorting applied individually, examining how well each method was able to sort the assemblage independently. Then, this chapter will address how the order of application of these methods affects how well the assemblage is sorted. Finally, this chapter will report any changes to the demographic profile of the assemblage after sorting.

MNI/GMT/MLNI

MNI, GMT, and MLNI were calculated to gain a baseline for the number of individuals expected to be represented within this assemblage. In addition to this, MNI with and without the consideration of sex was calculated to evaluate if there were any significant skew in sex to inform the demographic profile. The results of this analysis are provided in Table 3, which gives a summary of the MNIs, both without and with metric sex determinations, GMT, and MLNI, with the elements recovery probabilities and standard errors. Figure 4 provides a graphic representation of the recovery probability for each element to illustrate the trends in this measure.

Table. 3. Summary of the MNI's without and with metric sex determinations, the GMT, and MLNI with the elements recovery probabilities and standard errors.

Element	MNI	MNI Male	MNI Female	GMT	MLNI	r	r S.E.
Clavicle	10	3	4	17	28	0.3000	0.1336
Scapula	11	0	1	54	110	0.0364	0.0354
Humerus	12	9	7	26	50	0.2667	0.1063
Radius	18	8	2	29	46	0.3429	0.1033
Ulna	17	11	6	27	32	0.5405	0.0990
Os Coxa	16	9	8	57	113	0.2188	0.0690
Femur	14	9	4	24	33	0.4000	0.1131
Tibia	15	8	5	29	58	0.2424	0.0989
Fibula	14	1	3	28	83	0.1333	0.0848
Talus	22	0	0	29	47	0.4737	0.1001
Calcaneus	17	4	12	33	65	0.2632	0.0941

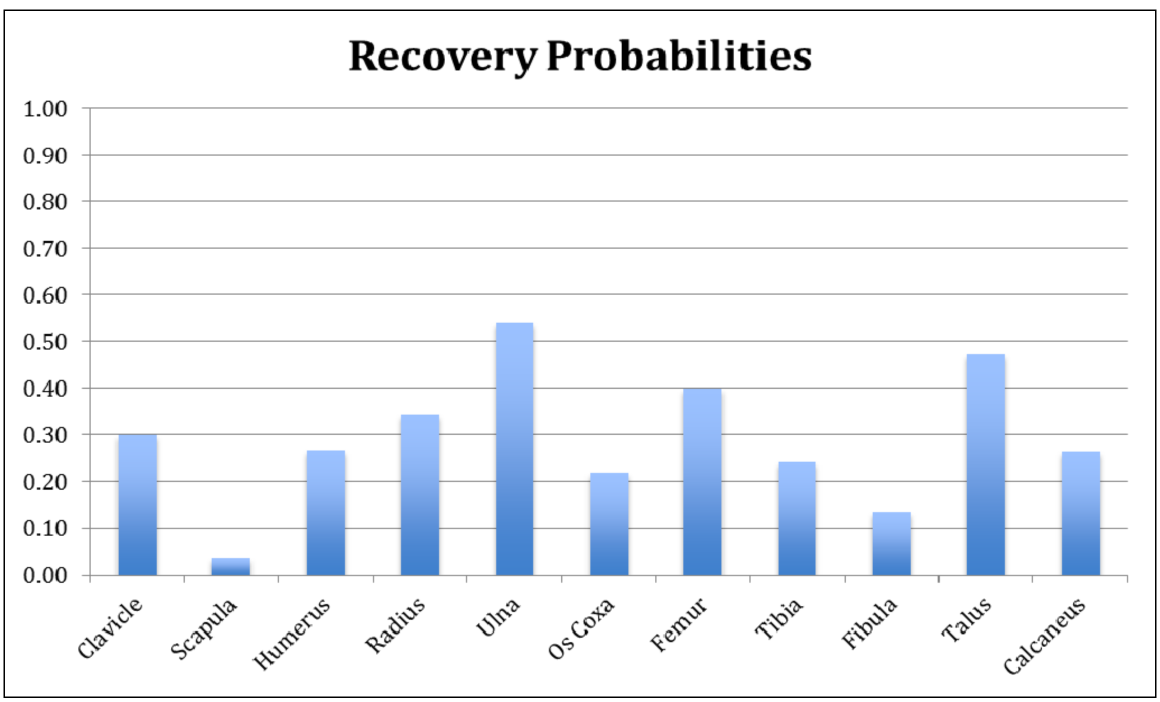

Figure 4. Graphic representation of recovery probabilities.

The MNI for this assemblage, without considering metric sex determinations, is 22 individuals based off the talus. However, when considering sex, the ulna has an MNI of 11 males, and the calcaneus has an MNI of 12 females, implying an MNI of 23 individuals, and reflecting no skew in sex for the demographics of this assemblage.

The GMT was determined to be 57 from the os coxa, and 54 from the scapula. These values are nearly double the GMT provided by the other elements, however, the os coxa and the scapula exhibit a high degree of fragmentation. This taphonomy affects the ability to establish pairs which dives up values for this calculation. More consistent with the preservation of the majority of the assemblage, the GMT of 33 provided by the calcaneus is not as heavily affected by taphonomy.

The MLNI also, is approximately double in the scapula, os coxa, and fibula; the recovery probabilities for these elements are also much less than those for the other elements. Excluding these three elements, the highest MLNI from the remaining elements is 65 from the calcaneus. The ulna, which has the highest recovery probability and number of confident pair matches, has an MLNI of 32.

To consider the GMT and MLNI across multiple elements, the four elements with the highest recovery probabilities were examined. This includes the radius, ulna, femur, and talus. These 4 elements produced GMT=29, a MNLI=37 with an $r=0.4429$ and r S.E.=0.0524. These elements maintained the assumption of independence with a $\rho=0.52$. The addition, of more elements violated this assumption.

Visual Pair Matching (VPM)

The process of VPM was conducted using the scaled system of good, moderate, and poor matches. While these categories provide possible matches, those matches that were determined to be strongly associated above all other possible matches or exclusions are reported as confident matches. All elements types included in this study were examined by this method, utilizing 308 total elements and 75% of this assemblage. Table 4 provides a summary of the n for all elements used in this analysis, possible combinations of pairs, exclusions, percent exclusions, total possible matches, percent possible matches, and confident matches. This method yielded high percentage of exclusions, low percentage of possible matches, and a high number of confident matches. By this method 57 total confident matches were made.

Table 4. Summary of the outcomes from the VPM method.

Element	n	Possible Combinations	Exclusions	Percent Exclusions	Total Possible Matches	Percent Possible Matches	Confident Matches
Clavicle	18	66	58	87.88%	8	12.12%	3
Scapula	18	116	106	91.38%	12	10.34%	1
Humerus	29	199	179	89.95%	20	10.05%	4
Radius	30	228	209	91.67%	19	8.33%	6
Ulna	29	221	202	91.40%	19	8.60%	10
Os coxa	40	267	252	94.38%	15	5.62%	7
Femur	23	128	119	92.97%	10	7.81%	6
Tibia	24	114	97	85.09%	17	14.91%	4
Fibula	28	175	172	98.29%	3	1.71%	2
Talus	38	352	336	95.45%	16	4.55%	9
Calcaneus	31	227	219	96.48%	8	3.52%	5

Joint Articulation (JA)

JA was also conducted using a scaled system, however confident matches could not be established, as this method produced more ambiguity in the possible matches. For the purposes of comparison to VPM, single good matches that do not repeat between elements were enumerated and were compared as confident matches. The method included all element types in this study, with the exception of the clavicle and the calcaneus, utilizing 193 total elements, or 47% of the assemblage.

A summary of the n for all elements used in this method, possible combinations of pairs, exclusions, percent exclusions, total possible matches, percent possible matches, and single good matches is presented in Table 5 and 6, for left and right joints respectively. Each table is broken into three categories of high confidence, medium confidence, and low confidence joint articulations. The method yielded low percent of exclusions, much higher percent possible matches, and much lower confident matches as compared to visual pair matching. Confident matches by this method totaled 19, nearly a one third of the confident matches made with VPM.

Osteometric Sorting

The osteometric measurements used for the following sorting methods are described in Buikstra and Ubelaker (1994), Moore-Jansen et al. (1994), Byrd (2008), Byrd and Legarde (2014), and Thomas et al. (2013). A summary of the measurements and the specific methods they were employed in can be found in Appendix A. The majority of measurements collected previously by the physical anthropology graduate students of CSU, Chico did not exhibit significant variance from those re-measured by

Table 5. Summary of outcomes for left joints from the JA method.

Confidence	Left Joints	n	Possible Combinations	Exclusions	Percent Exclusions	Total Possible Matches	Percent Possible Matches	Confident Matches
High	Humerus Ulna	12 16	192	93	48.44%	97	50.52%	0
High	Ulna Radius	16 18	264	229	86.74%	35	13.26%	4
High	Tibia Talus	4 16	64	53	82.81%	11	17.19%	2
Medium	Os Coxa Femur	14 8	112	65	58.04%	47	41.96%	1
Medium	Femur Tibia							
Medium	Tibia Fibula							
Low	Scapula Humerus	9 9	81	48	59.26%	33	40.74%	0

Table 6. Summary of outcomes for right joints from the JA method.

Confidence	Left Joints	n	Possible Combinations	Exclusions	Percent Exclusions	Total Possible Matches	Percent Possible Matches	Confident Matches
High	Humerus Ulna	7 11	77	43	55.84%	34	44.16%	0
High	Ulna Radius	12 9	88	66	75.00%	12	13.64%	4
High	Tibia Talus	8 19	152	131	86.18%	21	13.82%	3
Medium	Os Coxa Femur	11 8	88	47	53.41%	41	46.59%	0
Medium	Femur Tibia	6 8	48	34	70.83%	14	29.17%	3
Medium	Tibia Fibula	4 5	20	17	85.00%	3	15.00%	2
Low	Scapula Humerus	10 8	80	42	52.50%	38	47.50%	0

the author. The details of the ICC results, including the ICC coefficient, the 95% confidence interval, and the significance values for each measure can found in Appendix B. The seven measurements that did exhibit significant inter-rater variability were the sagittal and vertical diameters of the midshaft of the clavicle, the minimum diameter of the midshaft of the humerus, the sagittal diameter of the midshaft of the radius, the dorso-volar diameter of the ulna, and the iliac height and breadth of the os coxa. As can be seen the majority of measurements subject to higher rates of inter-rater reliability are predominately midshaft measurements of the long bones, this variability may likely be attributed to the incorrect location of the midshaft point by some observers.

Pair Matching

OSPM employed all element types except the talus, using a total of 224 elements and 55% of the assemblage. Initial assessments of exclusions or possible pairings were made based on each individual measurement, as per the method. However, the final determination of exclusions or possible matches was based on the combination of all measurements available for each element, a possible match is only classified as such if all measurements available were also classified as a possible match.

Impacts of sex on possible pairings were examined in multiple iterations of the pair matching procedures. For this method, three measures: the sagittal diameter of the midshaft of the clavicle, the physiological length of the ulna, and the anterior-posterior diameter of the midshaft of the femur, were cited as having shown to be impacted by sex (Thomas et al. 2013: 955). However, they exhibited no changes to the results in this analysis. Additional iterations of pair matching were examined for impacts of sex on pairings in the clavicle and humerus. While differences occurred occasionally in the pair matchings of individual measurements, they disappeared upon combining all measures for an element. Therefore, the analysis of how sex impacted osteometric pairing matching was not pursued further.

