# A BIOARCHAEOLOGICAL STUDY OF OSTEOARTHRITIS OF AGRO-PASTORALISTS FROM MISTIHALJ, BOSNIA AND HERZEGOVINA: A LIFESTYLE SET IN TIME

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# ABSTRACT

Activity stresses are an important factor in the development, patterning, and severity of osteoarthritis. This bioarchaeological thesis explores the prevalence and patterning of osteoarthritis between individuals buried at a Late Medieval Necropolis and a church Crypt built in the 19th century at the Mistihalj site in Bosnia and Herzegovina to understand the physiological effects of their peasant agro-pastoralist lifestyle. Composite scores of osteoarthritis were generated for visual observations of upper limb joints (shoulder, elbow, and wrist) and lower limb joints (hip, knee, and ankle) of 37 female and 39 male adult (between 20 and 50 or more years of age) skeletons. These were analyzed and compared by limb, age, sex, and time period. Low ranking peasant status for individuals was inferred by the location and type of burial. Odds ratio analyses show a positive correlation between the prevalence of osteoarthritis and age among Necropolis individuals. Correlation by age is expected, as the prevalence of osteoarthritis increases due to senescence and longer exposure to activities. A positive correlation between the severity of osteoarthritis and burial location between male skeletons overall and among older adults suggests that distinctive factors, perhaps differential workloads, played a role in the effects of this condition among these individuals. The reasons for the lack of any other significant differences in the osteoarthritic effects within and between the individuals from the two burial locations are discussed, including systemic factors that might lead to generalized osteoarthritis. However, overall these data suggest that the individuals within and between these time periods were generally involved in similar activities reflecting long term traditional lifestyles that continued over centuries. This thesis adds to the nascent bioarchaeological knowledge about past populations from Bosnia and Herzegovina and

contributes to an anthropological understanding of lifestyles and their effect on physiological health.

To my grandfather, Žarko.  I will always cherish the memory of our hikes through the mountains of beautiful Bosnia and Herzegovina in our search for *Stećci*.

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# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| A=Ankle | MDOA=Moderate osteoarthritis |
| AD=Anno Domini | MOA=Mild osteoarthritis |
| AL=Ankle Left | N=Necropolis |
| AR=Ankle Right | n=number of individuals |
| BC=Before Christ | n/N = number observed/total number examined |
| C=Crypt | NF=Necropolis female |
| CF=Crypt female | NM=Necropolis male |
| CM=Crypt male | NMA=Necropolis middle-aged adult |
| CMAA=Crypt middle-aged adult | NMAF=Necropolis middle-aged female |
| CMAF=Crypt middle-aged female | NMAM=Necropolis middle-aged male |
| CMAM=Crypt middle-aged male | NOA=Necropolis old adult |
| COA=Crypt old adult | NOAF=Necropolis old adult female |
| COAF=Crypt old adult female | NOAM=Necropolis old adult male |
| COAM=Crypt old adult male | NYA=Necropolis young adult |
| CYA=Crypt young adult | NYAF=Necropolis young adult female |
| CYAF=Crypt young adult female | NYAM=Necropolis young adult male |
| CYAM=Crypt young adult male | OA=Old adults |
| E=Elbow | OAF=Old adult female |
| EL=Elbow Left | OAM=Old adult male |
| ER=Elbow Right | ÔR=Odds ratios |
| F=Female | POA=Pronounced osteoarthritis |
| H=Hip | R=Right |
| HL=Hip Left | S= Shoulder |
| HR=Hip Right | SL=Shoulder Left |
| K=Knee | SR=Shoulder Right |
| KL=Knee Left | T=Total |

| | |
|---|---|
| KR=Knee Right | ULJ=Upper limb joints |
| L=Left | W=Wrist |
| LLJ=Lower limb joints | WL=Wrist Left |
| M=Male | WR=Wrist Right |
| MA=Middle-aged adult | YA=Young adults |
| MAF=Middle-aged adult female | YAF=Young adult female |
| MAM=Middle-aged adult male | YAM=Young adult male |

# CHAPTER 1: INTRODUCTION

One of the goals of bioarchaeological research is to contribute to a broader anthropological understanding of lifestyles and their effects on the physiological health of past populations. To do this, bioarchaeologists examine human skeletal remains within biocultural contexts (Knudson and Stojanowski, 2008). Bioarchaeological studies commonly focus on elucidating behavioral variability in the past via the examination of osteoarthritis, a chronic condition that affects joints (Weiss and Jurmain, 2007). The reason for this is that one of the major factors that contributes to the development of this condition is behavioral stress and loading on joints (Bernard et al., 2010; Eng, 2016; Kirkhorn et al., 2003; Muraki et al., 2009; Rossignol et al., 2005; Sandmark et al., 2000; Yoshimura et al., 2000). These biological results are commonly interpreted together with historical and mortuary contexts and the ethnographic information available to holistically elucidate past behaviors (e.g., Klaus et al., 2009). The study of activity levels and patterns offers potential to explain culturally defined labor inequalities and activity intensification as reflected in the division of labor by age, gender, social status, subsistence regimes, or socio-economic changes in past (e.g. Bridges, 1991; Klaus et al., 2009; Schrader, 2012; Sperduti, 1997). Despite this, few studies have been conducted on populations that lived in the socio-economically complex societies in Balkans in Late Medieval period and later centuries.

## Study purpose

The broad purpose of this study is to contribute to the nascent anthropological knowledge about the lifestyles of peasants that lived in the Trebinje region of Bosnia and Herzegovina in

Late Medieval and late-19th century through 20th century. To this end, this study examines and compares osteoarthritis data among and between skeletons from a Necropolis that dates to 15th century and a church built in the 19th century and most likely used into the 20th century at the Mistihalj site in Trebinje (Vucinich, 1967) in order to explore what these data can tell us about similarities and differences in their activity levels and patterns. Analyses of mortuary practices from archaeological data suggest that the individuals from both of these sites were of low or peasant social status (Vucinich, 1967). Thus, this inference and the excellent preservation of female and male adult skeletons from Mistihalj offers a unique opportunity to examine whether the bioarchaeological results support the historical and ethnographic evidence that culturally defined labor inequalities existed among and between peasants from Late Medieval and late-19th through 20th century Trebinje (Tošić, 1995a:78-81; 1995b; Zorić,1989 ).

## Theoretical background

Bioarchaeologists perceive skeletal materials as embodiments of the biological and social experiences of past individuals. The premise for this is that the human body is a biological and social construct (Agarwal, 2016). Thus, evidence embodied in skeleton is a consequence of complex interactions of biological factors such as age and sex, and social factors such as the gender and social status of examined individuals (Sofaer, 2006). Converging lines of inquiry within bioarchaeological research design that incorporate examination of skeletal data by age at death and sex of examined individuals together with the analyses of ethnographic, historical, and mortuary data analyses to infer these individuals' gender and social status roles ultimately enable us to explore past variability of lived experiences as interdependent on biological and social constructs. For the purposes of this study, gender is understood as a socially constructed concept that categorizes individuals primarily into categories of females and males (Armelagos, 1998:1). Furthermore, social status is defined as a specific position an individual occupies relative to others within ranked hierarchical systems that is often associated with status markers such as economic standing, education, land-ownersipand occupation (Dubois and Ordabayeva, 2015:332).

## Theoretical frameworks for mortuary analyses

Many archaeological studies focus on interpreting social status by analyzing mortuary practices, particularly burials. For example, tomb elaborations have been found to correlate with hierarchical social status (Soles and Davaras, 1992). It has been widely suggested that material wealth of graves correlates with social status, and that the differential distribution of grave goods might point to differences in social status among individuals. The premise for these assumptions is that some mortuary practices require more investment and energy expenditure than others and that those are representative of the burial of individuals of higher social status (Binford, 1971; Tainter, 1978). Others argue that other variables also correlate with mortuary practices, in particular ideologies and beliefs of the people (Carr, 1995). Nonetheless, anthropologists agree that the interpretation of mortuary practices is context specific and, when examined as such, can provide information about a number of variables, including the social status of those that lived in the past (Hodder, 1982).

### Methodological background

Common conditions in human skeletons (e.g., osteomalacia and osteoarthritis) are, in correlation with other factors (e.g., genetic susceptibility), expressions of environmental (e.g., climate) and behavioral stresses (e.g., diet and daily occupations) (Bernard et al., 2010; Bridges, 1991; Elidrissy et al., 2012; Eng, 2016; Feng et al., 2013; Felson et al., 1998; Kirkhorn et al., 2003; Klaus et al., 2009; Muraki et al., 2009; Rossignol et al., 2005; Sandmark et al., 2000; Yoshimura et al., 2000; Woo and Sciulli, 2013). Thus, holistic bioarchaeological analyses of these conditions in ancient skeletons within biocultural contexts can contribute to a broader anthropological understanding of past lifestyles and their effect on physiological health. Currently, many scientists view physiological health as the ability of an organism to adapt and self-manage under internal and external challenges (Huber et al., 2011) and physiological health will be viewed as such in this research study.

Osteoarthritis, a condition most often affecting synovial joints that can lead to long-term disability, is a commonly examined indicator of compromised joint health (Lieverse et al., 2016; Loeser, 2011; Weiss and Jurmain, 2007). Osteoarthritis develops because of a number of single factors or multiple factors and is characterized by the progressive loss of articular joint cartilage and atrophic (porosity or erosion and bone polishing or eburnation) and hypertrophic (osteophytes or lipping) bone changes (Castaño-Betancourt et al., 2013; Goldring and Marcu, 2009). Both clinical and bioarchaeological research shows that the prevalence of osteoarthritis increases with age due to senescence (physiological breakdown of normal cellular repair) and long-term use of joints (Bernard et al., 2010). Epidemiological studies also demonstrate that the patterning of osteoarthritis and the increase in the severity of bone lesions in a skeleton correlate with an overuse of joints under a heavy load or repetitive mechanical stress (Bernard et al., 2010; Eng, 2016; Kirkhorn et al., 2003; Muraki et al., 2009; Rossignol et al., 2005; Sandmark et al., 2000; Yoshimura et al., 2000). Thus, bioarchaeologists analyze the prevalence and patterning of osteoarthritis in archaeological skeletal collections to explore the general activity patterns among and between past populations (e.g. Bridges, 1991; Klaus et al., 2009; Schrader, 2012; Sperduti, 1997).

However, due to the fact that the etiology of osteoarthritis can be multifactorial (e.g., age, anatomy, genetics, occupational stress, sex, and obesity) some have suggested that the analyses of osteoarthritis data should not be used to directly interpret the specific activities of those living in the past (Rogers et al., 2004; Weiss and Jurmain., 2007).Others have pointed out that the lack of uniformity in the methods used for diagnosing osteoarthritis between anthropological studies, and between these studies and clinical and epidemiological studies, make comparisons of this condition's prevalence rates among different populations difficult (Bridges, 1991; Waldron, 1992). Nonetheless, many anthropologists agree that the examination of osteoarthritis patterns within a body and between individuals of different ages and sexes, and with consideration of their culturally defined lifestyles, can help elucidate what role different factors, including behavioral stresses and loadings, might have played in the development of this condition among and between individuals living in the past (Bridges, 1992; Jurmain, 1980; Waldron, 1992; Woo and Sciulli, 2013). Furthermore, osteoarthritis studies with such research designs, in conjunction with social and mortuary data analyses, have successfully demonstrated socio-economic inequalities and their impact on the joint health of individuals in past complex societies (e.g. Schrader, 2012; Sperduti, 1997).

In this study osteoarthritis was diagnosed via a visual examination of three principal morphological changes (lipping, porosity and eburnation) to the subchondral joints' bones which are diagnostic of this pathological condition. Osteoarthritis was scored using standard methods that involve recording the severity of modifications to the subchondral bone surfaces and margins and the extent of the affected area (Buikstra and Ubelaker, 1994:122-123). Although eburnation has been regarded as a definitive indicator of severe osteoarthritis (Rothschild, 1997; Waldron, 1992), the progression of osteoarthritic changes is poorly understood and cannot be quantitatively inferred.

## Archaeological context

The Mistihalj mortuary complex was located in Trebinje in the southern region of Bosnia and Herzegovina (Figure 2). Mistihalj consisted of a Necropolis dated to the $15^{th}$ century (Figure 4)and the Church of Saint Nicholas and its cemetery (Vucinich, 1967) (Figures 5).The church was built in the $19^{th}$ century (Kajmaković, 1962). The salvage excavation of skeletons from all locations, in preparation for dam construction on the Trebisnjica River, took place from 1967 to 1968. Today, the skeletons are located at the Peabody Museum of Archaeology and Ethnography at Harvard University.

This study examines and compares osteoarthritis data of 76 complete and nearly complete female (n=37) and male (n=39) adult skeletons from Mistihalj. There are 21 young adults (between 20 and 34 years of age), 28 middle-aged adults (between 35-49 years of age) and 27 old adults (50+ years of age). Of these 76 individuals, 60 skeletons are from the Necropolis, and 16 are from the church Crypts.

## Socio-economic context

In order to holistically elucidate behavioral variability among and between Trebinje's peasants that lived in the 15th and late-19th and 20th centuries, it is necessary to understand the socio-economic contexts that guided their existence. This study relies on historical information to understand this context in 15th century Bosnia and Hercegovina, and historical and ethnographic information to understand this context in 19th and 20th centuries in this region.