Table 7 provides a summary of the n for each element used in this procedure, the possible combinations, exclusions, percent exclusions, possible matches, and percent matches. This method yielded high exclusion rates and produced low possible matches. Unlike with the qualitative methods, no confident matches could be determined, as multiple elements were produced as potential matches and had significant overlap among elements.

Table 7. Summary of results from sorting with the OSPM method.

Element	n	Total Possible Combinations	Number of Exclusions	% Exclusions	Possible Matches	% Possible Matches
Clavicle	9	18	16	88.89%	2	11.11%
Scapula	16	60	49	81.67%	11	18.33%
Humerus	28	179	142	79.33%	38	21.23%
Radius	30	217	192	88.48%	25	11.52%
Ulna	31	231	206	89.18%	25	10.82%
Os Coxa	28	191	151	79.06%	40	20.94%
Femur	23	119	106	89.08%	14	11.76%
Tibia	22	100	86	86.00%	14	14.00%
Fibula	15	60	49	81.67%	11	18.33%
Calcaneus	22	117	83	70.94%	34	29.06%

OSPD examined the humerus, radius, ulna, femur, tibia, and fibula. This method requires that several specific measures be present for each element to be considered by the statistical models, this limits the number of elements able to be considered in this analysis; a total of 114 elements or 28% of the assemblage was sorted by this method. Two models for each element were provided in Byrd (2008) and Byrd and LeGarde (2014) to assess both non-fragmented and fragmented elements. A summary of the specific measures used in each statistical model can be found in Appendix C.

Tables 8 and 9 provide the n for each element, the possible combinations, exclusions, percent exclusions, possible matches, and percent matches for both the non-fragmented and fragmented element models respectively. This method produced both moderate levels of percent exclusions and possible matches, with more exclusions than possible matches being made apart from the femur in the non-fragmented model. This method, in comparison OSPM method, was easier and faster to employ, but produced more ambiguous results and was only able to address a much smaller portion of the total assemblage.

Table 8. Summary of results of OSPD for non-fragmented elements.

Element	n	Total Possible Combinations	Number of Exclusions	% Exclusions	Possible Matches	% Possible Matches
Humerus	9	20	15	75.00%	5	25.00%
Radius	15	44	33	75.00%	11	25.00%
Ulna	12	36	22	61.11%	14	38.89%
Femur	4	3	1	33.33%	2	66.67%
Tibia						
Fibula	6	9	6	66.67%	3	33.33%

Table 9. Summary of results of OSPD for fragmented elements.

Element	n	Total Possible Combinations	Number of Exclusions	% Exclusions	Possible Matches	% Possible Matches
Humerus	24	143	92	64.34%	51	35.66%
Radius	26	160	102	63.75%	58	36.25%
Ulna	23	132	78	59.09%	54	40.91%
Femur	21	108	82	75.93%	26	24.07%
Tibia	14	33	23	69.70%	10	30.30%
Fibula						

<u>Joint Articulation</u>

OSJA employed all element types, except the clavicle and calcaneus, using 153 total elements and 37% of the assemblage. The joints examined by this method are the same as those examined by the qualitative joint articulation method, except the ulna-radius and tibia-fibula joints were excluded, and the humerus-radius joint was added. A summary of the measures used in each statistical model to examine these articulations can be found in Appendix C.

Tables 10 and 11 provide summaries of the n for each element, the possible combinations, exclusions, percent exclusions, possible matches, and percent matches for the left and right joint articulations respectively. There is no apparent trend the percent exclusions and percent possible matches identified with this method. Additionally, there is no correlation between those joints classified as high and medium confidence

Table 10. Summary of results for OSJA for the left joints.

Left Joint Articulations	n	Total Possible Combinations	Number of Exclusions	% Exclusions	Possible Matches	% Possible Matches
Scapula Humerus	6 8	48	43	89.58%	5	10.42%
Humerus Radius	6 13	78	17	21.79%	61	78.21%
Humerus Ulna	6 13	78	22	28.21%	56	71.79%
Os Coxa Femur	12 7	84	48	57.14%	36	42.86%
Femur Tibia						
Tibia Talus	3 16	48	28	58.33%	20	41.67%

Table 11. Summary of results for OSJA for the right joints.

Right Joint Articulations	n	Total Possible Combinations	Number of Exclusions	% Exclusions	Possible Matches	% Possible Matches
Scapula Humerus	10 6	60	60	100.00%	0	0.00%
Humerus Radius	5 3	15	7	46.67%	8	53.33%
Humerus Ulna	5 10	50	22	44.00%	28	56.00%
Os Coxa Femur	11 8	88	42	47.73%	46	52.27%
Femur Tibia	4 4	16	9	56.25%	7	43.75%
Tibia Talus	6 18	108	25	23.15%	83	76.85%

articulations by the qualitative method and the percent exclusions and possible matches. The low confidence articulation, of the scapula and humerus, yielded very few or no possible matches.

Comparison of Individual Method Performance

Assessment of how each individual method performed in relation to each other was examined through the comparison of percent exclusions and percent possible matches. As is widely accepted in all sorting methods, the power of the tests lies with their ability to exclude elements that do not associate with the element being examined. A sorting method that provided only exclusions however, would be as ineffective as a test that only provided possible matches. Additionally, a test that provided a balance of exclusions and possible matches, while providing useful data would not be sufficient to sort an assemblage independently. Therefore, the measure of how well each test performs individually was based on the premise that an effective test would exclude as many possible elements, while providing a low but present set of possible matches.

For matching of homologous pairs qualitative and quantitative results were compared by element. For this analysis, non-fragmented and fragmented results from OSPD were combined into a single data set. Figures 5 and 6 present the percent exclusions and percent possible matches for the pair matching methods, respectively.

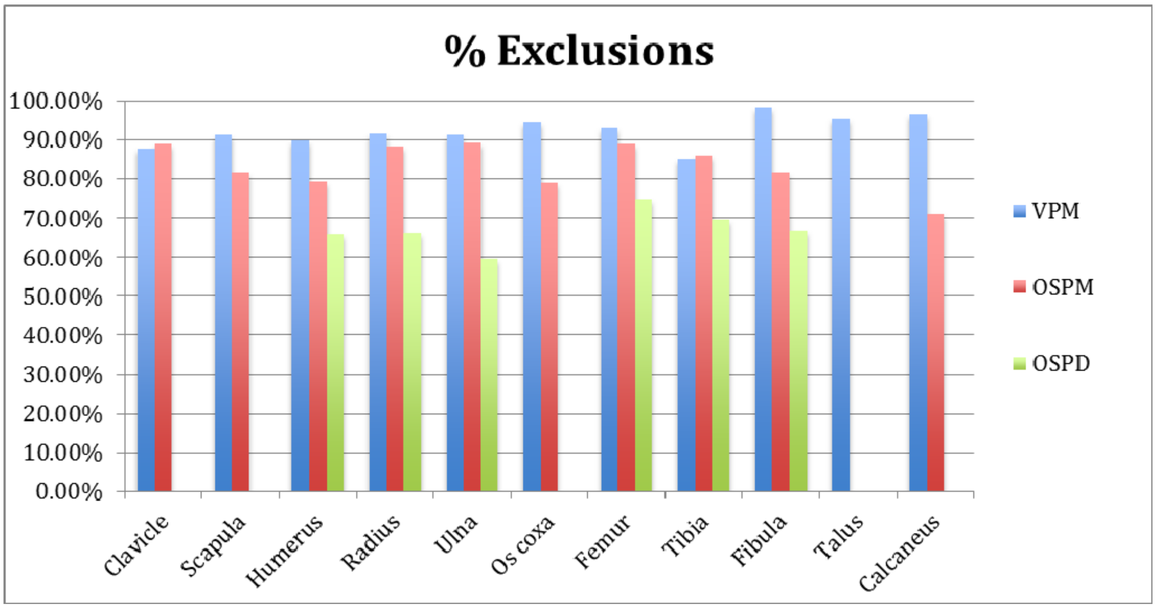

Figure 5. Summary of the percent exclusion produced by each pair matching sorting method.

These figures reflect that visual pair matching yielded the highest percent exclusions, while providing a low rate of possible matches, suggesting that this is the most independently critical of all the pair matching methods. OSPM provides the second highest exclusion rate while still yielding possible matches, but produces many more possible matches than visual pair matching. OSPD produced the lowest percent of exclusions, and the highest percent of possible matches, proving to be the least discerning

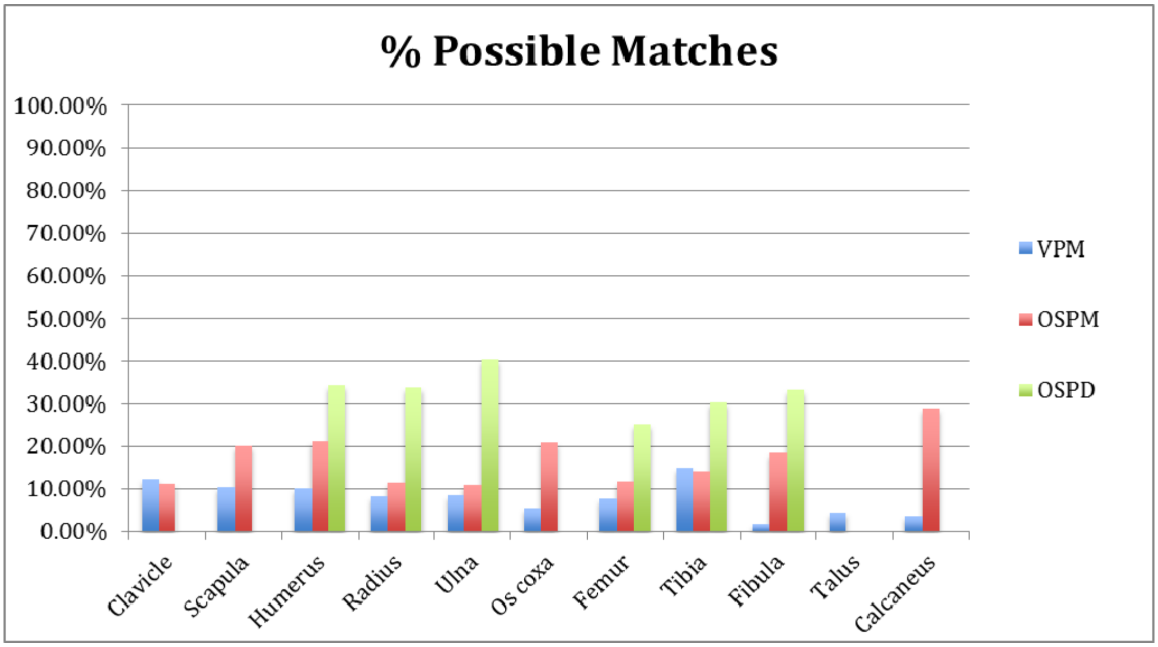

Figure 6. Summary of the percent possible matches produced by each pair matching sorting method. Please note the change in y-axis scale.

independent test. What must also be considered is that visual pair matching was able to produce 57 confident matches, an outcome that could not be produced using either osteometric sorting method.