In the end of 14th century (A.D. 1388), Trebinje was annexed to the southern region of the Kingdom of Bosnia (A.D. 1377-1463). The rule of the Kingdom of Bosnia in this region was marked by a civil war in the mid-15th century when nobleman Herceg Stjepan engaged in a civil war successively with Kingdom of Bosnia proclaiming this region to be the state of Hercegovina and himself sovereign of it. Finally, towards the end of 15th century this region was conquered by the Turks and sometime in the early 16th century became fully integrated into the Ottoman state (Vucinich, 1976). Like other Late Medieval monarchies, the Kingdom of Bosnia practiced a feudal socio-economic system in which peasant labor was exploited by noble landowners who were given lands in return for the military protection of the king and the kingdom. The majority of the population held a hereditary social status of either noble landowner or peasant-surf. The latter were legally obliged to work on the noble landowner's property (Tošić, 1995a:77). However, during the rule of Kingdom of Bosnia, the Trebinje region also had a population of free peasants who worked on their own or communal lands or as wage laborers. Historic sources describe these Late Medieval peasants as primarily involved in varied agro-pastoralist activities that comprised subsistence farming of grains, vegetables and fruit, and animal herding and husbandry.  Such sources also describe the peasants as involved in a loosely- based division of labor between individuals of different ages and sexes (Tošić, 1995a:78-81; 1995b).

In the 19th and early 20th centuries, the Trebinje region was a part of the Eyelet of Bosnia ruled by the Ottoman state. In this region, the Ottomans practiced a socio-economic system much like the one practiced by the Kingdom of Bosnia. In this system, the labor of Christian and Muslim tenured peasants was exploited by Turkish or local noblemen, but only those that professed Islam. These noblemen were given lands that mostly remained the property of the Ottoman state in return for military service to it (Sugar, 1977:37-38). After the end of the Ottoman rule, this region of Bosnia and Herzegovina was annexed in 1908 and ruled by Austria-Hungary, a monarchy, until 1918 and from 1918 until 1941 by the Kingdom of Serbs, Croats and Slovenes known as Kingdom of Yugoslavia from 1929 (Newman, 2011). During the rule of Austria-Hungary the territories of present day Bosnia and Herzegovina continued to follow almost identical socio-economic system imposed during Ottoman rule (Banac, 1988:367). However, during the Kingdom of Serbs, Croats, and Slovenes peasants were given small land holdings for agricultural production with a tariff system (Lampe and Jackson, 1982:160; 329-330).  Much like Trebinje's peasants during the Kingdom of Bosnia, peasants in this region during the 19th century and 20th century were involved in varied agro-pastoralist activities with a loosely based division of labor between individuals of different ages and between men and women (Lampe and Jackson, 1982; 336; Zorić, 1989;). However, peasant rebellions against Ottoman, Austro-Hungarian and later socio-economic systems across the territories of Bosnia and Herzegovina, including Trebinje, led to frequent military unrest between the ruling classes and guerillas comprised of peasant men (Radović, 2002:36).

## Study questions

Comparisons among skeletons from each time period at Mistihalj site could show whether there are significant differences between different adult age and sex cohorts and whether these differences might be due to labor inequalities suggested by the historical sources for Late Medieval Trebinje's peasant populations and by ethnographic sources for 19th century Trebinje's peasant populations (Zorić, 1989). Since Mistihalj skeletons are believed to represent a homogenous population of individuals that lived within the same region, but in different time periods (Vucinich, 1967) and thus under different socio-economic circumstances, comparisons between individuals of the same age and sex from Necropolis and Crypts are expected to show whether there are significant differences between these populations and whether these are due to different lifestyles, in particular activity levels and labor patterns. This approach will offer insights into whether evidence embodied in bone of Mistihalj individuals agrees with the historical and ethnographic descriptions of labor inequalities among and between adult male and female peasants that lived in Late Medieval and 19th century Trebinje (Tošić, 1995a:79-81; 1995b; Zorić, 1989). If these biological and cultural lines of evidence converge, then this will affirm not only ethnographic and historic data about the lifestyles of Trebinje peasants, but also the inferred social status of Necropolis and Crypt individuals. Thus this study attempts to answer the following questions:

1) Will the data on the prevalence of osteoarthritis demonstrate different or the same patterns of this condition by upper limb joints and lower limb joints among Mistihalj individuals? Will the severity of this condition positively or negatively correlate with joint location? What can this information tell us about variation or lack thereof in the

extent of use of upper and lower limbs among and between Mistihalj individuals? Can this information provide clues as to whether Mistihalj individuals practiced or did not practice labor specialization in either time period?

2) Will the prevalence of osteoarthritis be different or the same in the upper or lower limb joints between individuals of different ages and sexes? Will the severity of this condition in upper or lower limb joints positively or negatively correlate with the age and sex of Mistihalj individuals? What can this information tell us about variation or lack thereof in labor intensity between individuals from different age cohorts and sex cohorts? Can this information provide clues as to whether Mistihalj individuals practiced or did not practice a division of labor by age and sex?

3) Will the prevalence of osteoarthritis be different or the same in the upper or lower limb joints between individuals of the same age and sex from the two time periods? Will the severity of this condition in upper or in lower limb joints positively or negatively correlate with either burial location among these groups? What can this information tell us about the variation or lack thereof in labor intensity between individuals of the same age and sex from the two time periods? Can this information provide clues as to whether the Necropolis and Crypt individuals were involved in different or similar levels of activity? Can this information be used to infer whether the Necropolis and Crypt individuals were involved in activities of similar or different intensities?

## Hypotheses and expectations

To examine these questions, I hypothesize that there will be significant differences in the effects of osteoarthritis among the Mistihalj skeletons examined by joint location, age and sex, and burial location.

Based on previous studies conducted on past agro-pastoralist populations (Bridges, 1991; Novak, 2011), and populations of low social status (Schrader, 2012; Sperduti, 1997) using skeletal osteoarthritis data, I predict that the results of the examination of osteoarthritis among Mistihalj skeletons will satisfy the expectations for a differential use of joints by location and a division of labor by age and sex during both time periods, and possibly a different type or intensity of labor by time period.

1) I hypothesize that osteoarthritis effects will differ by joint locations among all skeletons examined.

2) I hypothesize that the effects of osteoarthritis will be higher in older adults than in young and middle-aged adults among individuals from both burial locations.

3) I hypothesize that the effects of osteoarthritis will be higher among males than females from both burial locations.

4) I hypothesize that osteoarthritis effects will differ between individuals from two burial locations.

## Organization of thesis

In the following chapters, I will explore these questions by analyzing and discussing this study's results and their significance. Chapter 2 will explain the theory and background for the use of prevalence and patterning of osteoarthritis in the examinations of activity levels and patterns in past societies and provide a summary of such studies conducted on archaeological Late Medieval European populations and 19$^{th}$ and later centuries European populations. This chapter will also include an examination of the evidence for social complexity within the Trebinje region during the Late Medieval period and 19$^{th}$ and 20$^{th}$ centuries, and the importance of mortuary analysis for this sample. Chapter 3 will provide detailed information about the sample and the methods used in collecting and analyzing data. Chapter 4 will report the results of the statistical analysis of the prevalence of osteoarthritis and its severity among all individuals examined by age and sex. Chapter 5 will discuss the results of analyses focusing on the effects of osteoarthritis within and between individuals in the context of ethnographic, historical and mortuary data. Chapter 6 will conclude, pointing to the limitations of this study to suggest directions for future research, and provide an explanation of the anthropological significance of this research.

# CHAPTER 2: LITERATURE REVIEW

This chapter begins by briefly introducing bioarchaeology as a multidisciplinary approach that can enable the examination of the effects of different factors, including human behavior, on physiological health in archaeological populations. Next, I introduce osteoarthritis as a useful tool in bioarchaeological studies to explore past human behavior and summarizes past assessments of osteoarthritis as an activity-related condition in past Late Medieval and later centuries European and Balkan populations. Then, I review the theoretical approaches for mortuary data analyses that are used as a means to infer social status of the Mistihalj individuals and describe mortuary practices in the Kingdom of Bosnia, Bosnian and Herzegovinian territory in the 19$^{th}$ century. Finally, this chapter describes task distribution of both men and women and also child labor among peasants that lived in Trebinje during the rule of the Kingdom of Bosnia and the 19$^{th}$ century and 20$^{th}$ century, which will guide the discussion of osteoarthritis results for the Mistihalj skeletal sample.

## Bioarchaeology

Bioarchaeology as a discipline bridges biological and social sciences in that it incorporates osteological analyses of archaeological skeletal material together with methods of analyses and theoretical approaches from other disciplines to investigate past human behavior (Knudson and Stojanowski, 2008). From a bioarchaeological perspective, the body is a product of social and biological factors. The premise for this concept is that the body is a dynamic organism that changes and adapts itself in response to lived or epigenetic experience mediated by external variables such as environment and culture (Agarwal, 2016) and internal variables such as host resistance and genetic variation (Larsen, 1997). As such, the body embodies these experiences. Today, bioarchaeological studies examine skeletal materials within cultural contexts using ethnographic, historical, and mortuary data analyses to investigate broader biocultural and socio-cultural phenomena such as human frailty and their effects on disease development (DeWitte and Bekvalac, 2010), socio-economic inequalities and their effects on health (Redfern and DeWitte, 2011), social identity (Klaus et al., 2010), and behavioral patterns (Klaus et al., 2009).

Commonly, bioarchaeological studies focus on examining the correlation between biomechanical factors, particularly culturally guided behavior- related stresses and loading, and the prevalence and patterning of osteoarthritis (e.g., Klaus et al., 2009). Data analyses are by age and sex of individuals within assumed genetically homogenous groups that do not exhibit evidence of genetic abnormalities and trauma affecting bones in order to control for as many factors that can affect interpretation of the data. Furthermore, analysis of osteoarthritis data is often explored together within historical and mortuary contexts and the ethnographic information about examined populations to elucidate general activity levels and the effect of lifestyles defined by gender and social status on skeletal health in past populations (Bridges, 1991; Klaus et al., 2009; Schrader, 2012; Sperduti, 1997). This study relies on biological data analyses, in particular analyses of the prevalence and patterning of osteoarthritis among and between individuals of different adult cohorts and sex cohorts from Mistihalj Necropolis and the church Crypts, to investigate activity patterns of these individuals that lived in the Trebinje region during the rule of the Kingdom of Bosnia and 19th century and perhaps later centuries in order to draw inferences about their behaviors. However, as in the above mentioned studies, this study employs a similar multidisciplinary approach using ethnographic and historical evidence, and the mortuary data analyses by excavators to draw contextual inferences about these behaviors, particularly those guided by age, gender and social status. While ethnographic and historical studies can provide information about social behaviors, including task distribution and the division of labor by age and gender of examined populations, mortuary data analyses can offer information about social status (Binford, 1971; Carr, 1995; Hodder, 1982; Saxe 1970; Tainter, 1978) that primarily guided these behaviors.

## Osteoarthritis

A commonly examined, activity-related skeletal health indicator is osteoarthritis or degenerative joint disease. This progressive condition that affects appendicular and vertebral joints can lead to long term disability or impaired joint function (Lieverse et al., 2016; Loeser, 2011; Weiss and Jurmain, 2007). Osteoarthritis develops when the congruity of a joint as a system is compromised due to a specific factor or multiple factors (Goldring and Marcu, 2009). Osteoarthritis can involve any one or more of the following changes to the joint system: breakdown and loss of articular cartilage, synovial fluid inflammation, joint space narrowing and joint capsule enlargement, meniscus degradation, modifications in subchondral bones of joints such as osteophyte formation at the joint surfaces and margins, bone plate porosity and pitting, and bone on bone polishing or eburnation (Loeser, et al., 2012). These specific changes are common in individuals with osteoarthritis even if different factors or a combination thereof might initiate its development (Loeser, 2011).

## Osteoarthritis risk factors

Stimuli that initiate osteoarthritic changes in the joint system are often multifactorial and can include inherent factors, non-genetic host factors, and environmental factors. Inherent risk factors that have been identified are systemic and include polymorphisms and mutations in genes that play a role in the maintenance of joint homeostasis (Palotie et al., 1989). Risk factors for osteoarthritis can also be genetic abnormalities that affect joint alignment and anatomy. For example, individuals with gene defects that exhibit congenital cartilage dysplasia have an earlier onset of osteoarthritis due to affected joint alignment and its congruity (Kim et al., 2003). Inherent anatomical variances can also play a role in the development of osteoarthritis. For example, individuals with longer tibias have increased risk at developing knee osteoarthritis (Hunter et al., 2005). A major non-genetic host factor that increases systemic susceptibility to the development of osteoarthritis among both sexes is age- related changes to the joint system (Loeser, 2010). For example, 30-50% of older adults over age 65 are diagnosed with this condition (Murphy et al., 2008). Another non-genetic host factor among women that is associated with the development of osteoarthritis is the loss of estrogen, which plays a role in maintenance of cartilage homeostasis (Sowers et al., 2006). Finally, obesity-related increases in the production of adipokines and cytokines that result in joint cartilage degradation play a role in the development of osteoarthritis (Hui et al., 2012). Major environmental risk factors for osteoarthritis include biomechanical stresses and loading related to obesity (Coggon et al., 2001) and activities and occupations (Bovenzi et al., 1987; Mintz and Fraga, 1973; Muraki et al., 2009; Sandmark et al., 2000). Another environmental factor associated with osteoarthritis is trauma to the joint that affects the joint system congruity (Buckwalter and Lane, 1997). Table 1 shows these risk factors categorized as systemic factors and local biomechanical factors.

**Table 1 Local biomechanical factors and systemic risk factors for osteoarthritis, modified after (Felson et al., 2000).**

| Systemic factors | Local biomechanical factors |
|---|---|
| Polymorphisms and mutations in genes that play a role in maintaining joint homeostasis<br><br>Genetic abnormalities affecting joints' alignment and anatomy<br><br>Anatomical variances<br><br>Older age-related changes to the joint system<br><br>Female sex<br><br>Obesity related effects that play a role in maintaining joint homeostasis | Obesity- related stresses and loading<br><br>Activity and occupation related stresses and loading<br><br>Trauma that affects joint congruity |

Although interactions among these factors in the etiology of osteoarthritis remain poorly understood, scientists suggest that the site and severity of osteoarthritis is most often the consequence of the interplay between systemic factors that lead to joint vulnerability and biomechanical factors that lead to joint injury (Felson et al., 2000; Loeser, 2010; Rogers et al., 2004; Weiss and Jurmain, 2007) (Figure 1). For example, an individual might have a genetic predisposition for osteoarthritis but might develop it solely when biomechanical stresses or loading occur. However, local biomechanical factors can cause osteoarthritis even when individual is not predisposed for its development (Felson et al., 2000). In fact, numerous clinical studies demonstrate an association between activities, occupation- related biomechanical stresses, loading, and osteoarthritis (Andersen et al., 2012; Bovenzi et al., 1987; Holmberg et al., 2004; Mintz and Fraga, 1973; Sandmark et al., 2000).

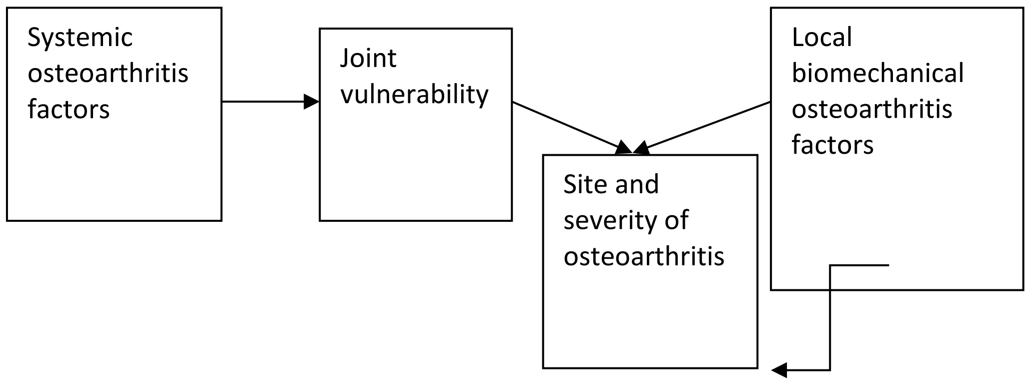


**Figure 1 Relationship between osteoarthritis risk factors that play a role in site and severity of osteoarthritis, modified after (Amoako and Pujalte, 2004; Felson et al., 2000; Loeser, 2010).**

The majority of clinical studies concerning occupational and activity-related risk factors for osteoarthritis focus on lower body joints, in particular the knee. One such study showed that osteoarthritis of the knee increases among male and female individuals involved in heavy physical work (Sandmark et al., 2000). As for knee osteoarthritis, individuals involved in more strenuous physical work had an increased risk of developing hip osteoarthritis (Andersen et al., 2012).

## Bone changes associated with osteoarthritis

The normal synovial joint structure consists of subchondral bone surfaces separated by articular cartilage that absorbs and distributes comprehensive load and withstands stress imposed by biomechanical forces during joint movement (Lotz and Loeser, 2012). Cartilage is composed of a cartilaginous extracellular matrix and cells called chondrocytes that both synthesize and degrade it (Loeser, 2011). These tissues are situated within a joint capsule held by ligaments. The synovial membrane lines the joint capsule posteriorly and provides lubrication between the bones by secreting synovial fluid. Osteoarthritic changes often affect all the parts of a joint structure (Loeser et al., 2012).

Bone structure and function are also adaptations to biomechanical stresses in that bone reacts to mechanical loading and it can adapt or remodel itself in response to it (Wollf, 1986). Normal bone remodeling involves the removal and reabsorption of older bone and the deposition of newer bone (Hadjidakis and Androulakis, 2006). Thus, continued biomechanical stress imposed on joints with a degraded cartilage matrix leads to both reabsorption and deposition of subchondral bone and results in modifications to its height and contour. Reabsorption of subchondral bone in osteoarthritis is often manifested in bone plate thinning and pitting and, eventually, joint surface porosity (Bettica et al., 2002). Cartilage loss can lead to bone on bone contact that might result in eburnation or bone polishing (Layton et al., 1988). Bone deposition associated with osteoarthritis is frequently manifested in osteophyte formation at the joint surfaces and margins and results from endochondral ossification (Loeser et al., 2012).

**Defining osteoarthritis**

In clinical studies, osteoarthritis can be defined through symptoms reported by patients such as joint pain, swelling, stiffness and limited joint function (Yucesoy et al., 2015) and radiologically by observing the remodeling of bone (i.e. osteophytes) and other bone changes associated with osteoarthritis including joint space narrowing, subchondral sclerosis and cyst formation (Arden and Nevitt, 2006). In skeletons, the effects of osteoarthritis in vertebral and other joints are more visible than in radiological examinations of joints (Jurmain and Kilgore, 1995). It is suggested that anthropologist define osteoarthritis by visually observing for three principal bony changes associated with osteoarthritis (lipping or osteophytes, porosity and eburnation) (Buikstra and Ubelaker, 1994:81-82) and in this study osteoarthritis is defined based on the observation and the extent of articular joint surface (porosity and eburnation) and joint margins (osteophytes or lipping) affected (described in Chapter 3).

## Past assessment of osteoarthritis as activity related pathological condition in Late Medieval and later centuries European populations

Bioarchaeological studies of the activity patterns among archaeological agricultural populations generally suggest that osteoarthritis prevalence increases with age due to older individuals' longer exposure to biomechanical stresses and loading and age related changes to joint systems (Eng, 2016; Novak, 2011; Sperduti, 1997; Šlaus, 2002). Furthermore, such studies in general suggest that men tend to have significantly or insignificantly higher osteoarthritis prevalence rates (Sperduti, 1997; Šlaus, 2000; 2002; Zampetti et al., 2016) or more severe forms of this condition (Bridges, 1991) than women most likely due to more labor intensive lifestyles.

Bioarchaeological studies of the activity patterns, specifically in Late Medieval rural agricultural European populations that examine osteoarthritis data in limb joints are scarce, but are a part of broader bioarchaeological analyses of skeletal materials mostly from Croatia (e.g., Novak, 2011; Šlaus, 2000; 2002). While all of these studies show insignificant differences in osteoarthritis rates between men and women, in the majority of these studies men tend to have higher crude prevalence of osteoarthritis and it is suggested that this is due to these men performing more labor intensive activities (Šlaus, 2000; 2002). These studies also show that osteoarthritis prevalence rates increase with age in these populations (Novak, 2011; Šlaus, 2002). When such issues are examined, studies show that these populations have mild and moderate forms of osteoarthritis and rarely severe forms of this condition (e.g. Šlaus, 2002).

Studies that examine osteoarthritis data to infer activity patterns among 19th and later century's rural agricultural European populations are few. One study from the early 20th century cemetery in Sardinia, Italy shows significant differences in prevalence of osteoarthritis between men and women with increase in age and that men in general have higher prevalence of osteoarthritis than women (Zampetti et al., 2016). The authors suggest that these differences might be due to different social roles and activities between men and women. Another study of rural Dutch from the 19th century shows that men and women had similar osteoarthritis prevalence rates and the authors suggest that these similarities might be due to similar activities or levels of activities performed by these groups but also anatomical and hormonal differences (Palmer et al., 2016).

## Theoretical approaches to the concepts of sex and gender in this study

This study defines sex by biological differences between females and males and it distinguishes it from the concept of gender in that the latter is understood to mean a social construct that categorizes individuals primarily into categories of males and females (Armelagos, 1998:1). Although studies show that some individuals do not chromosomally match either of the binary sex categories (Ratcliffe et al., 1992) and that in many societies there are other culturally defined genders besides females and males (Rescoe, 1998), this study assumed binary concepts of females and males in both sex and gender determination, because societies in Medieval and later period in Europe understood these concepts as such binaries (Laqueur, 1990:10-1; Salisbury, 1996:81-82). Furthermore, this study assumes that gender differences exist and that these are reflected in gender roles. For the purposes of this study gender roles are defined as culturally defined behaviors and activities regarded as appropriate for a specific gender (Conkey and Spector, 1998:24-25).

This study also assumes that gender roles of Mistihalj individuals were predicted by their sex, because Medieval and later century European societies perceived sex differences between men and women as the basis for their culturally- defined gender roles (Laqueur, 1990:10-11; Salisbury, 1996:81-82). Therefore, with careful examination of the data between sexes together with ethnographic and historical information about gender- defined behaviors and activities this bioarchaeological study will provide information as to whether osteoarthritis data results among Mistihalj individuals of different sexes support ethnographic and historical data descriptions of gender-defined behavior among Trebinje's peasants in Late Medieval and 19$^{th}$ and later centuries. Since ethnographic and historical sources describe gender roles as age and status specific among Trebinje's populations in these time periods (Tošić, 1995a:79-81; 1995b; Zorić, 1989), this study also examines the osteoarthritis results by sex within Mistihalj samples' age groups against the backdrop of task distribution and activities of Trebinje's peasant females and males in childhood and adulthood .

## Theoretical frameworks for mortuary analyses

Among anthropologists it is commonly understood that mortuary practices have social meanings. However, what inferences about past societies can be made via the mortuary data analyses of archaeological material data associated with these practices is the center of theoretical debate within the field of anthropology. This debate is briefly reviewed below.

The theoretical framework for the interpretation of mortuary data as reflections of social meanings begins with the work by the American processualist anthropologists Saxe (1970) and Binford (1971) in response to previous assertions that mortuary practices are not related to socio-cultural aspects of societies (Kroeber, 1927). In his doctoral thesis, Saxe (1970) theorized that mortuary practices are reflections of social complexity and structure. To correlate mortuary practices as an index for social complexity and structure, he used ethnographic data analyses to test eight hypotheses. For example, he accepted his Hypothesis 8 that stated that the emergence of maintained, formal cemeteries correlates with the emergence of agnatic descendent groups as a means to control resources. Like Saxe (1970), Binford (1971) also theorized that the examination of mortuary practices could be used to infer the social complexity and structure of a society. He stated that: "the form and structure which characterize the mortuary practices of any society are conditioned by the form and complexity of the organizational characteristics of the society itself" (1971:23).

The "Saxe-Binford" (Brown, 1995) theoretical approach assumes that each individual within a society has a social persona which is an agglomeration of social identities. This approach also assumes that a social persona is determined by social structure and dependent on identity determinants (e.g. age, sex, social rank, etc.), and materialized in death by the mourners (Binford, 1971). As such, variable treatment in death and burial is a reflection of different individuals' personae, which in studies guided by this theoretical framework is often replaced by the concepts of social status or rank (Gillespi, 2001). Binford (1971), Tainter (1978), and Carr (1995) further expand this theory by proposing that complex mortuary practices require more energy expenditure and are reflections of higher social rank or status. This energy expenditure can be assessed in burial contexts via the examination of grave location as opposed to other graves, complexity of a grave itself, number of sacrificial victims (Tainter, 1978), and quantity and quality of grave goods (Binford, 1971; Carr;1995).

The "Saxe-Binford" approach was criticized by post- processualist anthropologists because although burial elaborations can be reflective of a dead individual's social status (Hodder, 1982), mortuary practices might reflect other things besides the social status of the dead. Central to this criticism is Saxe and Binford's view of social identity as fixed and determined by societal structures that can be compared (Binford, 1971; Saxe, 1970). These criticisms are rooted in the post-processualist interpretations of the concept of social identity and social determinants as mutable in life but also in death as a consequence of individual and collective agency within various social contexts. Therefore, the living as participants in mortuary rituals and practices can control and manipulate symbols of social identity of the dead, including social status (Hodder, 1982). Post-processualist anthropologists also argue that mortuary practices can correlate with social identities of the living and not the dead, including those that they aspire to (Parker-Pearson, 1982:99-103), collective ideologies and worldviews (Morris, 1991) and economic relationships (Brown, 1995). In summary, for post-processual anthropologists mortuary practices are context specific and can be often examined as reflections of social identities of the dead and ideologies of the living (Cannon, 1989; Parker- Pearson, 1982:99-103).