Qualitative and quantitative results for methods of joint articulation were examined through the comparison of percent exclusion and percent possible matches for each joint. For this analysis left and right joints were combined into a single data set. Figures 7 and 8 present the percent exclusions and percent possible matches for these methods. These figures show that the results of JA do not follow the distinct patterns seen with the pair matching methods. The qualitative method of JA more frequently produces higher percentages of exclusions and lower percentages of possible matches than osteometric joint articulation. However, these percentages do not vary greatly, and suggest that the qualitative method is only slightly more effective as an independent

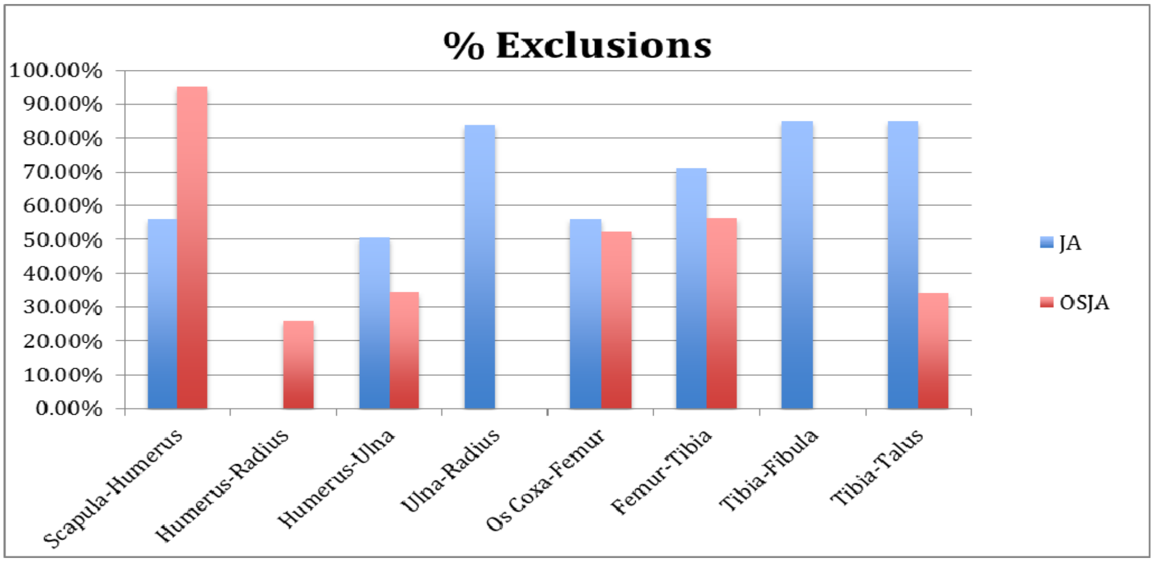

Figure 7. Summary of the percent exclusion produced by each joint articulation sorting method.

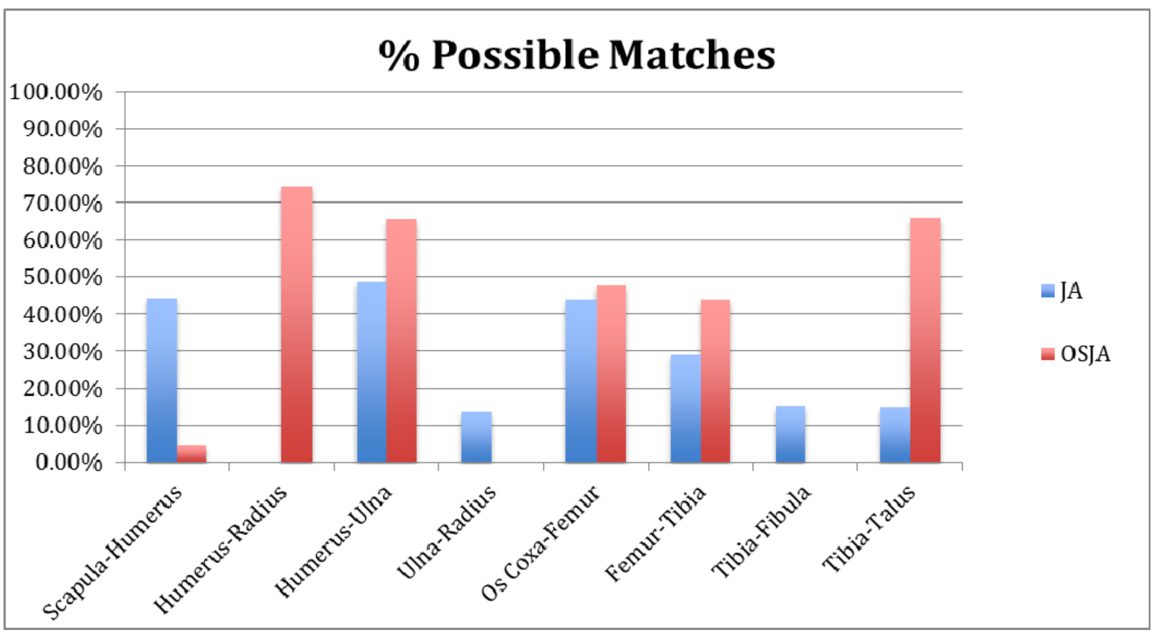

Figure 8. Summary of the percent possible matches produced by each joint articulation sorting method.

method of sorting than the quantitative method. This trend is reversed for the scapula-humerus joint. The degree of fragmentation in the scapula was quite high, with almost no articulations having the acromion and coracoid processes present, which dramatically affected how well one could assess the joint fit. Therefore, in this instance, the qualitative method was much less effective than the osteometric assessment of the joint.

When examining the joints based on confidence levels as described in Adams and Byrd (2006), high confidence joints in the qualitative method, ulna-radius and tibia-talus, did yield higher exclusion percentages with low possible match percentages, with the exception of the humerus-ulna joint. Rather, the medium confidence joint, between the tibia and fibula, reflected this trend. However, joints with two points of articulation, like the tibia and fibula, are much more specific in their fit to one another, and therefore this joint should potentially be changed to a high confidence joint classification. For the quantitative method, moderate and low confidence joints produced higher percentages of exclusions with lower percentages of possible matches, suggesting that osteometric sorting may be a more critical test of the fit of these joints than can be done with a qualitative assessment.

Order of Application of Methods

Qualitative then Quantitative

For this assessment, the qualitative methods of VPM and JA were conducted first. The possible matches produced by this initial sort were then sorted through the application of their quantitative counterparts, osteometric sorting pair matching and joint articulation. Changes to the percent exclusions and possible matches were examined to determine how well the assemblage was sorted.

Figures 9 and 10 present the percent exclusions and percent possible matches for VPM alone, and VPM with either OSPM or OSPD subsequently applied. The percent of exclusions increased with the application of both the quantitative methods. However, neither produced large increases, with OSPM providing more than OSPD method. The percent possible matches showed a corresponding trend, with decreases in both osteometric-sorting methods, with the greatest decrease in the application of OSPM. While recognizing that the power of these methods lies with their ability to exclude elements from matching, possible matches gain more credibility when they are matched by multiple methods. In the application of the OSPM model 68% of the possible matches

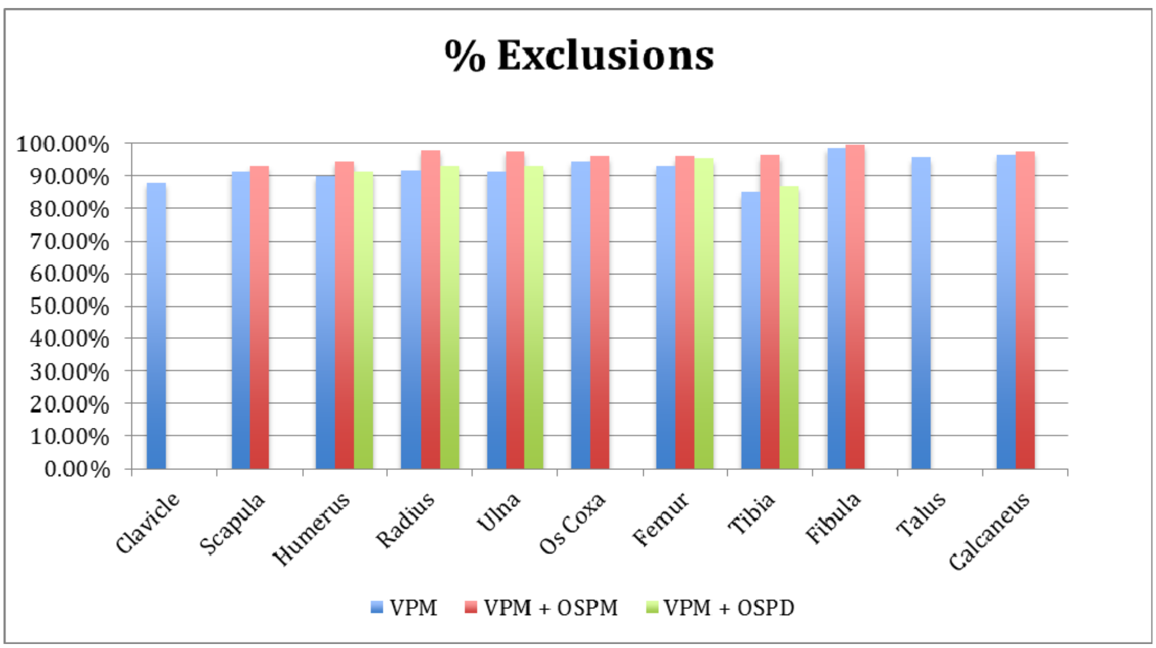

Figure 9. Summary of percent exclusions by VPM alone, and for VPM with either OSPM or OSPD being applied.

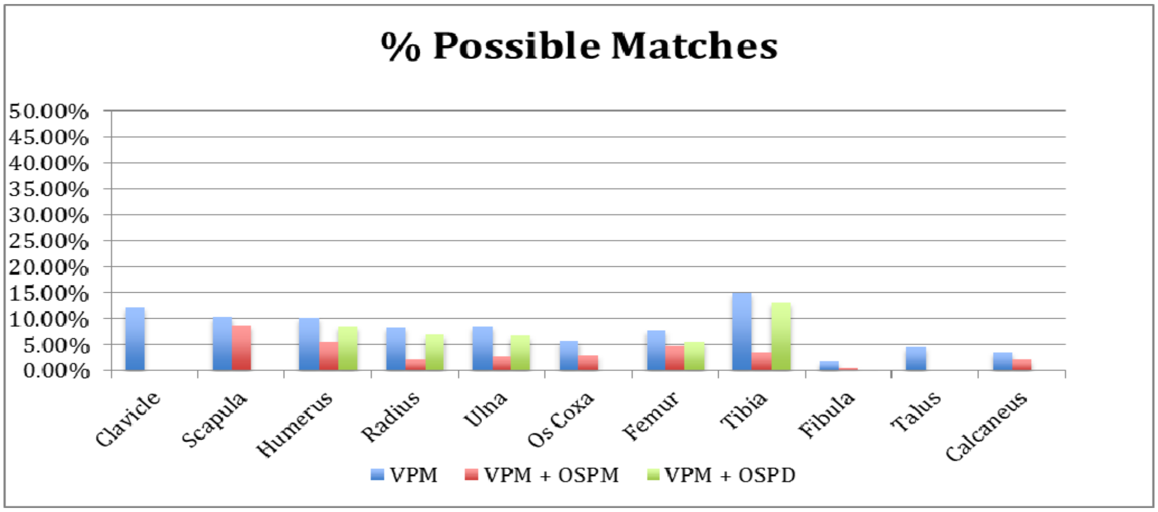

Figure 10. Summary of percent possible matches by VPM alone, and for VPM with either OSPM or OSPD being applied. Please note the change in y-axis scale.

were matched by both methods. In the OSPD model 54% of the possible matches were matched by both methods.