Thus, mortuary practices when examined using the analyses of archaeological data from burials and cemeteries can be reflective of a number of variables. However, this variability is context specific, and when examined as such including human remains, can enable bioarchaeologists to broaden their interpretations. Numerous bioarchaeological studies that analyzed mortuary data have contributed to our understanding of social identities including social status of individuals living in past and thus, the health disparities as they relate to lifestyles defined by social status within socio-economically complex societies (Schrader, 2012; Sperduti, 1997). Although such bioarchaeological studies within the context of Late Medieval and 19$^{th}$ century Trebinje could not be found, studies in mortuary archaeology and history, particularly those from Late Medieval Bosnia, Trebinje and Mistihalj site, offer information about buried individuals' social status and these studies are reviewed in the next section. Archaeological and historical studies demonstrate that the majority of individuals living in Trebinje under the Kingdom of Bosnia and the Ottoman Empire held a hereditary status of noble landowner, a free peasant or a peasant-surf (Benac et al., 1963: XVIII; Tošić, 1995a:77-80; 1996). Thus, during these time periods in Trebinje, individuals' ancestry was reflected in their status markers, particularly economic standing and occupation, and is expected to be present in mortuary context (Tošić, 1995 a: 77-81).

Mortuary practices in the Kingdom of Bosnia and Ottoman Eyalet of Bosnia, Mistihalj site and interpretations of Mistihalj site mortuary practices

## Mortuary practices in the Kingdom of Bosnia and Ottoman Eyelet of Bosnia

Previous archaeological and historic studies that focus on the examination of mortuary practices in the Kingdom of Bosnia focus on burial location and tomb elaboration and epitaphs. Studies of mortuary practices in the Kingdom of Bosnia suggest that these differed by individuals' social status, which included their either noble or peasant ancestry (Benac et al., 1963: XII-XIII; Lovrenović, 2010:29).

Archaeological and historical evidence from the 14th and 15th centuries in the territories of present day Bosnia and Herzegovina indicate that the royal Bosnian family was buried in the family church crypt in Bobovac, north of Trebinje with tombstones containing epitaphs and elaborate chivalric and dancing scenes, often positioned above the grave (Lovrenović, 2010:29). Similarly, noble landowners were buried in family church (Catholic and Eastern Orthodox) crypts or an adjacent necropolis with tombstones containing epitaphs and elaborate decorations often including chivalric, hunting and dancing scenes and anthropomorphic representations of dead individuals (Benac et al., 1963: XXIII; Lovrenović, 2010:29). Epitaphs often stated the deceased's name, profession, political status, social status, family lineage, and religious affiliation: Christian (Benac et al., 1963: XXVIII). Archaeological and historical studies also suggest that the economically successful free peasants in the Kingdom of Bosnia, particularly from Trebinje region, were buried in necropolises near the communal churches with tombstones positioned above the grave often lacking epitaphs and decorations (Vucinich, 1967).

Archaeological and historical sources suggest that Christians from Balkans, including Mistihalj site, were buried in church crypts and adjacent cemeteries after Late Medieval period until 20th century and later (Jakšeković, 1990; Kajmaković, 1962; Šlaus, 2000; Vucinich, 1967) and thus it is likely that the individuals buried at Mistihalj church Crypts were Christians. Since, Trebinje region in the 19th century was under the rule of the Ottoman Empire (Džaja, 2012; Fine, 1984) and Christians in the Ottoman Empire's Eyelet of Bosnia were tenured peasants (Sugar, 1977:40), it is likely that Crypt individuals from Mistihalj site were also tenured peasants.

**The Mistihalj site and interpretation of Mistihalj's mortuary practices**

The Mistihalj mortuary complex was located in the southern Trebinje municipality of present day Bosnia and Herzegovina that surrounds the town of Trebinje (Figure 2) which was also the southern region of the Kingdom of Bosnia and a region of Ottoman Empire at the beginning of the 19th century (Bojanovski, 1960/61; Vucinich, 1967). The Mistihalj site was situated on the left bank of the Trebisnjica River between the towns of Bileća and Trebinje near the area of Miruše that today remains submerged under water as a result of the dam built in 1969 (Vucinich, 1967) (Figure 3). The salvage excavation of this site, in preparation for dam construction on the Trebisnjica River, took place from 1967 to 1968 by Dr. Wayne S. Vucinich, a professor of East European and Balkan history at Stanford University, and Arden and Judy Redfield, together with archaeologists from the Zemaljski Muzej (museum) in Sarajevo (Vucinich, 1967).

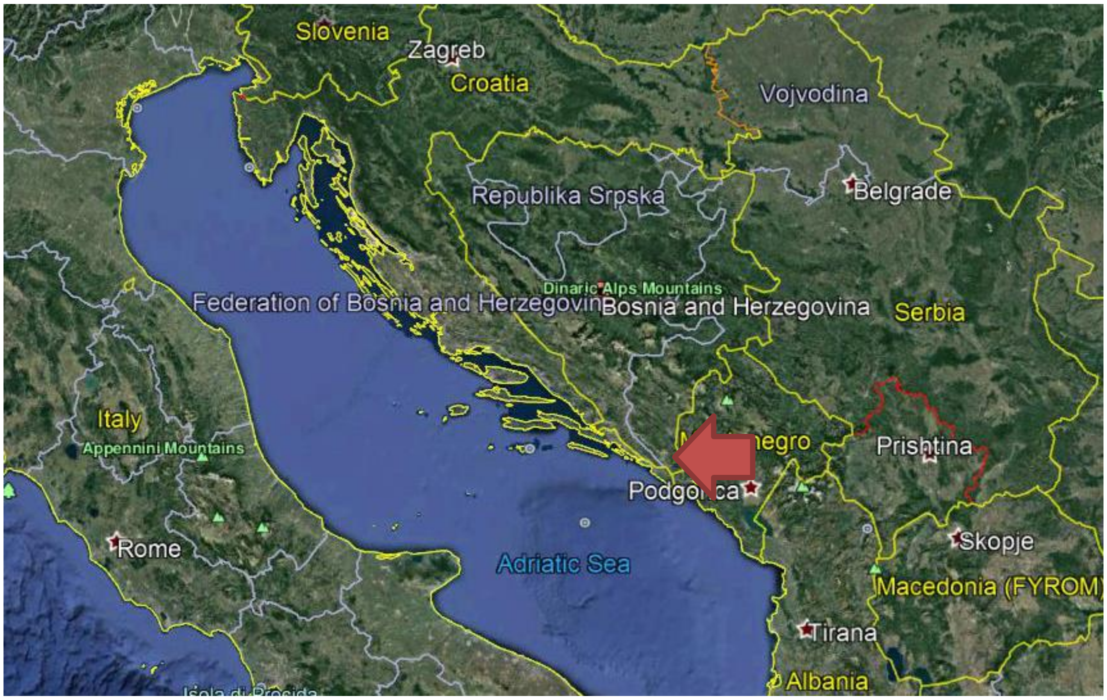


**Figure 2 Map demonstrating location of Bosnia and Herzegovina in relation to neighboring countries with an arrow pointing to Bileća lake where Mistihalj site is submerged under water in southern Trebinje region of the country. Map created with Google Earth Pro.**

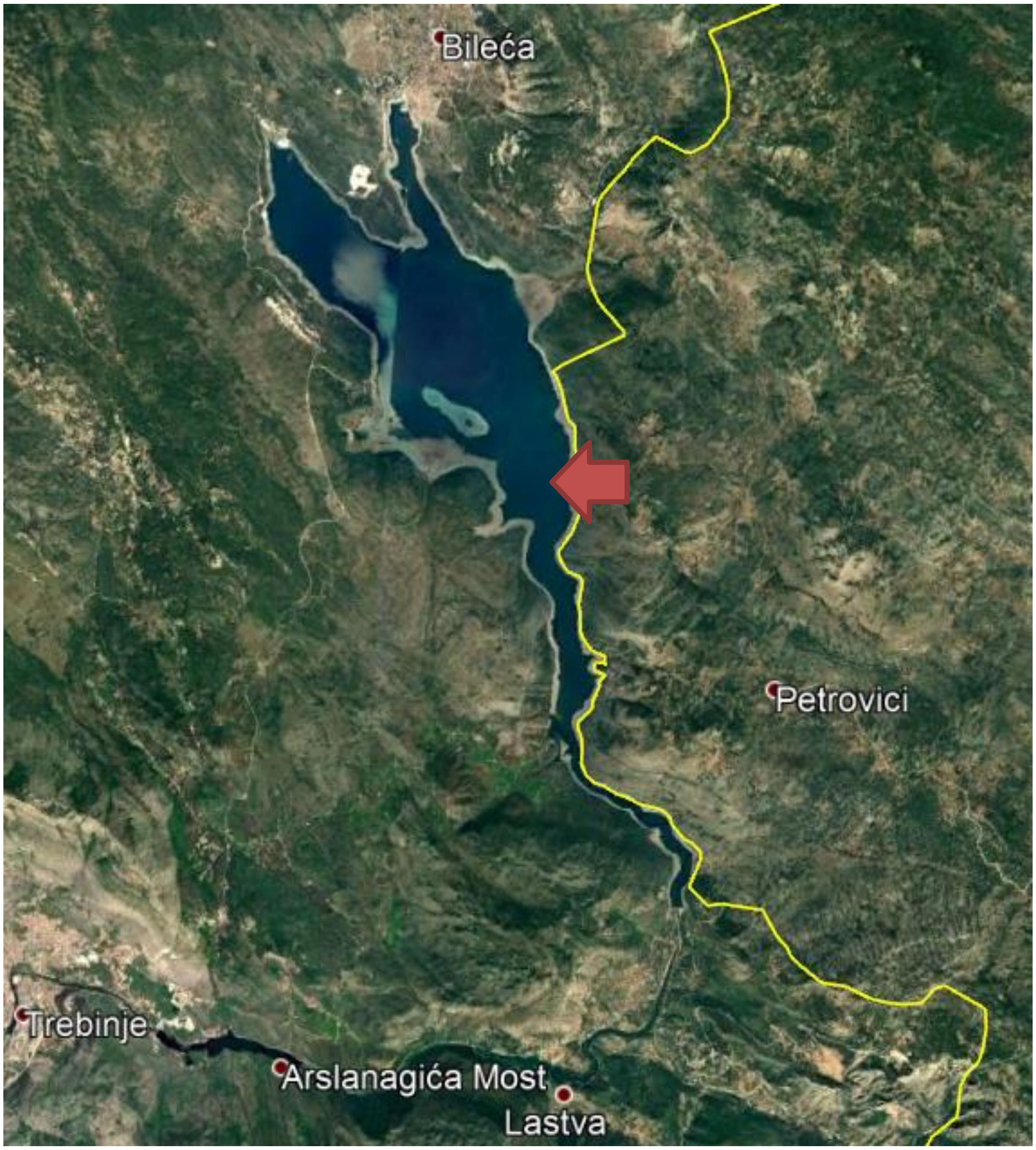


**Figure 3 Map of a part of Trebinje region with an arrow pointing to the water submerged location of the Mistihalj site that was located on the left bank of Trebisnjica River south of town of Bileća and northeast of city of Trebinje in Bosnia and Herzegovina. Map created with Google Earth Pro.**

The Mistihalj site consisted of a Late Medieval Necropolis and the 19th century Church of Saint Nicholas, and adjacent cemetery (Kajmaković, 1962; Vucinich, 1967) (Figure 4).

From sketch maps of the Mistihalj site, the Late Medieval Necropolis was approximately 100 meters long with its width varying between 5 and 30 meters and contained 221 graves of which 171 were underneath tombstones with grave markers according to the available documents at Peabody Museum of Archaeology and Ethnology of Harvard University (Figure 5).  Most of the graves contained single individuals, but 56 graves contained more than one individual and two contained up to five individuals.

**Figure 4 Church of Saint Nicholas at Mistihalj, redrawn after the photograph (Bešlagić, 1962).**

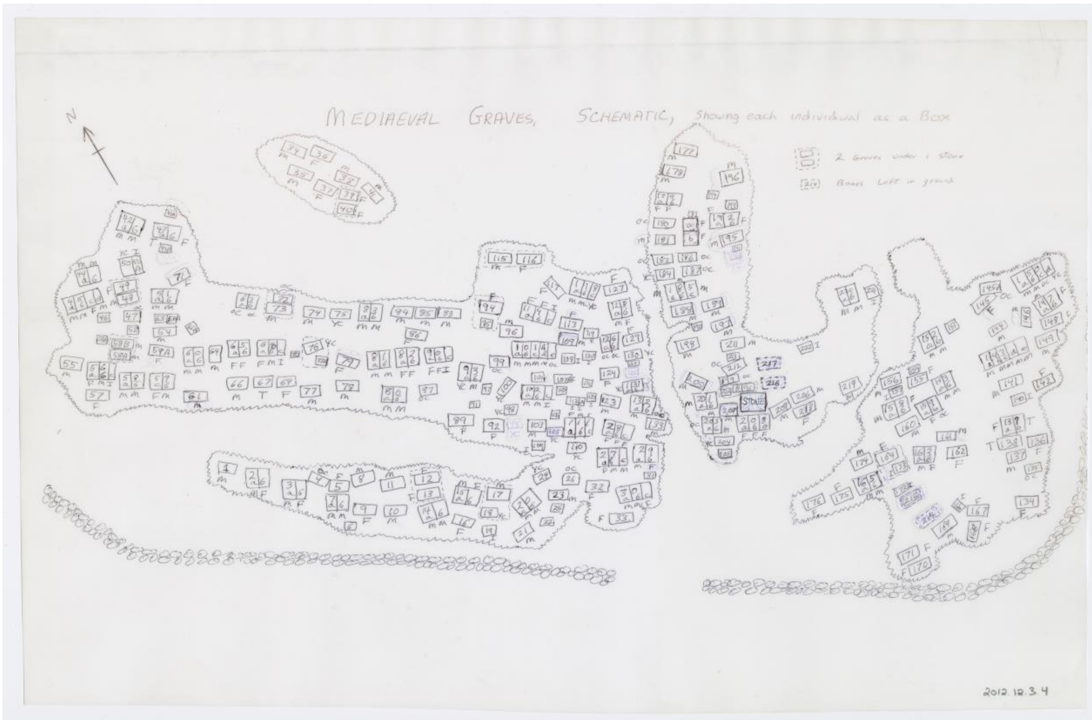


**Figure 5 Map sketch of Mistihalj Necropolis tombstones.** ***Gift of Judith Redfield, 2012. © President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology, PM# 2012.12.3.4 (*****Permission to use in Appendix A).**

The tombstones or *Stećak* at the Mistihalj site lack epitaphs (Vucinich, 1967) (except for a *Stećak* above grave 57); however, what the epitaph stated was not recorded in field notes. Decorative motifs on tombstones at Mistihalj are rare. When decorative motives are present, they include: “geometrical motifs, borders, bounded arches, transitional “A” arches, horseshoes, crosses and swastikas, hollows and rings, male dancers, male and female dancers, single horseman, and two horsemen with deer between them ” (Vucinich, 1967) ( Figure 6). Thus, excavators argue that it is likely that the majority of these tombstones were grave markers of individuals who could afford these stone markers to be quarried and transported but who could not afford the more elaborate scenes and epitaphs that are present on royal and noble tombstone (Vucinich, 1967). Researchers also argue that, judging by the sheer amount of grave markers at

Mistihalj, it is unlikely that so many low socio-economic status individuals, such as surf-peasants, could have afforded these expenditure and labor intensive tombstones during the Late Medieval period (Vucinich, 1967), rather it is proposed that those tombstones are the grave markers of better socio-economically off free peasants (Wenzel, 1965:15).

**Figure 6 Single horseman with a lance from a Late Medieval tombstone in Mostar, Bosnia and Herzegovina that is almost identical to a single horseman from a tombstone at Mistihalj necropolis, image courtesy of Dr. J Marla Toyne (permission to use in Appendix A).**

According to the available sketch map (no formal plan drawings were created) from the field notes of the Mistihalj excavation at the Peabody Museum of Archaeology and Ethnology archives at Harvard University, the Mistihalj church had a north and a south crypt, but it is not clear how many graves each of these contained. There were also approximately 47 individual graves adjacent to the Mistihalj church (Figure 7). Excavators did not make an attempt in suggesting as to who might have been buried in the church Crypts and adjacent cemetery.

However, since these individuals would have been Christian and Christians in the rural areas of Bosnia and Herzegovina during Ottoman rule were low social status peasants with or without land -lease holdings (Tomašević, 1955: 28-33), it is likely that individuals buried at Mistihalj church Crypts and adjacent cemetery were of low social status.

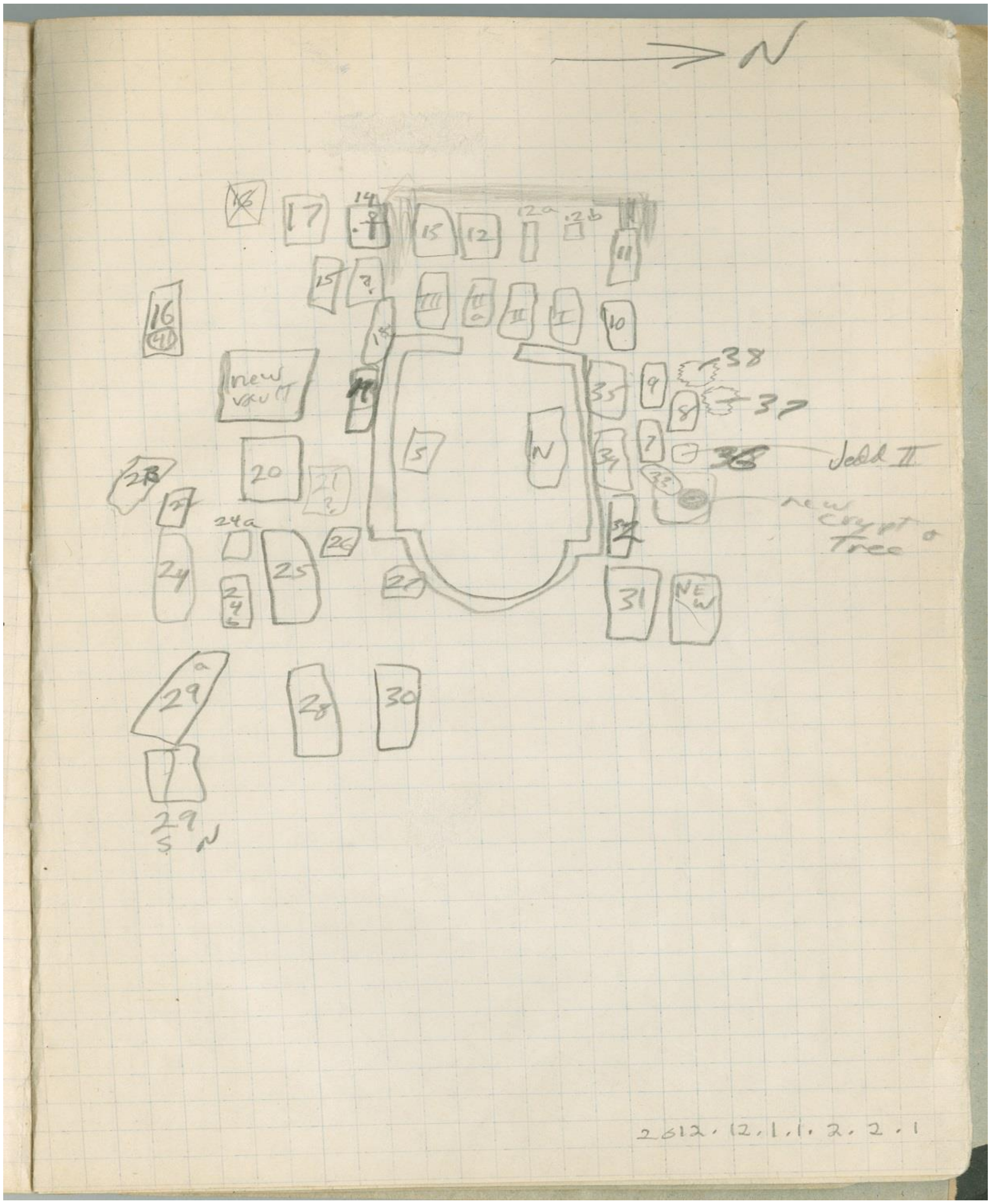


**Figure 7 Map of the Mistihalj church and surrounding cemetery graves.** ***Gift of Judith Redfield, 2012. © President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology, PM# 2012.12.1.1.2.2.1*** **(Permission to use in Appendix A).**

## The socio-economic context in Trebinje during the rule of the Kingdom of Bosnia and the Ottoman Empire

Historic evidence suggests that the Kingdom of Bosnia was the most powerful kingdom in the Balkans between A.D. 1377-1463 and, like other European kingdoms at the time, had a feudal political system in that the labor of unfree or surf-peasants was exploited by noble landowners who were given lands by the Bosnian monarchs in return for the military protection of the crown (Kurćehajić, 2013; Tošić, 1995a:77). The trade and transport hub of the Kingdom of Bosnia was the Trebinje region (Tošić, 1995a:80; 1996), situated in the karst terrain between the Adriatic littoral and Balkan hinterland on the border of the city-state of Dubrovnik (Vucinich, 1967). Noblemen in the Trebinje region grew and sold grains (e.g., wheat, barley, oat, millet, and einkorn); vegetables (e.g., cabbage, onion) and legumes (e.g., bob). Additionally, these noblemen raised their own domestic animals (e.g., goats, sheep, pigs, cows, donkeys, and horses) and girded for profit domestic animals of the citizens of Dubrovnik (Tošić, 1995a:80; 1995b). Others were craftsmen and merchants who belonged to craft and trade associations in Dubrovnik. Trebinje craftsmen were smiths, tailors, wool producers and textile weavers. Additionally, the inn-owning profession, especially among the noble priests was common because this region was a major trade route between the city-state of Dubrovnik and other Balkan regions (Tošić, 1995a:80).

In the $14^{th}$ -$15^{th}$ centuries, the Trebinje region also had a population of free peasants who supported their household needs by growing vegetables and grapes in house gardens and small vineyards or by growing grains if they owned fields or had access to communal peasant fields (Tošić, 1995a:80). Additionally, these peasants kept bees for honey and beeswax. Some supplemented the needs of their households by raising their own domestic animals, e.g. horses, cows, donkeys, sheep, goats and pigs, or by billeting animals for the citizens of Dubrovnik on their own or on communal pastures for profit. This profit was less often monetary. Most of the Trebinje peasants received half of the yearly offspring of girded animals and half of the products (e.g. cheese, wool) obtained from these (Tošić, 1995b). Some peasants also performed seasonal work such as hunting and fishing, making charcoal and transporting goods across the region on horses (Tošić, 1995a:81; 1995b). Small amounts of the products of these agro-pastoralists and hunters were used for family consumption and historical sources suggest that Trebinje peasants sold most of these products, for example, beeswax, cheese, hides, honey, meat, and wool, at Dubrovnik markets for money (Tošić, 1995b).

According to historical sources, the living spaces of the inhabitants of Late Medieval Trebinje were guided by an individual's social status. While noble landowners lived in large, well-constructed houses covered with tile roofs, peasant-surfs and free peasants, and their family members and animals they owned, lived in one-bedroom houses constructed of wood or dry plaster covered with hay. Unhygienic conditions in the latter households and the lack of water for personal use due to Trebinje's geography led to the spread of different epidemics in AD1419, 1424, 1451 and 1456 in this region. Additionally, Trebinje's peasants' agro-pastoralist existence was often made more difficult by droughts, storms and floods. As in the majority of Europe at the time, Trebinje's population decreased due to these natural disasters (Tošić, 1995a:82).

After conquering the last Kingdom of Bosnia's stronghold in Trebinje region in AD 1463, the Ottoman Empire imposed a form of feudal system in its Eyelet of Bosnia. Much like during the rule of the Kingdom of Bosnia, Ottoman sultan gave large holdings of land (*zaims*) and smaller amounts of land (*timars*) to military nobleman (*spahis*) in return for military service to the empire. The largest amounts of land (*hass*) were given to the Sultan's family members. Holders of all these estates used tenured peasants' labor for agro-pastoralist activities (Sugar, 1977:37-38). However, the peasants were only obliged to work three days a year for the noblemen, give the latter 10 to 20 percent of their annual harvest and pay various taxes, including head tax for males within a household in exclusion to the military service to the Ottoman state (Lampe and Jackson, 1982:24-25).

Peasants' lives and rights during the rule of the Ottoman Empire did not seem to differ much from those of Late Medieval peasants living in the territory of present day Bosnia and Herzegovina. Like Late Medieval Kingdom of Bosnia's peasants, these peasants, of any religious affiliation, had a right to leave their tenured position, particularly at *timar* estates. While both Christians and those of the Muslim faith had access to land for their own household's agro-pastoralist activities through land lease, those peasants that professed Islam had also the right to own the land. Land leasehold could be inherited and the lease of land could be sold by lease holding peasants. Again, much like in the Kingdom of Bosnia, peasants in rural acres of Eyelet of Bosnia, such as Trebinje, grew grains, vegetables and fruits, and were involved in animal husbandry and production of animal products (Sugar, 1977:40). Furthermore, ethnographic sources summarized by Zorić (1989) also described these peasants as involved in trap hunting. All peasants had to pay taxes and some male peasants in border regions of eyelet of Bosnia, such as those in Trebinje region, are also described as performing guard duties of strategic positions such as mountain passes in return for tax exemption (Sugar, 1977:39).

However, majority of the peasant men were also involved in guerilla warfare against the Ottoman soldiers throughout the 19th century (Radović, 2002:36).

During the rule of the Austro-Hungarian Empire (A.D. 1908-1918) (Newman, 2011), the lifestyle and rights of peasants did not change as the agrarian system imposed during the Ottoman rule continued. For example, in 1910, 91% of noble landowners were Muslim and of tenured peasants, 73% were Orthodox and 21% Catholic and the peasants continued to be taxed (Banac, 1988:367). During the rule of the Kingdom of Serbs, Croats and Slovenes, peasants were given small taxable land holdings, but after the World War I and during the rule of Kingdom of Yugoslavia these holdings became smaller and taxes increased (Lampe and Jackson, 1982:160; 329-330). Thus, peasant rebellion in the form of guerilla warfare against the ruling class continued (Newman, 2011).