To examine the impact made on the confident matches made by VPM the original matches were enumerated, but in addition any element that paired to a single additional element by the qualitative method and one of the quantitative methods was also considered a confident match. For OSPM 41 of the 57 matches could be assessed by the osteometric sorting models. Of these, the OSPM method excluded 16 of the original confident matches, a 39% reduction. However, this method either confirmed or produced a total of 34 confident matches, a 17% reduction. For OSPD the osteometric models could assess only 21 of the original 57 confident matches, excluding 5 for a 24% reduction. However, this method in total produced 23 confident matches, nearly a 10% increase.

Figures 11 and 12 show the percent exclusions and percent possible matches for joint articulation performed alone, and JA in conjunction with the OSJA. The

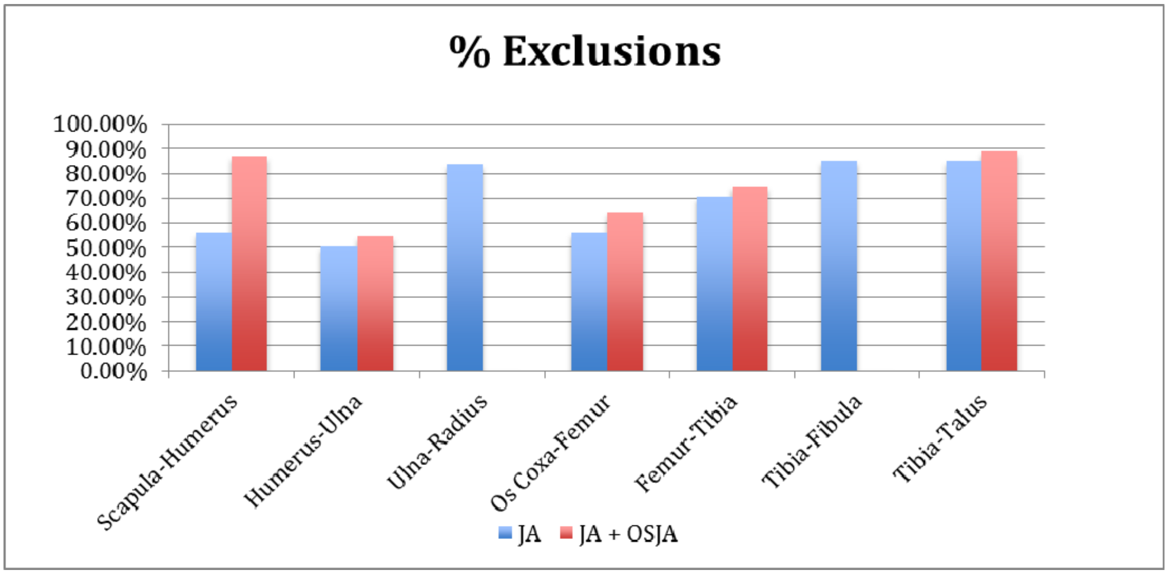

Figure 11. Summary of percent exclusions by JA alone, and JA + OSJA.

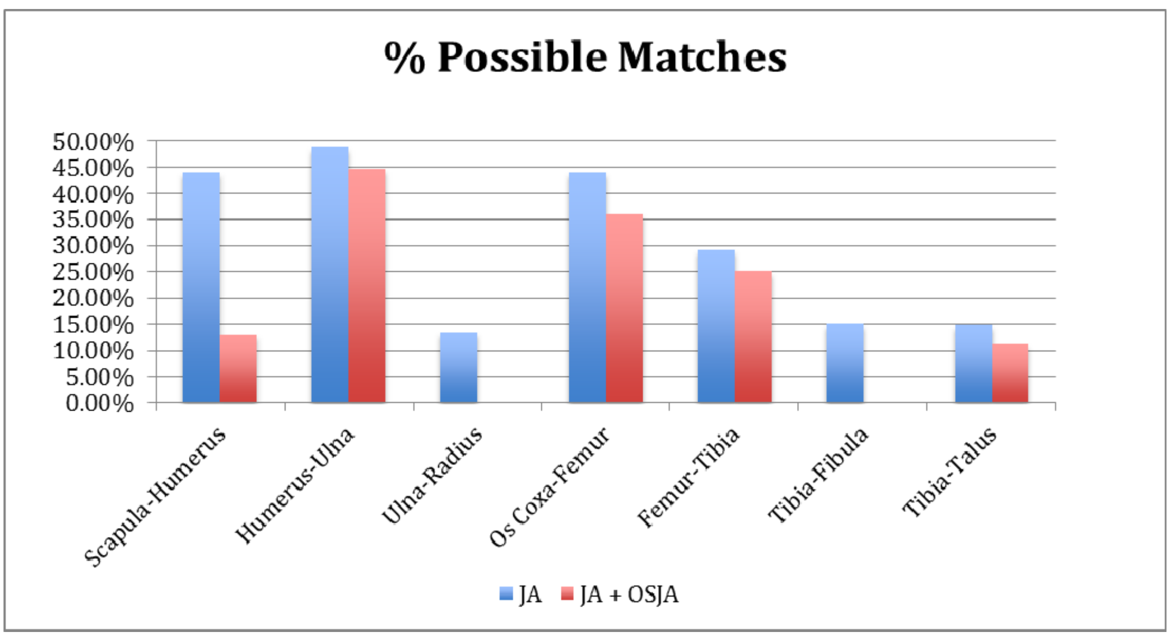

Figure 12. Summary of percent possible matches by JA alone, and JA + OSJA. Please note the change in y-axis scale.

application of the qualitative method again produces only slight increases in the percent exclusions and decreases in the percent possible matches. The largest differences in exclusions and possible matches are seen were in the scapula-humerus joint. This is likely due to the fragmentation in that joint that prevented a truly rigorous sorting in the qualitative method. Of the total possible matches after the application of both methods, 55% of the possible matches were confirmed by both methods.

For comparison to the pair matching methods, confident matches were also assessed in this analysis. Again, previous single good matches were enumerated, in addition to single matches made by both qualitative and quantitative methods. Of the 19 original confident matches, only nine could be assessed by the OSJA. Of these original matches three were excluded, a 33% reduction. From the application of both methods eight confident matches in total were either confirmed or produced, an 11% reduction the matches able to be examined by both methods.

In general, the changes made by the secondary application of osteometric sorting methods only produced small increases to the number of elements excluded. The greatest increase was seen in the JA method for the scapula-humerus joint. However, this effect may be due to fragmentation, as discussed above. Additionally, the decreases in possible matches occurred in the pair matching methods with the application of the OSPM method, suggesting that this may be the most discerning means to sort commingled remains when starting with qualitative methods and subsequently applying quantitative methods.

Quantitative then Qualitative

For this assessment, the quantitative methods of osteometric sorting for pair matching, using both the OSPM and OSPD, and OSJA were applied to the assemblage first. The possible matches generated by this analysis, were further sorted by the qualitative methods of VPM and JA. Again, percent exclusions and percent possible matches were used to evaluate the effectiveness of this order of methods.

Figures 13 and 14 show the comparison between the percent exclusions and the percent possible matches for osteometric pair matching using the OSPM alone; then the application of OSPM with VPM subsequently applied. Figures 15 and 16 also show the percent exclusions and the percent possible matches for OSPD alone, and OSPD in conjunction with VPM. With both pair matching quantitative methods the application of VPM resulted increased percent exclusions and large reductions in possible matches.

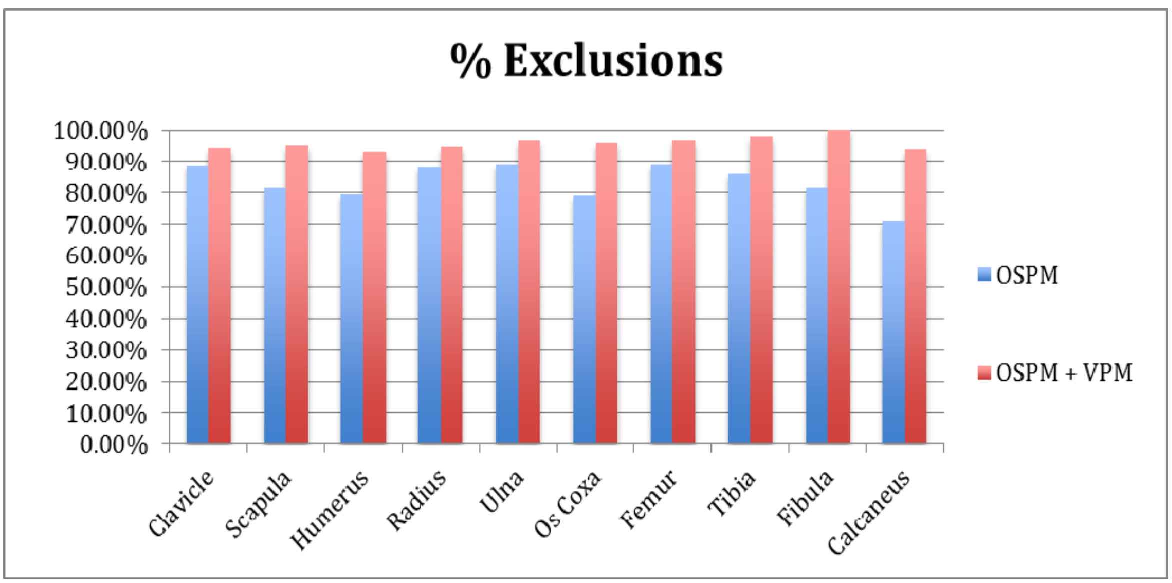

Figure 13. Summary of the percent exclusions from OSPM being applied alone, compared to the percent exclusions from OSPM + VPM being applied together.