Ethnographic studies suggest that the living spaces of 19th century Trebinje peasants were similar to household structures inhabited by the Late Medieval Kingdom of Bosnia's peasants (Tošić, 1995a:81-82; Zorić, 1989). Peasants in 19th century Trebinje also lived in small mud structures with their animals. These sources also describe these peasants' households owning nothing but a few cooking utensils. Peasants are described as modestly dressed with many children even up to the age of 12 wearing only shirt cloths and shoeless even during the winter time. Furthermore, these sources describe 19th century Trebinje peasants experiencing frequent famines due to lack of crops from natural disasters such as floods and droughts (Zorić, 1989).

## Division of labor among peasant men and women

In the rural areas of Late Medieval Europe like Trebinje, the peasant men most often worked in the fields to cultivate their own or other's grains, and peasant women raised children and prepared food to satisfy their own family's consumption by cultivating kitchen gardens and looking after domestic animals (Hanawalt, 1986:3-9). Additionally, historical evidence suggests that women in Late Medieval Trebinje often worked as servants in noble houses where they performed household chores (Tošić, 1995a:79).

However, a decrease in population numbers due to epidemics and famine, and the lowering of wages in the 14$^{th}$-15$^{th}$ centuries had an impact on the gendered division of labor across urban and rural Europe and Trebinje (Tošić, 1995a:81). Female labor, especially in menial work, had increased and many peasant women from Trebinje worked alongside their male counterparts in the fields and as hired laborers to local stone makers, smiths, wool producers and cloth makers (Tošić, 1995a:81). This loose division of labor between genders seems to have persisted during the rule of the Ottoman Empire as ethnographic sources from the 19$^{th}$ century describe Trebinje's men and women equally involved as a labor force in both the agricultural and pastoralist activities (Zorić, 1989). However, some division of labor persisted as some men also participated, as mentioned above in hunting and military activities (Sugar, 1977:39; Zorić, 1989).

## Child labor among peasants

Peasant boys and girls living in Trebinje during the rule of the Kingdom of Bosnia were expected to help their family's income by working as hired laborers. Boys worked as shepherds and cattle herders. They shepherded cows, horses, sheep and goats in the local communal and private pastures daily and returned them to their owners at nightfall (Tošić, 1995b). Girls were expected to do the same activities as their mothers (Tošić, 1995a:79). Ethnographic sources from the 19th century Trebinje do not suggest that Trebinje children worked as hired laborers during the rule of the Ottoman Empire, and these sources describe both female and male children involved solely in pastoralist activities (Zorić, 1989).

## Summary

This chapter established bioarchaeology as an approach that incorporates biological data analyses together with methods from other disciplines including the social sciences in order to investigate past human behavior. Then, this chapter introduced osteoarthritis as a progressive condition that enables bioarchaeologists to investigate activity patterns in past populations, first introducing osteoarthritis risk factors, including occupation and activity- related biomechanical stresses and loading, and its effects on joints, then briefly described how osteoarthritis is defined in clinical and bioarchaeological studies and, finally, provided a literature review of past assessments of osteoarthritis in archaeological Balkan populations. This chapter also described theoretical approaches for mortuary data analyses. Later, this chapter provided a literature review of mortuary practices during the Kingdom of Bosnia and the Eyelet of Bosnia during the Ottoman rule, and introduced the Mistihalj site and mortuary practices at this site and their interpretations by excavators. Finally, this chapter described the socio-economic contexts in Trebinje during the rule of the Kingdom of Bosnia and Ottoman Empire and described the loosely based division of labor by gender and child labor among peasants in Trebinje during both time periods.

# CHAPTER 3: MATERIALS AND METHODS

This chapter is divided into three sections. The first section is an overview of the skeletal materials used in this study including their provenance and preservation. The second section discusses the osteological methods used to estimate age and sex of the individuals analyzed in this study and the methods used in the collection of osteoarthritis data in this study. The third section explains the statistical methods used for osteoarthritis data analyses in this study.

## Materials

The Mistihalj excavation yielded fragmentary, partial, and complete adult and juvenile skeletons (MNI = 439) that are now housed at the Peabody Museum at Harvard University in Cambridge, Massachusetts. The church Crypt included 59 skeletons, and the cemetery Necropolis included 380 skeletons.

The skeletal sample selected for this study consists of 76 adult individuals that were completely or nearly completely preserved as defined by Buikstra and Ubelaker (1994:6-8). In this study cranial elements, long bones, proximal and distal articular surfaces, and other postcranial bones were defined as complete if at least 75% of each of these elements were present, nearly complete if between 25% and 75% of these units were present, and absent if less than 25% of these units were present. Of these 76 individuals, 60 skeletons are from the Late Medieval Necropolis, and 16 are from the 19th century Crypt. Sample size from the Crypt is smaller, because complete or nearly complete skeletons from this burial context were fewer. The age and sex of these 76 individuals had been estimated by the excavators, but I did not locate documentation that described the methods used. Therefore, each of the selected 76 skeletons was aged and sexed by the author using multiple methods recommended by Buikstra and Ubelaker (1994:16-38) discussed below.

## Osteological Methods

### Sex Estimates

In human populations, sex estimation in adult skeletons is based on observations of sexually dimorphic morphological traits in the os coxae and cranium that develop in puberty and the measurements of dimorphic dimensions, particularly those of the long bones (Buikstra and Ubelaker, 1994:16). Since sexual dimorphism varies between populations, metric standards developed for one population might not be useful for measurements of skeletons from other populations. Additionally, since such measurements are time consuming and due to time constraints during data collection, this method was not used to estimate the sex of skeletons examined in this study. In this study, the sex of each skeleton was estimated by observing morphological differences in the os coxae and cranium as suggested by Buikstra and Ubelaker (1994:16-21). For the ox coxae, I observed attributes of subpubic region, the form of a greater sciatic notch and the presence of preauricular sulcus. For the cranium, I observed expressions of the rugosity of the nuchal crest, the volume of mastoid processes, the thickness of supraorbital margins, the prominence of the glabella and the projection of mental eminence. As suggested (Buikstra and Ubelaker, 1994:21), based on all of the observations for the ox coxae and then separately for the cranium, each individual was assigned to one of the following sex categories: undetermined sex, female, probable female, ambiguous sex, probable male, or male.

## Age Estimates

Estimates of skeletal age at death are based on observations of age-related changes in skeletons such as in cranial suture closure and arthritic changes. However, morphological age related changes in pubic symphyseal face are suggested to be one of the best skeletal indicator of age at death (Buikstra and Ubelaker, 1994:21).Thus, the skeletal age of each individual in this study was estimated by observing morphological age- related changes of the left and right pubic symphyseal face, when available, using Suchey-Brooks symphysis scoring system (Brooks and Suchey, 1990; Katz and Suchey, 1986). Additionally, the auricular surface changes associated with age were also observed and scored (Lovejoy et al., 1985), because it is recommended that skeletal age be estimated using multivariate approaches (Buikstra and Ubelaker, 1994:15). Due to time constraints during the collection of data in this study, other approaches could not be used. As with the sex observations, observations of age-related changes in pubic symphyseal surfaces and auricular surfaces were directly recorded for both sides on a recording form suggested by Buikstra and Ubelaker (1994:15) and were compared to estimated ages for each individual. Individuals were categorized into one of the following age groups: young adult (20-34 years of age), middle-aged adult (35-50 years of age) and old adult (50+ years of age).

## Osteoarthritis observations

In the field of bioarchaeology, osteoarthritis data collection and analyses vary between studies. The principal differences lie in the diagnoses of this condition, their scoring, and the selection of articular surfaces observed for the joint complexes. Finally the statistical analyses used to examine osteoarthritis prevalence vary between researchers. Some researchers suggest that the presence of eburnation should be considered as definitive diagnostic of the condition, because eburnation is a pathognomonic of osteoarthritis (Rogers and Waldron, 1995), but also an indicator of the most severe form of this condition (Rothschild, 1997). Therefore, in some bioarchaeological studies, osteoarthritis is diagnosed when eburnation is observed or, if eburnation is absent, when two of the other features of osteoarthritis including lipping, porosity (sometimes used interchangeably as pitting), and changes in the bony contour of the joint are observed (e.g., Eng, 2016; Waldron, 1992). However, recent clinical research shows that the lipping, porosity, and the changes of the bone contour are also pathognomonic of osteoarthritis (Bettica et al., 2002; Botter et al., 2008; Botter et al., 2011; Dedrick et al., 1993; Hayami et al., 2004; Li et al., 1999). Furthermore, some clinical research results suggest that besides eburnation, the pronounced lipping, porosity, and thickening of subchondral bone plate and the increase in bone area affected by these features are also indicators of more severe forms of osteoarthritis (Carlson et al., 1996; Siebelt et al., 2013; Wen et al., 2013). Finally, in some studies osteoarthritis is scored as present or absent (e.g., Eng, 2016; Klaus et al., 2009), and in other studies osteoarthritis is scored using a four unit ordinal scale (e.g. Woo and Sciulli 2013). However, currently there is no uniform scaling system used by researchers.

Consequences of different methods used for osteoarthritis diagnosis in bioarchaeological studies result in highly varied prevalence rates of this condition even among the same population (Roja-Sepulveda et al., 2008). Roja-Sepulveda and colleagues (2008) examined osteoarthritis frequency using different methods for diagnosis in a past population and their results suggest that the frequency of osteoarthritis is the lowest when the eburnation alone is used as diagnostic of the condition and the highest when any one of the other typical features observed is considered as diagnostic of the condition. Roja-Sepulveda and colleagues (2008) also showed in their study that frequency of osteoarthritis when osteoarthritis is diagnosed if at least two typical features are observed, is somewhere in between the frequencies when the two other methods are used. Thus, for this present study a moderate approach was selected.

The selection of the articular surfaces of the major joints (shoulder, elbow, wrist, hip, knee, and ankle) of which to collect osteoarthritis data varies between anthropological researchers. For example, some researchers (e.g., Eng, 2016; Klaus et al., 2009) observe only glenohumeral surfaces in the shoulder, others (e.g., Lieverse et al., 2016) include acromioclavicular surfaces, and others (e.g., Zampetti et al., 2016) further include sternoclavicular surfaces. Also, while a majority of researchers (e.g. Eng, 2016; Lieverse et al., 2016; Woo and Sciulli, 2013) include the surfaces of the tibiofemoral and patelofemoral joints when collecting data for the knee, others (Schrader, 2012) also observe the proximal tibiofibular joint surfaces. In fact, clinical research suggests that the proximal tibiofibular joint surfaces can be considered a part of the knee, because these surfaces have a musculoskeletal communication with all the compartments of the knee (Bozkurt et al., 2003). Other clinical researchers (e.g., Boya et al., 2008) suggest that osteoarthritis data should be collected for the proximal tibiofibular surfaces as a part of the knee joint, because osteoarthritis results for proximal tibiofibular and tibiofemoral surfaces correlate significantly among affected individuals.

### *Osteoarthritis data collection and scoring methods*

I examined the major non-weight bearing upper limb joints (shoulder, elbow, and wrist) and major weight bearing lower limb joints (hip, knee, and ankle) that can manifest joint osteoarthritis. As recommended by Rogers and Waldron (1995), each of these joint systems is treated as a single joint. Articular surfaces that were 25% or more present that constitute joints of each of six joint complexes (Table 2) were visually examined for the presence of osteoarthritis. Although, articular surfaces examined were those suggested by Larsen et al. (1995), I also included articular surfaces of the acromioclavicular and proximal tibiofibular joints, because these can also exhibit osteoarthritis (Horvath and Kery, 1984; Oztuna et al., 2003; Yoshinoby Nakama et al., 2003). For the wrist joint complex, only the distal articular surface of radius was examined, because clinical studies show that osteoarthritis changes in other joints that constitute wrist joint complex are secondary to osteoarthritis development on the distal articular surface of radius (Watson and Ballet, 1984).

**Table 2 Joint complexes and their articular surfaces, modified from Larsen et al., 1995.**

| Joint complex | Articular surfaces |
|---|---|
| Shoulder | Acromion; lateral end of clavicle; glenoid fossa; head of humerus |
| Elbow | Trochlea of the distal humerus; trochlear notch of ulna; coronary process of ulna; capitulum of humerus; head of radius; radial notch of ulna |
| Wrist | Distal surface of radius |
| Hip | Acetabulum; head of femur |
| Knee | Medial and lateral femoral condyles; medial and lateral tibial condyles; patello-femoral surfaces; articular surface of the head of fibula |
| Ankle | Medial malleolar surface of tibia; distal articular surface of tibia; lateral malleolar surface of fibula, superior trochlear surface of talus |

This study uses the method suggested as a standard for osteoarthritis data collection in the past populations which requires researchers to observe the three principal bony changes associated with osteoarthritis (lipping, porosity, and eburnation) (Buikstra and Ubelaker, 1994: 122-123). This method involves recording the maximum degree of each change and its extent using specific codes. Lipping in the margins of articular surfaces can be recorded as barely discernable (8.1.1), a sharp ridge sometimes curled with spicules (8.1.2), extensive spicule formation (8.1.3), and ankyloses (8.1.4). Surface porosity can be recorded as pinpoint (8.3.1), coalesced (8.3.2), and both pinpoint and coalesced (8.3.3). Eburnation can be recorded as barely discernable (8.5.1), polish only (8.5.2) and polish with groove(s) (8.5.3). Further, the extent of each can be recorded as less than one third (8.2.1 for lipping, 8.4.1 for porosity and 8.6.1 for eburnation), one third to two third (8.2.2 for lipping, 8.4.2 for porosity and 8.6.2 for eburnation), and more than two thirds (8.2.3 for lipping, 8.4.3 for porosity and 8.6.6 for eburnation).

First, osteoarthritis was scored for each joint, separately for the left and right sides of the body in all articular surfaces available that constitute a specific joint (Appendix B). Scoring of osteoarthritis for each joint ranged from zero to three, where zero indicates osteoarthritis was absent, one indicates mild, two moderate and three pronounced. Table 3 shows osteoarthritis definitions for each of these categories. After, for each individual, the data for each of six joints were collapsed for left and right sides into a single composite score for each joint by adding the two scores and dividing it by two and defined accordingly (Appendix E). This was justified, because there were no significant differences in osteoarthritis prevalence rates between left and right sides in any joint examined (Appendix F). Also, for each individual, data for the three upper body joint complexes were combined into an upper limb joint (shoulder, elbow and wrist) composite score (added and divided by 3) and data from the three lower body complexes were collapsed into a lower limb joint (hip, knee, and ankle) composite score and graded accordingly (Appendix E). Osteoarthritis remained defined as absent if the score was below 1, mild if it ranged between 1 and 1.99, moderate if it ranged between 2 and 2.99, and pronounced if it was 3 or higher. Definitions of these scores were recorded on an Excel ® spreadsheet for each individual together with their burial location and their age category and sex estimate (Appendix E).

**Table 3 Osteoarthritis category definitions with a corresponding score for a joint complex.**

| **Osteoarthritis Score** | **Definition** |
|---|---|
| Absent<br><br>0 – 0.99 | No principal bony changes associated with osteoarthritis are observed or all principal changes associated with osteoarthritis are observed in the first degree (barely discernable lipping , pinpoint porosity, barely discernable eburnation) on all articular surfaces of the joint complex |
| Mild<br><br>1 – 1.99 | One of the three principal changes associated with osteoarthritis is of the second degree (sharp ridges sometimes curled with spicules, coalesced porosity, eburnation with polish only) and affecting more than 2/3 of the circumference or of the third degree (extensive formation of spicules, pinpoint and coalesced porosity, eburnation with both the polish and the grooves) or fourth degree for lipping (ankyloses) and is affecting less than 1/3 of the circumference or surface of at least one articular surface of the joint complex |
| Moderate<br><br>2 – 2.99 | One of the three principal changes associated with osteoarthritis is of the third degree (extensive formation of spicules, pinpoint and coalesced porosity, eburnation with both the polish and the grooves) or fourth degree for lipping (ankyloses) and is affecting between 1/3 to 2/3 of the circumference or surface of at least one of the articular surface of the joint complex |
| Pronounced<br><br>>= 3 | One of the three principal changes associated with osteoarthritis is of the third degree (extensive formation of spicules, pinpoint and coalesced porosity, eburnation with both the polish and the grooves) or fourth degree for lipping (ankyloses) and is affecting more than 2/3 of the circumference or surface of at least one of the articular surface of the joint complex. |

Composite scores allow for the separate examination of osteoarthritis prevalence rates in upper limb joints and lower limb joints for each individual within this study. Although such examinations are less commonly used in anthropological research than examinations of osteoarthritis prevalence rates among individual joints by individual and among individuals, such analyses are important, because they allow for the examination of the cumulative effects of osteoarthritis by body region and might provide insight into what role different risk factors played in the development of osteoarthritis by the body region (Weiss, 2004). For example, studies show that during tasks such as lifting of heavy objects all three main joint systems of the upper limbs (shoulder, elbow, and wrist) (Gates et al., 2016) and the lower limbs (hip, knee and ankle) (Hyodo et al., 2017) are put under concurrent stresses that can lead to osteoarthritis. However, while the increased body weight increases stresses on weight bearing joints of the lower limbs (Aaboe et al., 2011), no studies on the effects of stress imposed by increased body weight on upper limb joints could be found. Furthermore, not only can these systemic factors have implications in osteoarthritis prevalence rates between upper limbs and lower limbs within individuals, but also between sexes due to biological differences between males and females that might include anatomical differences. For example, a study by Weiss (2004) showed that the lower limb composite osteoarthritis prevalence rates were significantly higher among females than males, while sex differences in composite osteoarthritis prevalence rates in upper limbs were insignificant. Moreover, the same study showed that the severity of osteoarthritis was significantly higher in the lower limbs among individuals of smaller size while such size differences were insignificant in upper body limbs. Finally, even though in this thesis' study the prevalence of osteoarthritis could not be examined for individual joints for all individuals from two skeletal samples due to absence of materials, it could be examined using the composite scores for upper and for the lower limb joints for all individuals examined.

## Analytical Methods

Prevalence for the presence of osteoarthritis was calculated (using the number of affected individuals as numerator and the overall number of individuals examined as denominator) for the upper and the lower limb joints for individuals overall and within each age, sex, and aged- sex cohort from both burial locations. Prevalence for each definition of osteoarthritis (mild, moderate, and pronounced) was calculated (using the number of individuals for specific definition of osteoarthritis as numerator and overall number of individuals affected by osteoarthritis as denominator) for the upper and the lower limb joints for individuals overall and within each age, sex and aged- sex cohort from both burial locations.

First, statistical analyses were conducted in order to examine if the prevalence of osteoarthritis differed between upper and lower limb joints among the individuals overall and within each age, sex, and aged- sex cohorts from both burial locations. I also tested if the prevalence of osteoarthritis in the upper and the lower limb joints differed between age, sex, and aged-sex cohorts from both burial locations. Next, I tested if the prevalence of osteoarthritis in the upper and the lower limb joints differed between the Necropolis and Crypt individuals overall and between individuals of the same age, sex, and aged -sex cohort. Also, osteoarthritis prevalence rates for individual joints were compared between sex cohorts from each burial location and between all the Crypt and Necropolis individuals overall. Finally, statistical analyses were conducted to examine if the severity of osteoarthritis for individuals overall and within each age, sex, and aged-sex cohort from both burial locations correlated with its location; if the severity of this condition in the upper and the lower limb joints correlates with age, sex, and aged-sex cohorts of individuals from both burial location; and if the severity of osteoarthritis in the upper and in the lower limb joints correlates with the burial location of individuals overall and within same age, sex, and aged -sex cohorts from the two burial locations.

Prevalence comparisons for the presence of osteoarthritis were conducted using Odds Ratios ($\hat{O}R$). Odds ratios calculate whether the odds for certain outcome (e.g., osteoarthritis) are the same between two groups (e.g. group A and group B) (McHugh, 2009). The formula for the odds ratio is (a*d)/(b*c), where *a* is the number of individuals with outcome (e.g., osteoarthritis) in a first group (e.g. Crypt individuals), *c* is the number of individuals with outcome (e.g., osteoarthritis) in a second group (e.g., Necropolis individuals), *b* is the number of individuals without outcome (e.g., osteoarthritis absent) in the first group (e.g., Crypt individuals) and *d* is the number of individuals without outcome (e.g., osteoarthritis absent) in the second group (e.g., Necropolis individuals). An odds ratio higher than 1 signifies that the first group (e.g., Crypt individuals) has higher prevalence of osteoarthritis, while an odds ratio lower than 1 means that the second group (e.g., Necropolis individuals) has higher prevalence of osteoarthritis. For example, if the odds ratio for Crypt individuals is 3.76, then the prevalence of osteoarthritis among these individuals is 3.76 greater, while if the odds ratio is 0.25 for Necropolis individuals than their prevalence of osteoarthritis is 4 (1/0.25) times greater. An odds ratio of 1 signifies that both groups are equally likely to have osteoarthritis. The significance test for the Odds Ratios was the Fisher Exact test. In all tests, the level of significance was at $p = 0.05$. Both the Odds Ratios and *p* values were calculated using MEDCALC software available at www.Medcalc.org.

The prevalence for each degree of osteoarthritis data was analyzed using the Freeman-Holton extensions of the Fisher Exact test results in order to explore the correlation between the independent variables of the location of osteoarthritis, age, sex, aged-sex of skeletons, location of burial, and the dependent variable of degree of osteoarthritis. The level of significance was at $p = 0.05$. Calculations for the Freeman-Holton extensions of the Fisher Exact test were calculated using Free Statistic Calculators version 4.0 available at www.danielsoper.com.

## Summary

This chapter described the skeletal sample and the osteological methods used to estimate the sex and age of individuals examined in this study and the methods used to collect osteoarthritis data, including definitions for the categories of osteoarthritis and a corresponding scoring system that was used as a framework for osteoarthritis data analyses using the composite scores for upper limb joints and lower limb joints for each individual. Finally, this chapter described the statistical methods used to explore prevalence of osteoarthritis and degree of osteoarthritis in the upper limb joints and the lower limb joints.

# CHAPTER 4: RESULTS

This chapter is divided into four sections. The first section presents results for sex and age estimates. The second section provides osteoarthritis results for the Necropolis (N) skeletal sample and the third section provides osteoarthritis results for the Crypt skeletal sample (C). The final section presents the comparisons between the two skeletal groups.

## Age and sex estimates

This study includes 21 young adult skeletons, 28 middle-aged adult skeletons and 27 old adult skeletons (Table 4). There are 19 young adult skeletons from the Necropolis and two young adult skeletons from the Crypt, 22 middle-aged adult skeletons from the Necropolis and six middle-aged adult skeletons from the Crypt and 19 old adult skeletons from the Necropolis and eight old adult skeletons from the Crypt (Table 4).

**Table 4 Distribution of young adults (YA), middle-aged adults (MA) and old adults (OA) analyzed in this study.**

| Samples | YA | MA | OA | Total |
|---|---|---|---|---|
| N | 19 | 22 | 19 | 60 |
| C | 2 | 6 | 8 | 16 |
| Total | 21 | 28 | 27 | 76 |

One individual from the Necropolis is categorized as probable female and three individuals are categorized as probable males, and one individual from the Crypt is categorized as probable male. For the purposes of the data analyses in this study, the probable female individual is included into a female group and the probable male individuals are included into the male group. In this study the female skeletal sample consists of 37 individuals and the male sample consists of 39 individuals (Table 5). There are 30 females and 30 males from the Necropolis and seven females and nine males from the Crypt (Table 5).

**Table 5 Distribution of the female (F) and male (M) individuals analyzed in this study.**

| Samples | F | M | Total |
|---|---|---|---|
| N | 30 | 30 | 60 |
| C | 7 | 9 | 16 |
| Total | 37 | 39 | 76 |

The female sample in this study includes 11 young adults, 13 middle-aged adults and 13 old adults. The male sample consists of ten young adults, 13 middle-aged adults and 14 old adults (Table 6). The female individuals from the Necropolis are evenly divided into ten individuals from each age cohort. There are nine young adult males, 12 middle-aged males and nine old adult males from the Necropolis. In the Crypt sample, there is one young adult female and one young adult male, three middle-aged females and three middle-aged males and three old adult females and five old adult males.

**Table 6 Distribution of the total number of females and males by age group analyzed in this study.**

| Samples | YAF | YAM | MAF | MAM | OAF | OAM | Total |
|---|---|---|---|---|---|---|---|
| N | 10 | 9 | 10 | 12 | 10 | 9 | 60 |
| C | 1 | 1 | 3 | 3 | 3 | 5 | 16 |
| Total | 11 | 10 | 13 | 15 | 13 | 14 | 76 |

Osteoarthritis results for the Necropolis skeletal sample

## Prevalence comparisons between upper and lower limb joints

While osteoarthritis is absent among some Necropolis individuals (Figure 8), mild, moderate and pronounced forms of this condition are observed in individual joints of a number of individuals (Figures, 9, 10, 11). An examination of data based solely for the presence of osteoarthritis among the Necropolis skeletons reveals that the prevalence of this condition is relatively high in both the upper and the lower limb joints of these individuals overall (Table 7). There are no significant differences between the prevalence of osteoarthritis in the upper limb joints and the lower limbs joints overall, but the prevalence of this condition is slightly higher in the upper limb joints than the lower limb joints (Table 7). The examination of data by severity reveals that the majority of individuals with osteoarthritis are affected by the mild form of this condition in both the upper and the lower limb joints and that the severity of osteoarthritis is independent of the joints' location (Table 8). Crude prevalence data for osteoarthritis presence and by severity show similar patterns (Figures C1 and D1).