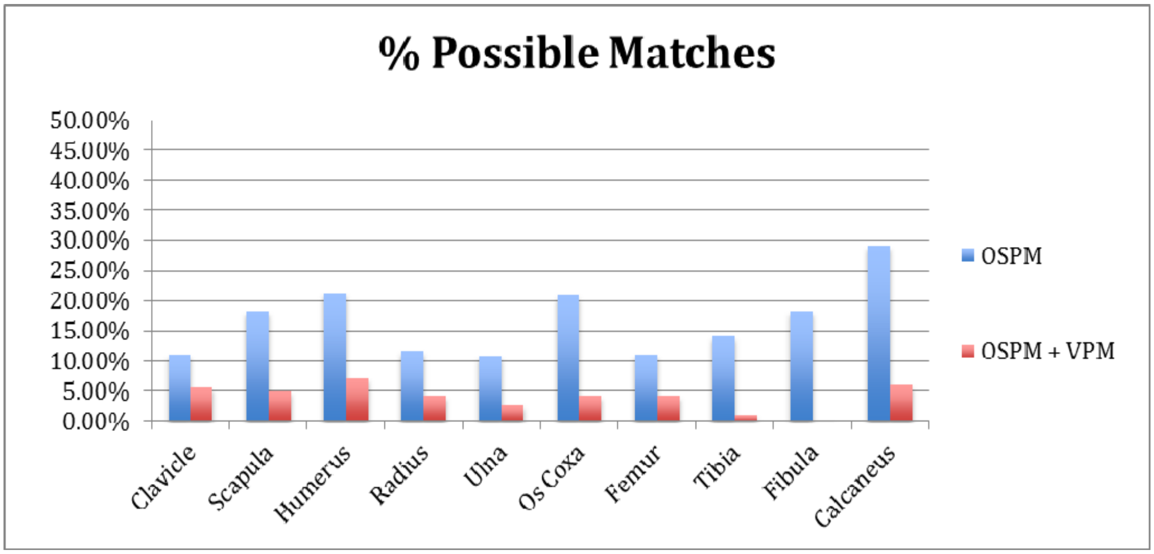

Figure 14. Summary of the percent possible matches from OSPM being applied alone, compared to the percent possible matches from OSPM + VPM being applied together. Please note the change in y-axis scale from percent exclusions.

However, with OSPD + VPM these increases in exclusions and reductions in possible matches are more pronounced, suggesting that the application of these methods, in conjunction with one another, provide a more rigorous sorting of the assemblage.

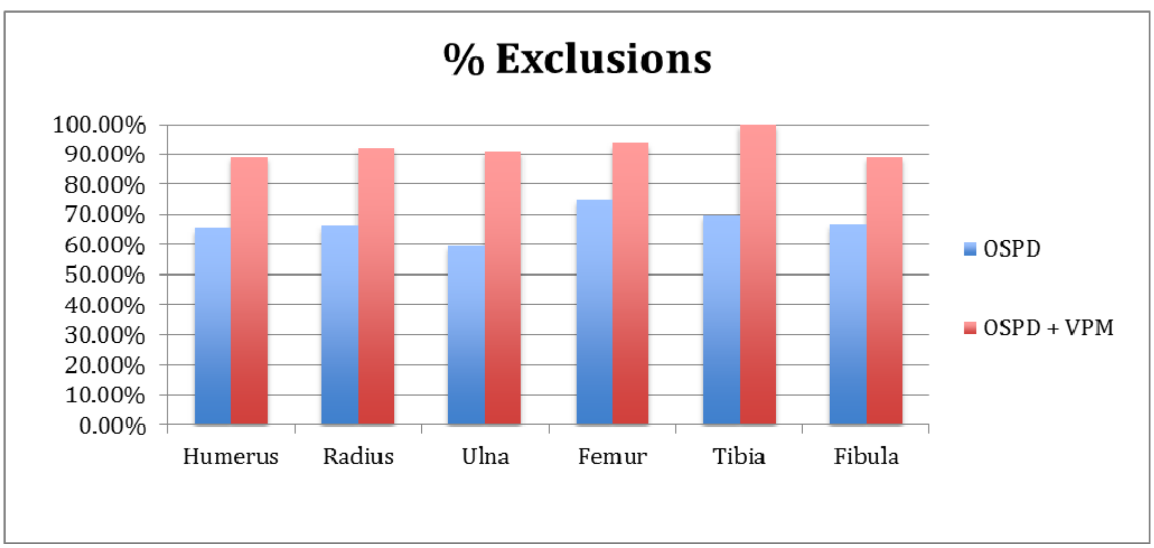

Figure 15. Summary of the percent exclusions from OSPD being applied alone, compared to the percent exclusions from OSPD + VPM being applied together.

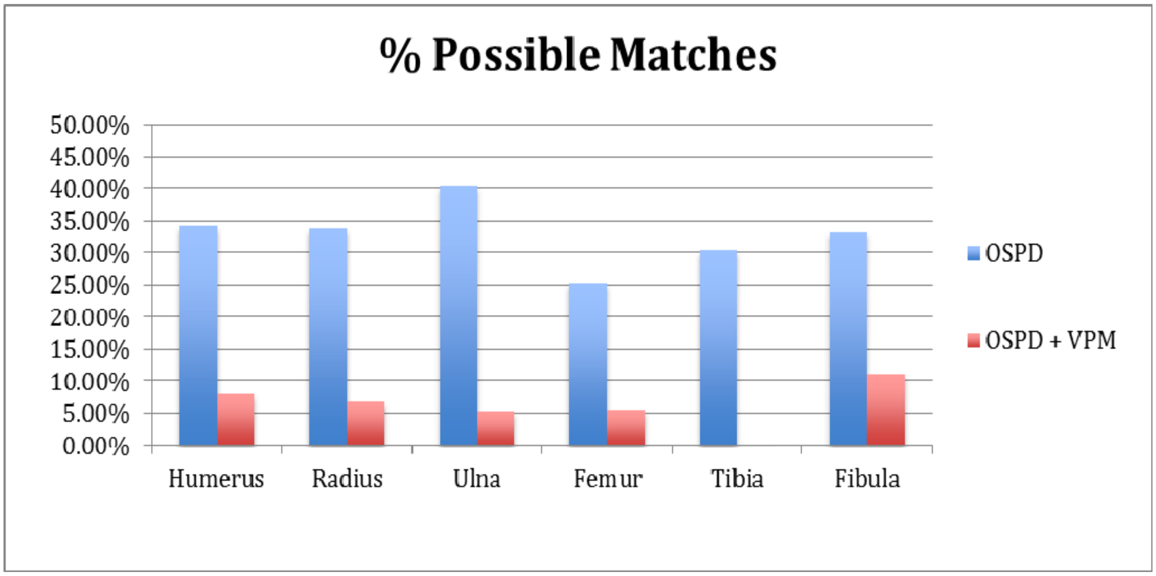

Figure 16. Summary of the percent possible matches from OSPM being applied alone, compared to the percent possible matches from OSPM + VPM being applied together. Please note the change in y-axis scale from percent exclusions.

Unlike with the qualitative to quantitative analysis, all possible matches could be addressed by the secondary method. Therefore, all possible matches after the application of the secondary methods were confirmed by both tests. Just as when VPM was performed individually, confident matches were identified by this method as well. In the OSPM + VPM method 27 confident matches were identified, with OSPD + VPM 19 matches were identified.

Figures 17 and 18 show the percent exclusions and the percent possible matches for OSJA performed alone, and for OSJA with JA performed subsequently. Again, there was an increase in the percent exclusions, and moderate to large decreases in the possible matches, depending on the joint. Moderate confidence level joints, as well as a single high confidence joint, humerus-ulna joint, showed the smallest decrease in possible matches, this reflects the similar ambiguity seen in the application of the JA

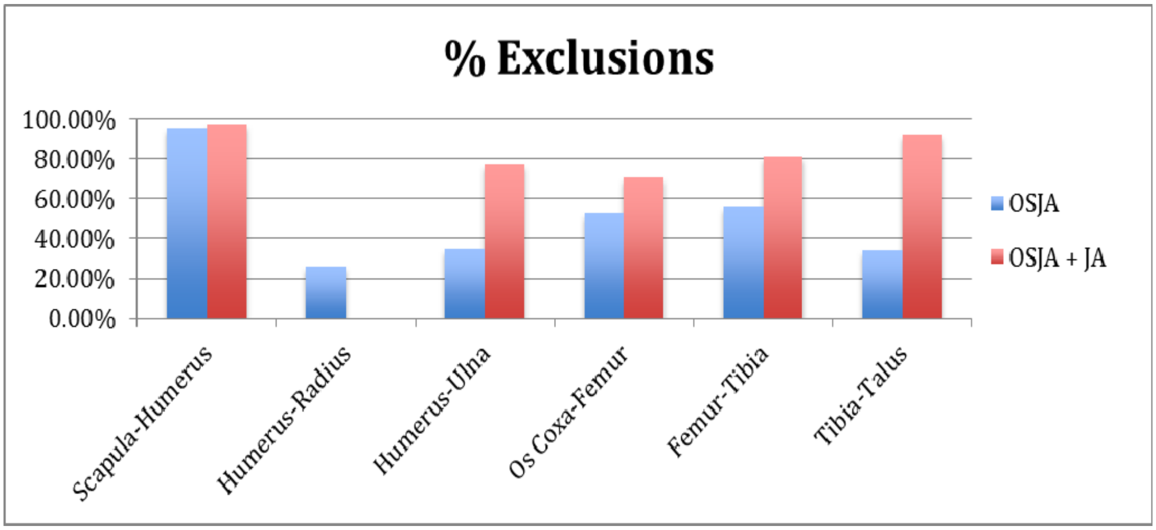

Figure 17. Summary of the percent exclusions from OSJA being applied alone, compared to the percent exclusions from OSJA + JA being applied together.

method alone. Additionally, the dramatic changes seen in the scapula humerus joint in the qualitative to quantitative comparison show the opposite trend for this analysis. This again supports the idea that for this particular joint the degree of fragmentation made the qualitative methods ineffective at assessing joint articulation.

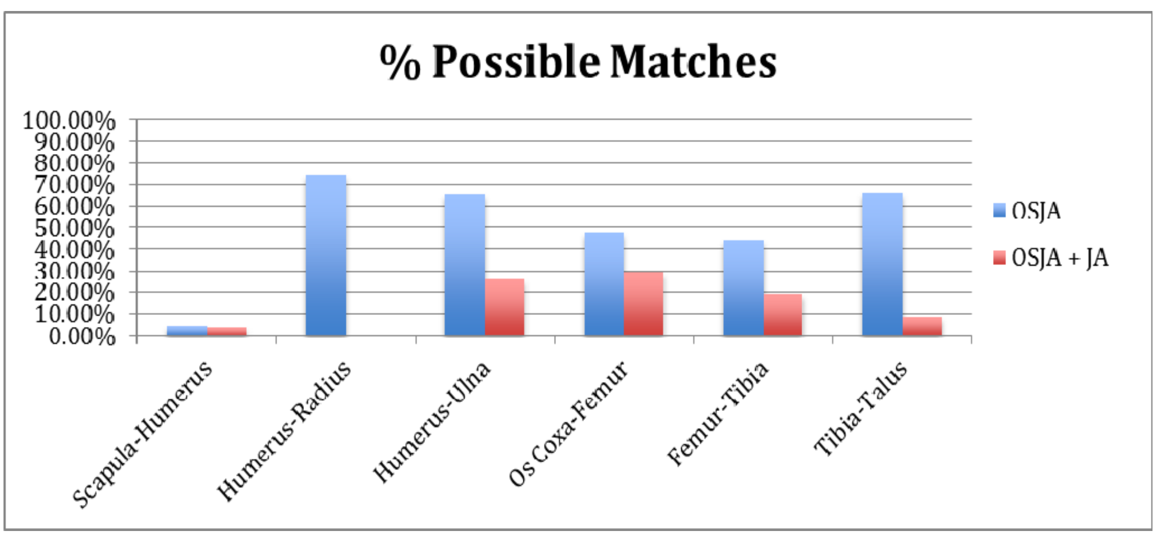

Figure 18. Summary of the percent possible matches from OSJA being applied alone, compared to the percent possible matches from OSJA + JA being applied together.

As with the pair matching analyses, under this approach, almost all possible matches could be assessed by the qualitative method. The only exception to this is the humerus-radius joint, which was not included under the qualitative method. Aside from this joint, all possible matches found after the application of OSJA and JA are all verified by both tests. Again, for the sake of comparison, single good matches established after the application of both methods were enumerated for comparison to the confident matches seen in the pair matching methods. From these methods 10 confident matches for joint articulation were identified. As with the application of JA alone, this amount is significantly less than the number of confident matches identified by the pair matching methods.

Demographics

Changes in the demographics of this assemblage could not be meaningfully assessed. While confident matches were tentatively made via one method or another, these matches did not always remain consistent across methods. Confident matches made initially by VPM were examined, as this was the largest group of confident matches made with in the study. Then only matches that remained a possible match between VPM and either OSPM or OSPD were considered, leaving 29 confident matches. Of these 29, 16 matches were consistent with their metrically determined sex classifications; 9 matches were made between an element of known sex and an element of unknown sex; 4 matches were composed of elements from the opposite sex. The results reflect some degree of ambiguity in sex being correctly assessed in 1 to 1 comparisons between elements. Additionally, while this sampling is the largest group of confident matches made in the study, this provides only a very small sample in the scope of the larger assemblage. Changes within this sample would not have significant impacts on the demographics of the assemblage as a whole.

Summary

This chapter first discussed the application of MNI, GMT, and MLNI to establish a baseline of individuals expected to be represented within this assemblage. Then the chapter turned to the examination of each method of sorting applied separately to the assemblage. After which these individual methods were compared to one another. Visual pair matching produced the highest percent exclusion and lowest percent possible matches of all the individual methods. Additionally, this method provided the largest set of confident matches. These results suggest that this method is the most individually effective for sorting commingled remains. Then this chapter addressed how the order of application of these methods effects how well the assemblage is sorted. The application of the quantitative methods, followed by the subsequent application of the qualitative methods, produced high percent exclusions and low percent possible matches, suggesting that this is the most effective order in which to apply methods of sorting. The reverse order yielded almost no change from the application of the qualitative methods alone. Finally, this chapter reported the effects of the sorting methods on the demographic assessment of the assemblage. While there were some changes in the determination of sex demographics made from individual matches, these were small and would have no effect on the overall demographic profile of the assemblage.

CHAPTER VI

DISCUSSION

Introduction

The chapter will discuss the implications of the results, how the research hypotheses were answered, and the conclusions that can be drawn from this study. The first section of this chapter discusses the results of the MNI, GMT, and MLNI analyses, as well as how each the sorting methods performed individually. The second section of this chapter will turn to the order of application of the methods, and the effects that changing the order had on the sort of the assemblage. Third, this chapter explores how the demographics of this assemblage allow for inferences about the potential origins of the assemblage. Finally, this chapter concludes with discussing the limitations of this study, directions for future research, and overall conclusions of this study.

Individual Method Performance

MNI/GMT/MLNI

Commingled assemblages present several hurdles to understanding the historical context in which the individuals that comprise the assemblage once lived. Calculations such as MNI, GMT, and MLNI help to establish a baseline for the number of individuals that may be represented within an assemblage. This information can help in understanding the demographic profile of the assemblage, as well as aid in making inferences about the mortuary behaviors that created the assemblage (Nikita and Lahr 2011:629). For this assemblage, the MNI was 22, without considering metric sex determinations, and 23 (11 males and 12 females) with sex considered. While these are "minimum" numbers, this balance suggests that the total assemblage is not skewed towards one sex or the other.

As stated in previous chapters, the calculation of MNI will consistently underestimate the number of individuals that are represented within an assemblage unless recovery rates approach 100%. Additionally, this calculation makes the assumption that elements that occur with less frequency within the assemblage are associated with the elements that occur with greater frequency (Adams and Konigsberg 2004:139). This assumption is potentially violated by the nature of this particular assemblage given that the pit feature was structured by element type, and there were very few articulated elements and no intact burials. This all suggests that it is unlikely that these remains are simply disturbed, or secondary deposits of burials. Evidence of disturbed burials may be provided by seeing a correlation between the recovery probabilities and the elements present, with denser elements occurring in greater frequency than those of less density (Willey et al. 1997). However, no such correlation is reflected in the recovery probabilities of this assemblage. Therefore, the possibility that this assemblage consists of an open population, subject to selective curation of the elements present cannot be dismissed.

The calculation of GMT attempts to address this issue, in that the assumption made by this calculation is that unpaired bones from different sides of an element originate from different individuals (Adams and Konigsberg 2004:139). GMTs for this assemblage ranged from 17-57 individuals depending on element. The low end of this range can obviously be dismissed, as it is lower than the established MNI for the assemblage. The high end of this range can also likely be dismissed. GMTs of 57 and 54 were calculated from the os coxa and scapula respectively. As GMT relies on pair matching, when pair matches are low the GMT value is driven up. This has much to do with the density and survivability of certain elements within as assemblage. Again, elements that are more regular in shape and denser are more likely to survive intact, and therefore will be more useful in pair matching than those that are more irregular and less dense (Adams and Konigsberg 2004:140; Willey et al. 1997). Given the high degree of fragmentation observed in the scapulae and os coxa of this assemblage, pair matches were somewhat difficult to establish. Likely, this means that the value for these particular elements were artificially driven higher than what should truly be represented in the assemblage overall. Eliminating the extremes in this calculation, the clavicle, scapula, and os coxa, the remaining eight element types have GMT values that range from 24-33 individuals. These values likely reflect a more accurate portrayal the true GMT for the assemblage; however, it is again important to recognize that the GMT, although less so than the MNI, will likely still underestimate the number of individuals represented in an assemblage (Adams and Konigsberg 2004:139; Horton 1984).

The MLNI attempts to address the problem of underestimation by calculating what is likely of true number of individuals that contributed to an assemblage. Again this calculation relies on pair matching, and is subject to the same limitations of survivability for particular elements, and should not be applied to highly fragmented assemblages (Konigsberg and Adams 2014:200). The MLNI for all element types has a large range from 28-113 individuals. Again, the scapula and os coxa, provide the extreme higher bound values, and the clavicle provides the extreme lower bound value. Eliminating these outliers, the remaining element types have MLNI's that range from 32-83 individuals. As this range is still somewhat large, the four elements with the highest recovery probabilities were examined in conjunction with one another. These produced an MLNI of 37, suggesting that the true MLNI of the assemblage is likely closer to that value.

These calculations can never be completely unbiased, however, studies have shown that when the recovery probability is greater than 0.5 and there are seven or more expected pairs, then with a 95% confidence interval, the bias of the equation becomes negligible (Adams and Konigsberg 2004:141–142). The ulna evaluated alone is the only element within the assemblage that meets these criteria, with a 0.54 recovery probability and 10 confident pair matches; the MLNI for this element is 32. Congruence between the MNI, GMT, and this value lend credence to its accuracy, and therefore, is likely a good estimate of the true size of the population for this assemblage (Adams and Konigsberg 2004:149).

Qualitative Methods

The qualitative methods in this study were approached in a way that is not completely traditional. Typically, in the process of VPM and JA, there are only elements that are excluded as non-matches, leaving a set of possible matches. This in essence was also done with this study, but additional classifications were made on the possible matches of good, moderate, and poor matches. This was done in an effort to classify degrees of variation that may have not been significant enough to exclude a match, and would be informative when additional methods were applied for a secondary sorting of the assemblage. The true strength of any of these tests lies with the ability to exclude matches; and as such, scaled system produced the same results as a binary classification of non-matches and possible matches.

As discussed in the previous chapter, evaluation of the effectiveness of a particular method for sorting a commingled assemblage is based on the premise that a rigorous method would produce a high percentage of excluded elements, while maintaining a low but present percentage of possible matches. When examining how the two qualitative methods of VPM and JA performed individually it is clear that VPM produced higher percentage of exclusions and a lower percentage of possible matches, whereas JA produced more ambiguous results. Additionally, the scaled system employed for possible match classifications was almost unused in VPM; matches tended to be able to be classified as good or confident matches or not matched at all. The determination of confident matches was highly conservative, recognizing that it is better to not classify a match than to match elements incorrectly. Confident matches were only classified as such when the morphology of one element matched another so well as to exclude all other possibilities. In contrast, JA exhibited a lot more ambiguity, with many elements able to potentially articulate with one another; therefore, the scaled system for possible matches provided informative data, especially with the secondary application of osteometric sorting.

The effectiveness of this sorting using the JA method varied between joints and maintained trends related to the classification of high, moderate, and low confidence joints as outlined in Adams and Byrd (2006). Percent exclusions for this method were highest in two of the three joints classified as high confidence joints (ulna-radius and tibia-talus joints) and the moderate confidence joint of the tibia-fibula. As discussed in the previous chapter, joints with two points of articulation were the easiest to match and produced the least amount of ambiguity with possible matches. Therefore, in the case where both articulation points are present the tibia-fibula articulation should also be classified as high confidence joint. Additionally, the articulation between the ulna and the humerus, while a tight-fitting joint, was not as easily classified. Many elements of similar size were able to potentially articulate, and exclusions for this joint could not be determined without significant shape and size differences between elements. This joint, performed similarly to the articulation between the os coxa and the femur, and should likely be reclassified as a moderate confidence joint.

Additionally, this method did not lend itself to the classification of confident matches in the same way that VPM did. Therefore, joint articulations classified as confident were produced only when a one to one good match between articulating elements was found. JA confident matches were only about 1/3 the amount seen in VPM. However, it is important to note that this reduction may not be exclusively due to a lack of rigor in the JA method, but may simply be a product of selective curation within the assemblage. While this possibility cannot be ruled out, when comparing these two qualitative methods, only VPM may be able to stand alone as a method of sorting. JA while providing extremely useful information did not produce enough discrete possible matches and requires the application of additional methods to refine the sorting of the assemblage.

Quantitative Methods

The osteometric sorting methods applied individually held similar trends to their qualitative counterparts. Pair matching by OSPM and OSPD produced higher percent exclusions and lower possible matches, than seen in OSJA. Between the two pair matching methods OSPM was more discerning than OSPD. Additionally, OSPM was able to assess a larger portion of the assemblage than OSPD, as OSPM evaluates each measure individually, and OSPD requires that multiple measures be present to be examined by the statistical models. It is important to note though that in the analysis of OSPM, possible matches were only classified as such if all measures available for a particular element were classified as possible matches. This does not account for the number of measures that made each classification, i.e. there may have been six measures present for an individual element and only two for another of the same type. Furthermore, exclusions could be made even if all but one measure was counted as a possible match. Therefore, elements counted as exclusions by the OSPM method, may have simply not been able to be analyzed by the OSPD method, or may have been excluded due to slight variation in a single portion of the element. Both of these factors could potentially significantly bias the results seen here.

The OSPD method, while not able to address as large a portion of the assemblage did not suffer from these biasing factors; all elements analyzed were classified as either not fragmented or fragmented, and analyzed by the same corresponding statistical model. Additionally, the calculations for the OSPD method were made significantly faster than those for the OSPM method. Since the OSPM method addresses measures individually, this method is more appropriate for small and potentially highly fragmented assemblages that the OSPD method would not be able to effectively analyze. However, in large assemblages of several hundred elements, such as the assemblage addressed in this study, the calculation for OSPM become extremely cumbersome, and the biasing factors discussed above would only become more significant.

OSJA, similar to its qualitative counterpart produced more ambiguous results. However again, noticeable trends corresponding to the confidence of the joint articulation could be seen. In this analysis, moderate and low confidence joints, with the inclusion of the single high confidence joint between the humerus and ulna, produced higher rates of exclusion and lower rates of possible matches. This trend was most pronounced in the scapula-humerus joint. As mentioned in the previous chapter, this is likely the result of the high degree of fragmentation in the scapula that prevented very discerning matches being made through the qualitative method. Additionally, the results for the humerus-ulna joint were again consistent with the moderate confidence joints, lending further support to the reclassification of this joint as also one of moderate confidence as well. In general, these trends suggest that quantitative analyses provide more critical assessment of joints that cannot be assessed with high confidence visually.

In contrast to the qualitative methods, the osteometric sorting methods could not produce any confident matches in an assemblage this large. The calculations very rarely produced single possible matches, and when this was the case, there was significant overlap among elements. For this reason alone, the hypothesis of the first research question must be rejected. At least for large commingled assemblages, the quantitative methods will fail to produce discrete results that would allow for the effective sorting by one of these methods alone. In addition, the application of the quantitative methods was significantly more time consuming and difficult than for either of the qualitative methods, consistent with the findings in Buikstra et al. (1984). For the two qualitative methods, VPM is the only method that had the potential to effectively sort the assemblage applied alone, as this method produced the most exclusions while maintaining a small proportion of possible matches, as well as producing the highest rate of confident matches out of all the individual methods.

Order of Application of Methods

Qualitative to Quantitative

For this analysis, the qualitative methods of VPM and JA were applied to the sorting of the assemblage first, and then the possible matches generated from that analysis were further sorted by the application of the osteometric sorting methods. For the pair matching methods only slight increases in the percent exclusion were seen, with only slightly more exclusions from the OSPM method than from the OSPD method. Decreases in the percent of possible matches were seen for both methods, with the decreases being more pronounced for the OSPM method. These trends again suggest that the OSPM method performs more effectively than the OSPD method, but the biases discussed above remain a confounding factor.

The application of the OSJA method to the initial sorting of JA also produced only slight increases in the percent exclusions and corresponding slight decreases in the possible matches. The exception to this trend is seen in the scapula-humerus joint, where there were large increases in the exclusions as well as a large decrease in the in the possible matches. However, as discussed above these dramatic changes may be due to the fragmentation associated with this joint, making the quantitative analysis much more accurate than the qualitative analysis could be in this case.

When assessing the confident matches produced by the initial analysis of the assemblage with the qualitative methods, the secondary application of the osteometric methods served as an additional confirmation of these matches' veracity. Additional confident matches were determined when a single element was paired to another element by both the qualitative and one of the quantitative analyses. Not all matches could be assessed by both, and in some cases either, quantitative method due to fragmentation in the elements. Again, the OSPM method was able to examine more of the confident matches (41 of 57 original matches), and excluded a higher percent of confident matches (16 matches or 39%), than those excluded by the OSPD method (Of 21 analyzed matches 5 were excluded or 24%). Additionally, even though both quantitative methods generated new confident matches (OSPM=34 and OSPD=23); only the OSPD method generated an increase in the confident matches than those initially able to be examined by this method.

Many factors may be at play to explain why these methods performed as they did. As the OSPD method excluded less previously established confident matches, and produced additional matches, may suggest that this method more accurately identifies these matches. However, the fact the OSPM method excluded more of the previous matches may reflect the potentially more rigorous nature of this analysis, but equally may reflect the biases that are discussed above. The application of the OSJA method to the confident matches established from JA method (19), also produced an overall reduction in the confident matches. Of the original confident matches nine could be assessed, three were excluded, and the method maintained or produced 8 confident matches. However given the heightened variability found with in both qualitative and quantitative JA analyses this reduction could be attributed to a more analytical assessment of a confident matches. Understanding the nuances of what specifically produces these results is difficult, and cannot be truly determined without further testing of these methods on simulated cases of commingling using documented collections. Additionally, it must be noted that when visually assessing confident matches, to some degree an osteologist is simply taking in the gestalt of an element or a joint. Some of the matches excluded by the osteometric sorting analyses when compared visually are clearly matches. Therefore, it is likely, that at least to some degree, these exclusions may simply highlight some of the error that is always inherent in any quantitative analysis.

Quantitative to Qualitative

In this analysis, the osteometric sorting methods were first employed to sort the assemblage, and their qualitative counterparts were used to examine the possible matches generated by the first analysis. Unlike with the qualitative to quantitative method all possible matches could be assessed the secondary analysis. For the pair matching methods, the secondary application of VPM produced significant increases to the percent of exclusions and decreases to the percent of possible matches for both OSPM and OSPD initial analyses, with the greater degree of change being evident from the OSPD+VPM method. Again, the true causes of these trends are difficult to tease out, they may reflect the OSPM method was more rigorous to begin with, and therefore the application of VPM had less of an effect on the results, or that the combination of the OSPD +VPM is in general more effective at sorting the assemblage. Direct comparisons of the elements excluded are not necessarily informative as both sets of quantitative analyses are not able to address the exact same sample of elements.

The application of JA to the initial OSJA analysis reflects the same trends seen in the application of JA alone. Moderate to high confidence joints exhibited greater increases in exclusions, and decreases in possible matches. In contrast to the other joints examined, there was almost no change seen in results from the application of OSJA alone to the addition of the qualitative JA method for the scapula-humerus joint. However, this lends credence to the idea that the quantitative assessments are far superior for analyzing this particular joint and that the qualitative analysis is simply not able to do an accurate analysis due to fragmentation.

Confident matches were established following the same criteria used in the application of the qualitative methods alone. From the OSPM+ VPM method, 27 confident matches were identified, and OSPD+VPM identified 19 confident matches. The application of OSJA+JA identified 10 confident matches, again producing significantly fewer matches than the pair matching methods; reflecting the same trends seen in the application of the qualitative methods alone. It is difficult to compare these results to those found in the qualitative to quantitative assessment. As there were no confident matches identified with the osteometric method alone, there are no exclusions of these matches by the application of the second method. This perhaps makes the results appear strong; but in truth they are not being assessed under the same conditions. On the other hand, confident matches identified by the qualitative methods do benefit from the ineffable gestalt that lends great confidence to the accuracy of these matches.

In general, the application of methods beginning with the quantitative methods, and the secondary analysis by the qualitative methods, appears to be much more effective at sorting the assemblage. Thereby, the hypothesis of the second research question is accepted. This order of methods reflects the greatest change in exclusions and possible matches from the application of the first method to the second, whereas the qualitative to quantitative methods do not improve much beyond the application of the qualitative methods alone. This is again consistent with the findings in Buikstra et al. (1984), which found that while the osteometric comparisons were consistent with the initial joint articulation of cervical vertebrae, these findings did not substantially improve or save significant amount of time in analysis. However, as Buikstra et al. (1984) did find that the osteometric sorting was consistent with the qualitative sorting, it is logical to conclude that with a large collection, an initial sort osteometric methods will provide a set of possible matches that can then be more accurately refined by the visual assessment, as shown in the current study.

Demographics

The results of these sorting methods did not provide discrete results significant enough to have a meaningful impact on the demographics of the unsorted assemblage. Therefore, the hypothesis to the third research question must be rejected, in that sorting of the assemblage will create meaningful changes to the demographics of the assemblage, and will aid in one's ability to make inferences about the origins of this assemblage.

Complete demographic, pathological, and taphonomic analyses of the unsorted assemblage can be found in Willey et al. (2016). A brief summary of the results of this report conclude that the Point San José Assemblage is composed predominately of middle age individuals, with a sex ratio that is similar to the 1870 census data. Additionally, ancestry estimations from the cranial remains found that there are equal numbers of Asian, or Asian-related, individuals represented within the assemblage as White individuals. Pathological conditions are found in only 20% of the entire assemblage. These are mostly degenerative conditions and poor oral health, which are consistent with middle age individuals of low socioeconomic status. Finally, taphonomic analysis found the cut and saw marks are found in all major portions of the body.

As discussed in Chapter II, individuals used for anatomical dissection were predominately the bodies of executed criminals, the deceased indigent from almshouses and hospitals, or simply the poor and socially marginalized of society buried in potter's fields. While African Americans were disproportionately targeted in many regions of the country, however, in 19th century California, Asian, Asian-related, and Hispanic individuals composed much of ethnic minorities of the region (Willey et al. 2016). Additionally, other immigrant groups such as White Irish or Italian individuals also frequently part of the low socioeconomic class within this country (Muller, Pearlstein, and de la Cova 2017; Nystrom 2011; Nystrom 2014; Sappol 2002; Richardson 2000). Therefore, findings from the analysis of the unsorted Point San José assemblage show that the assemblage is consistent with the groups of individuals that frequently became cadavers for anatomical study and dissection during that time.

Differentiating between unclaimed bodies from autopsy procedures and those used in skeletal dissection can be determined from multiple factors. Distinguishing factors of bodies frequently used for dissection exhibit a high degree of fragmentation, multiple cut marks throughout the regions of the body that are not associated with the determination of cause or manner of death, elements discarded with other medical waste and refuse, and associated artifacts that may suggest long term retention of the remains (Chapman and Kostro 2017; Nystrom 2011; Nystrom 2014; Sappol 2002). The remains of the Pont San José assemblage are consistent with the degree of fragmentation, the ubiquitous and repetitive cut and saw marks, and the associated medical refuse found within the pit feature. While the sorting of the assemblage was not able to provide additional information regarding the demographics of this assemblage, the current findings suggest that this is a collection of discarded remains that were used for dissection and anatomical study.

Limitations

The main limitation that affects all aspects of analysis of this study is that the population of this assemblage is likely an open population; as has been stated repeatedly, the power of the methods for sorting commingled remains lies with the ability to make associations between elements through the process of elimination. Therefore, these analyses, to be truly effective, must be conducted on a closed population of individuals. This allows for associations to be made on negative evidence (Byrd 2008; Byrd and LeGarde 2014). The fact that current assemblage may represent an unknown number of individuals, of which several may only be represented within the assemblage by as little as a single element, poses a direct conflict to this initial premise for sorting commingled remains.. As has been borne out, the assemblage could not be fully sorted, and this study was only able to make progress in the direction of a complete sort of the remains.

Confounding factors concerning the specific methods of the study first must be addressed in the qualitative methods. While, with all the methods, the strength of these analyses is in the exclusionary powers; the application of these methods is inherently inclusionary. Both visual pair matching and joint articulation are discussed as methods where associations between individual elements can be made based on similarities between elements or congruency within a joint (Adams and Byrd 2006). This would not present a significant bias in the analysis of closed population commingled assemblage. However, when applying these methods to an assemblage that represents an open population, an inclusionary application of a method may cause a researcher to seek out matches that may not be present. In this study, this potential bias was kept in mind during data collection; however, confident matches were inevitably made based on an inclusionary process, as establishing associations based on negative evidence was not possible with this assemblage.

Additional limitations to the application of the qualitative method are the subjective nature of the assessment. Visual pair matching was found to be effective in the humeri, femora, and tibiae, but only when assessed by an experienced osteologist (Adams and Byrd 2006:65). Additionally, joint articulation, while cited a more reliable assessment of element association, in this study was found to provide very ambiguous results. Additionally, the assessment of an articulation is also affected by the fit of the particular joint. Joints that are of lower confidence levels are found to be difficult to assess and may again be influenced by the experience level of the observer (Adams and Byrd 2006:65). To control for these influences inter-observer studies should be performed to examine if reliable classifications can be made by multiple individuals. These studies will be discussed in the following section.

The quantitative methods present fewer potential biases. Both the OSPD and OSJA methods do not introduce bias since specific measures must be present to be addressed by the statistical models. Therefore, while limiting on the amount of an assemblage that can be analyzed, all comparisons made are based on the same amount of information among elements. The OSPM method introduced more complexity; the method as outlined by Thomas et al. (2013) only addressed the application of the M-statistic to individual measures for each element. However, it was frequently the case that an element would match another by some measures, not by others. Therefore, to address this problem, possible matches were limited to those elements that matched by all present measures. However, this did not control for the number of measures that might constitute a match (i.e. one element may match another based on three measures, and another element may make a match based one measure due to fragmentation). Thus, the same level of rigor is not applied to each possible match; however there is no way to control for this in anything but an assemblage with fully intact remains. As discussed above, this method maybe best applied to much smaller and potentially highly fragmented assemblages where comparison of individual measures is only possible.

Future Research

There are many avenues of future research that should be conducted to continue moving this assemblage to a more comprehensive sorting. The first of these studies should be the application of the osteometric sorting for inter-element comparison. This method was not pursued in this particular study, as it did not have a direct comparison to a qualitative method. However, and inter-element comparison would provide an additional test to examine the associations of elements from joint articulation; as well as allow for associations to be made between elements that would otherwise not be possible, allowing for a more comprehensive sorting of the assemblage.

To address the second limitation of the application of the qualitative methods, a study examining inter-observer error should be conducted. Visual pair matching has been cited as being best assessed by an experienced osteologist, in the humeri, femora, and tibiae (Adams and Byrd 2006:65). To make accurate comparisons to the osteometric sorting methods, the inter-observer error studies, conducted by individuals of varying experience levels, should be examined, not only for the three previously specified elements, but for the clavicle, scapula, radius, ulna, os coxa, fibula, talus, and calcaneus as well.

Finally, a study further exploring the method outlined by Thomas et al. (2013) is needed to make this method of sorting truly applicable to large, intact assemblages. It is necessary to establish a threshold for the number of measurements that can cause an exclusion or possible match for an element. This may have the effect of reducing the number of elements that can be examined by this method. However, a study such as this would aid in removing the significant biases that make it impossible to assess the rigor of this method.

Conclusions

In conclusion, visual pair matching proved to be the most effective means of sorting the assemblage as an independent method. This method was able to examine the majority of the assemblage, and produce a high rate of exclusions, while still providing a few possible matches, many of which were confidently associated elements. While the osteological skill level of the observer potentially affects this method, future inter-observer error studies could examine the true impact this has on the results of the sorting (Adams and Byrd 2006).

The application of multiple methods lends greater confidence to the possible matches identified in this sorting. This is especially important for an open population, as the potential for making false matches is higher due to the inability to effectively make inferences from negative data. The application of the osteometric sorting methods was found to provide a set of potential matches, and refining these matches with the secondary application of visual pair matching or joint articulation, produced the most effective sort of the assemblage. Future applications of such methods as inter-element osteometric sorting may be able to produce more discrete matches within this assemblage.

Finally, significant changes to the demographics of the assemblage were not able to be determined, due the lack of discrete matches made by the sorting methods. However, the previous study of the unsorted assemblage by Willey et al. (2016), support that this assemblage is composed of mostly middle-age adults, of low socio-economic status, with equal representation from both men and women. Additionally, equal numbers of individuals of White and Asian ancestry was present. Finally, the pathological and taphonomic analyses do not reflect trends typically seen in autopsy, and in the pursuit if a cause or manner of death (Willey et al. 2016). Rather the high level of fragmentation, repetitive cut marks and saw marks throughout all regions of the body that are not associated with typical autopsy procedures, as well as the association of other medical refuse within the pit feature, all suggest that this assemblage is the discarded remains of an anatomical collection used for the purpose of dissection and study (Chapman and Kostro 2017; Nystrom 2011; Nystrom 2014; Sappol 2002).

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APPENDIX A

Summary of measurements, corresponding measure numbers, and sorting tests measures used. OSPM is the pair matching test from Thomas et al. (2013), OSPD value and OSJA are pair matching and joint articulation tests from Byrd (2008) and Byrd and LeGarde (2014). Descriptions of measurements found in Buikstra and Ubelaker (1994), Moore-Jansen et al. (1994), Byrd (2008), Byrd and LeGarde (2014), and Thomas et al. (2014).

Measurement	Measure #	Test		
		OSPM	OSPD	OSJA
Clavicle				
Maximum Length	35	✓		
Sagittal Diameter at Midshaft	36	✓		
Vertical Diameter at Midshaft	37	✓		
Scapula				
Height	38	✓		
Breadth	39	✓		
Maximum Height of Glenoid Fossa	39A	✓		
Maximum Breadth of Glenoid Fossa	39B	✓		✓
Humerus				
Maximum Length	40	✓	✓	
Epicondyle Breadth	41	✓	✓	
Capitulum-Trochlea Breadth	41A	✓	✓	✓
Maximum Vertical Head Diameter	42	✓		
Maximum Anterior-Posterior Head Breadth	42A	✓		✓
Maximum Diameter at Midshaft	43	✓		
Minimum Diameter at Midshaft	44	✓		
Minimum Diameter of Diaphysis	44B	✓	✓	
Radius				
Maximum Length	45	✓	✓	
Sagittal Diameter at Midshaft	46	✓	✓	
Transverse Diameter at Midshaft	47	✓	✓	
Maximum Diameter at Radial Tuberosity	47A	✓	✓	
Maximum Diameter of the Diaphysis Distal to Radial Tuberosity	47B	✓	✓	
Minimum Diameter of the Diaphysis Distal to Radial Tuberosity	47C	✓	✓	
Maximum Diameter of Radial Head	47D			✓

Measurement	Measure #	Test		
		OSPM	OSPD	OSJA
Ulna				
Maximum Length	48	✓	✓	
Dorso-volar Diameter	49	✓	✓	
Transverse Diameter	50	✓	✓	
Physiological Length	51	✓		
Minimum Diameter along the Interosseous Crest	51A	✓	✓	
Minimum Diameter	51B	✓		
Breadth of Distal End of Semilunar Notch	51C			✓

Os Coxa				
Height	56	✓		
Iliac Breadth	57	✓		
Maximum Thickness at Sciatic Notch	59A	✓		
Maximum Diameter of the Acetabulum	59E	✓		✓
Femur				
Maximum Length	60	✓	✓	
Epicondylar Length	61	✓		
Epicondylar Breadth	62	✓	✓	✓
Maximum Head Diameter	63	✓	✓	✓
Anterior-Posterior Subtrochanteric Diameter	64	✓	✓	
Transverse Subtrochanteric Diameter	65	✓	✓	
Anterior-Posterior Diameter at Midshaft	66	✓		
Superior-Inferior Neck Diameter	68D	✓		
Maximum Diameter along linea aspera	68E			
Tibia				
Maximum Length	69	✓	✓	
Maximum Breadth of the Proximal Epiphysis	70	✓	✓	✓
Maximum Breadth of Distal Epiphysis	71	✓	✓	✓
Maximum Diameter at Nutrient Foramen	72	✓	✓	
Transverse Diameter at Nutrient Foramen	73	✓	✓	
Maximum Anterior-Posterior Diameter Distal to Popliteal Line	74A	✓		
Minimum Anterior-Posterior Diameter Distal to Popliteal Line	74B	✓	✓	
Fibula				
Maximum Length	75	✓	✓	
Maximum Diameter at Midshaft	76	✓	✓	
Minimum Diameter of Diaphysis	76B	✓		

Measurement	Measure #	Test		
		OSPM	OSPD	OSJA
Calcaneus				
Length	77	✓		
Middle Breadth	78	✓		
Talus				
Minimum Breadth of Articular Surface (Trochlea)	79			✓

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APPENDIX B

Summary of ICC results. Bolded lines are measures that were flagged for the recollection of measurements on all elements.

Measure #	ICC co-efficient	95% CI		Sig.	Measure #	ICC co-efficient	95% CI		Sig.
		Lower	Upper				Lower	Upper	
35	0.994	0.976	0.999	0.000	60	0.998	0.659	1.000	0.000
36	**0.557**	**-0.330**	**0.888**	**0.570**	61	0.999	0.928	1.000	0.000
37	**0.380**	**-0.662**	**0.836**	**0.200**	62	0.953	0.737	0.992	0.001
40	0.999	0.873	1.000	0.000	63	0.951	0.743	0.989	0.000
41	0.970	0.678	0.994	0.000	64	0.914	0.661	0.979	0.001
42	0.978	0.915	0.994	0.000	65	0.980	0.918	0.995	0.000
43	0.985	0.903	0.997	0.000	66	0.953	0.767	0.991	0.000
44	**0.906**	**0.110**	**0.981**	**0.000**	69	0.999	0.987	1.000	0.000
45	0.984	0.936	0.996	0.000	**70**	**0.964**	**-0.027**	**0.998**	**0.001**
46	**0.858**	**0.100**	**0.969**	**0.000**	71	0.919	0.624	0.981	0.000
47	0.977	0.911	0.994	0.000	**72**	**0.956**	**0.403**	**0.992**	**0.000**
48	1.000	0.999	1.000	0.000	73	0.945	0.787	0.986	0.000
49	**0.764**	**-0.221**	**0.949**	**0.001**	75	1.000	0.989	1.000	0.000
50	0.911	0.663	0.977	0.001	76	0.982	0.877	0.997	0.000
51	0.998	0.993	1.000	0.000	77	0.905	0.644	0.976	0.001
56	**0.980**	**0.451**	**0.998**	**0.000**	**78**	**0.818**	**0.218**	**0.955**	**0.012**
57	**0.897**	**-0.092**	**0.983**	**0.000**					

APPENDIX C

Measures used for the osteometric comparison of paired elements for OSPD model as provided by Byrd (2008) and Byrd and LeGarde (2014).

Element	Measure Number	Element	Measure Number
Non-Fragmented Elements		Fragmented Elements	
Humerus	40, 41, 42	Humerus	44B
Radius	45, 46, 47	Radius	47A, 47B, 47C
Ulna	48, 49, 50	Ulna	49, 50, 51A
Femur	60, 62, 63, 64, 65	Femur	64, 65
Tibia	69, 70, 71	Tibia	72, 73, 74B
Fibula	75, 76		

Summary of measures used for the OSJA articulations as described by Byrd (2008) and Byrd and LeGarde (2014)

Joint Articulation	Measure Number	Joint Articulation	Measure Number
Scapula-Humerus	39B, 42A	Os Coxa-Femur	59E, 63
Humerus-Radius	41A, 47D	Femur-Tibia	62,70
Humerus-Ulna	41A, 51C	Tibia-Talus	71,79

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