**Figure 8 Photo of the left humeral head with no principal bony changes associated with osteoarthritis (osteoarthritis is absent), middle-aged male (Object number: 968-10-40/N8959.0) from Mistihalj Necropolis, (permission to use in Appendix A).**

**Figure 9 Photo of the right humeral head with second degree lipping affecting less than two thirds of circumference (mild osteoarthritis), middle-aged female (Object number: 968-10-40/N9054.0) from Misithalj Necropolis, (permission to use in Appendix A).**

**Figure 10 Photo of the right humeral head with third degree lipping affecting one third of circumference (moderate osteoarthritis), middle-aged male (Object number: 968-10-40/N9164.0) from Mistihalj Necropolis, (permission to use in Appendix A).**

**Figure 11 Photo of the right humeral head with third degree lipping affecting more than two thirds of circumferences (pronounced osteoarthritis), of a middle-aged female (Object number: 968-10-40/N9228.0) from Mistihalj Necropolis (permission to use in Appendix A).**

**Table 7 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints among all Necropolis adults.**

| Sample | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| Overall | ULJ | 39/60 | 65.0 | 1.15 | 0.7049 |
| | LLJ | 37/60 | 61.6 | ULJ+ | |

**Table 8 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints among all Necropolis adults.**

| Sample | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| Overall | ULJ | 38/39 | 97.4 | 1/39 | 2.56 | 0/39 | 0 | 1 |
| | LLJ | 36/37 | 97.2 | 1/37 | 2.7 | 0/37 | 0 | |

### *Within age cohorts*

Presence of osteoarthritis within age cohorts also does not reveal significant differences in the prevalence rates for the presence of osteoarthritis between the upper limb joints and the lower limbs joints in any of these groups. While young adults and old adults have slightly higher prevalence of osteoarthritis in the lower limbs joints than the upper limbs joints, opposite is true for middle-aged adults (Table 9). The examination of results by severity reveals that most of the affected individuals in all three cohorts have mild osteoarthritis and that relatively small percentage of old adults are also affected by moderate form of this condition in both the upper limb joints and the lower limbs joints. However, for all three age cohorts the severity of osteoarthritis is independent of joints' location (Table 10). Figures C2 and D2 show similar patterns for crude prevalence for osteoarthritis presence and by severity among these individuals.

**Table 9 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within age cohorts from the Necropolis.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| YA | ULJ | 6/19 | 31.5 | 0.79 LLJ+ | 0.7326 |
| | LLJ | 7/19 | 36.8 | | |
| MA | ULJ | 18/22 | 81.8 | 3.11 ULJ+ | 0.1058 |
| | LLJ | 13/22 | 59.0 | | |
| OA | ULJ | 15/19 | 78.9 | 0.44 LLJ+ | 0.3818 |
| | LLJ | 17/19 | 89.4 | | |

**Table 10 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within age cohorts from the Necropolis.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| YA | ULJ | 6/6 | 100.0 | 0/6 | 0.00 | 0/6 | 0 | 1 |
| | LLJ | 7/7 | 100.0 | 0/7 | 0.00 | 0/7 | 0 | |
| MA | ULJ | 18/18 | 100.0 | 0/18 | 0.00 | 0/18 | 0 | 1 |
| | LLJ | 13/13 | 100.0 | 0/13 | 0.00 | 0/13 | 0 | |
| OA | ULJ | 14/15 | 93.3 | 1/15 | 6.66 | 0/15 | 0 | 1 |
| | LLJ | 16/17 | 94.1 | 1/17 | 5.88 | 0/17 | 0 | |

### *Within sex cohorts*

An examination of data for the presence of osteoarthritis within either sex cohort does not reveal significant differences between the prevalence of this condition in the upper limb joints and the lower limbs joints. Both sexes overall have a slightly higher prevalence of osteoarthritis in the upper limb joints (Table 11). While most of the affected males and females have the mild form of this condition in both the upper limb joints and the lower limbs joints, a small percentage of females (5.26%) also has moderate osteoarthritis in the upper limb joints and a small percentage of males (5.26%) also had moderate osteoarthritis in the lower limb joints. However, for both cohorts the severity of osteoarthritis is independent of joints' location (Table 12). Crude prevalence of osteoarthritis and by severity of condition reflects similar patterns among sex cohorts (Figures C3 and D3).

**Table 11 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within sex cohorts from the Necropolis.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| F | ULJ | 19/30 | 63.3 | 1.15 | 0.7907 |
| | LLJ | 18/30 | 60.0 | ULJ+ | |
| M | ULJ | 20/30 | 66.6 | 1.15 | 0.7867 |
| | LLJ | 19/30 | 63.3 | ULJ+ | |

**Table 12 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within sex cohorts from the Necropolis.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| F | ULJ | 18/19 | 94.7 | 1/19 | 5.26 | 0/19 | 0 | 1 |
| | LLJ | 18/18 | 100.0 | 0/18 | 0.00 | 0/18 | 0 | |
| M | ULJ | 20/20 | 100.0 | 0/20 | 0.00 | 0/20 | 0 | 0.4871 |
| | LLJ | 18/19 | 94.7 | 1/19 | 5.26 | 0/19 | 0 | |

### *Within aged-sex cohorts*

Further examination of osteoarthritis results within aged-sex cohorts again does not reveal significant differences in the prevalence for the presence of this condition between the upper limb joints and lower limb joints among any of the cohorts examined. Young adult females have aslightly higher prevalence in the lower limb joints than the upper limb joints while opposite is true among young adult males. Within middle-aged cohort both sexes have slightly higher prevalence in the upper limb joints than the lower limb joints, while both sexes within old adult cohort have a higher prevalence in the lower limb joints than the upper limb joints (Table 13). These patterns are also reflected by crude prevalence data (Figure C4).  When the results are examined by the severity of osteoarthritis these reveal that only old adult females are affected by moderate osteoarthritis in the upper limbs and that only old adult males are affected by moderate osteoarthritis in the lower limbs. Crude prevalence by severity of osteoarthritis mirrors these patterns (Figure D4). However, for all aged- sex cohorts the severity of osteoarthritis is again independent of the joints' location (Table 14).

**Table 13 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within aged-sex cohorts from the Necropolis.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| YAF | ULJ | 3/10 | 30.0 | 0.64 LLJ+ | 0.6401 |
| | LLJ | 4/10 | 40.0 | | |
| YAM | ULJ | 3/9 | 33.3 | 1.07 ULJ+ | 0.9304 |
| | LLJ | 3/9 | 33.3 | | |
| MAF | ULJ | 9/10 | 90.0 | 6.00 ULJ+ | 0.1472 |
| | LLJ | 6/10 | 60.0 | | |
| MAM | ULJ | 9/12 | 75.0 | 2.14 ULJ+ | 0.3904 |
| | LLJ | 7/12 | 58.3 | | |
| OAF | ULJ | 7/10 | 70.0 | 0.58 LLJ+ | 0.6075 |
| | LLJ | 8/10 | 80.0 | | |
| OAM | ULJ | 8/9 | 88.8 | 0.29 LLJ+ | 0.4766 |
| | LLJ | 9/9 | 100.0 | | |

**Table 14 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within aged-sex cohorts from Necropolis.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| YAF | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | 1 |
| | LLJ | 4/4 | 100.0 | 0/4 | 0.0 | 0/4 | 0 | |
| YAM | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | 1 |
| | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | |
| MAF | ULJ | 9/9 | 100.0 | 0/9 | 0.0 | 0/9 | 0 | 1 |
| | LLJ | 6/6 | 100.0 | 0/6 | 0.0 | 0/6 | 0 | |
| MAM | ULJ | 9/9 | 100.0 | 0/9 | 0.0 | 0/9 | 0 | 1 |
| | LLJ | 7/7 | 100.0 | 0/7 | 0.0 | 0/7 | 0 | |
| OAF | ULJ | 6/7 | 85.7 | 1/7 | 14.2 | 0/7 | 0 | 1 |
| | LLJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0 | |
| OAM | ULJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0 | 1 |
| | LLJ | 8/9 | 88.8 | 1/9 | 11.1 | 0/9 | 0 | |

## Prevalence comparisons for upper limb joints and lower limb joints

### *Between age cohorts*

Comparisons of the data based on the presence of osteoarthritis between the three age cohorts reveals some significant differences in the prevalence of this condition between these groups in both the upper and the lower limb joints. All of the significant differences show a correlation with an increase in the prevalence of this condition with an increase in age. The prevalence of osteoarthritis is significantly higher in the upper limb joints of middle-aged adults than young adults and old adults than young adults. In the lower limb joints, old adults have a significantly higher prevalence of osteoarthritis than both the young adults and the middle-aged adults (Table 15). The examination of the results for the prevalence of osteoarthritis by severity reveals that although all young and middle-aged adults are affected only by mild osteoarthritis in both the upper limb joints and the lower limb joints, and while the old adults also have moderate osteoarthritis in both of these joints' locations, the severity of osteoarthritis is independent of age (Table 16). Crude prevalence for the presence of osteoarthritis and by severity mirrors these differences between age cohorts (Figures C5 and D5).

**Table 15 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between age cohorts from the Necropolis.**

| Cohort | ULJ % | ÔR | P-value | LLJ % | ÔR | p-value |
|---|---|---|---|---|---|---|
| YA | 31.5 | 0.10 MAA+ | *0.0021* | 36.8 | 0.4 MAA+ | 0.1589 |
| MA | 81.8 | | | 59.0 | | |
| YA | 31.5 | 0.12 OA+ | *0.0051* | 36.8 | 0.06 OA+ | *0.0025* |
| OA | 78.9 | | | 89.4 | | |
| MA | 81.8 | 0.16 MAA+ | 0.8172 | 59.0 | 0.16 OA+ | *0.0403* |
| OA | 78.9 | | | 89.4 | | |

**Table 16 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between age cohorts from the Necropolis.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| YA | ULJ | 6/6 | 100.0 | 0/6 | 0.00 | 0/6 | 0 | 1 |
| MAA | ULJ | 18/18 | 100.0 | 0/18 | 0.00 | 0/18 | 0 | |
| YA | ULJ | 6/6 | 100.0 | 0/6 | 0.00 | 0/6 | 0 | 1 |
| OA | ULJ | 14/15 | 93.3 | 1/15 | 6.66 | 0/15 | 0 | |
| MAA | ULJ | 18/18 | 100.0 | 0/18 | 0.00 | 0/18 | 0 | 0.4545 |
| OA | ULJ | 14/15 | 93.3 | 1/15 | 6.66 | 0/15 | 0 | |
| YA | LLJ | 7/7 | 100.0 | 0/7 | 0.00 | 0/7 | 0 | 1 |
| MAA | LLJ | 13/13 | 100.0 | 0/13 | 0.00 | 0/13 | 0 | |
| YA | LLJ | 7/7 | 100.0 | 0/7 | 0.00 | 0/7 | 0 | 1 |
| OA | LLJ | 16/17 | 94.1 | 1/17 | 5.88 | 0/17 | 0 | |
| MAA | LLJ | 7/7 | 100.0 | 0/7 | 0.00 | 0/7 | 0 | 1 |
| OA | LLJ | 16/17 | 94.1 | 1/17 | 5.88 | 0/17 | 0 | |

### *Between sex cohorts*

The prevalence of osteoarthritis does not significantly differ in either the upper or the lower limb joints between females and males overall. Osteoarthritis prevalence is slightly higher in both the upper limb joints and the lower limbs joints of males (Table 17). An examination of prevalence results by severity of osteoarthritis shows that the severity of osteoarthritis in both the upper limb joints and the lower limb joints was independent of sex (Table 18). For both the presence of osteoarthritis and the severity of osteoarthritis, crude prevalence rates show similarities between sex cohorts (Figures C6 and D6). Furthermore, the prevalence of osteoarthritis does not significantly differ for any individual joint between females and males

(Table 19). Figure 12 shows these similarities in the effects of osteoarthritis between these individuals.

**Table 17 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between sex cohorts from the Necropolis.**

| Cohort | ULJ % | ÔR | p-value | LLJ % | ÔR | p-value |
|---|---|---|---|---|---|---|
| F | 63.3 | 0.83 M + | 0.7867 | 60.0 | 0.86 M + | 0.7907 |
| M | 66.6 | | | 63.3 | | |

**Table 18 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between sex cohorts from the Necropolis.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| F | ULJ | 18/19 | 94.7 | 1/19 | 5.26 | 0/19 | 0 | 0.4871 |
| M | ULJ | 20/20 | 100 | 0/20 | 0.00 | 0/20 | 0 | |
| F | LLJ | 18/18 | 100 | 0/18 | 0.00 | 0/18 | 0 | 1 |
| M | LLJ | 18/19 | 94.7 | 1/19 | 5.26 | 0/19 | 0 | |

**Table 19 Odds ratio results, osteoarthritis prevalence comparisons by individual joints between sex cohorts from the Necropolis.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| F | Shoulder | 24/30 | 80 | 1.71 F+ | 0.3737 |
| M | Shoulder | 21/30 | 70 | | |
| F | Elbow | 25/30 | 83.3 | 0.80 M+ | 0.7592 |
| M | Elbow | 25/29 | 86.2 | | |
| F | Wrist | 18/26 | 69.2 | 0.45 M+ | 0.2182 |
| M | Wrist | 25/30 | 83.3 | | |
| F | Hip | 21/28 | 75 | 0.91 M+ | 0.8822 |
| M | Hip | 23/30 | 76.6 | | |
| F | Knee | 23/30 | 76.6 | 0.82 M+ | 0.7542 |
| M | Knee | 24/30 | 80 | | |
| F | Ankle | 19/30 | 63.3 | 0.52 M+ | 0.2629 |
| M | Ankle | 23/30 | 76.6 | | |

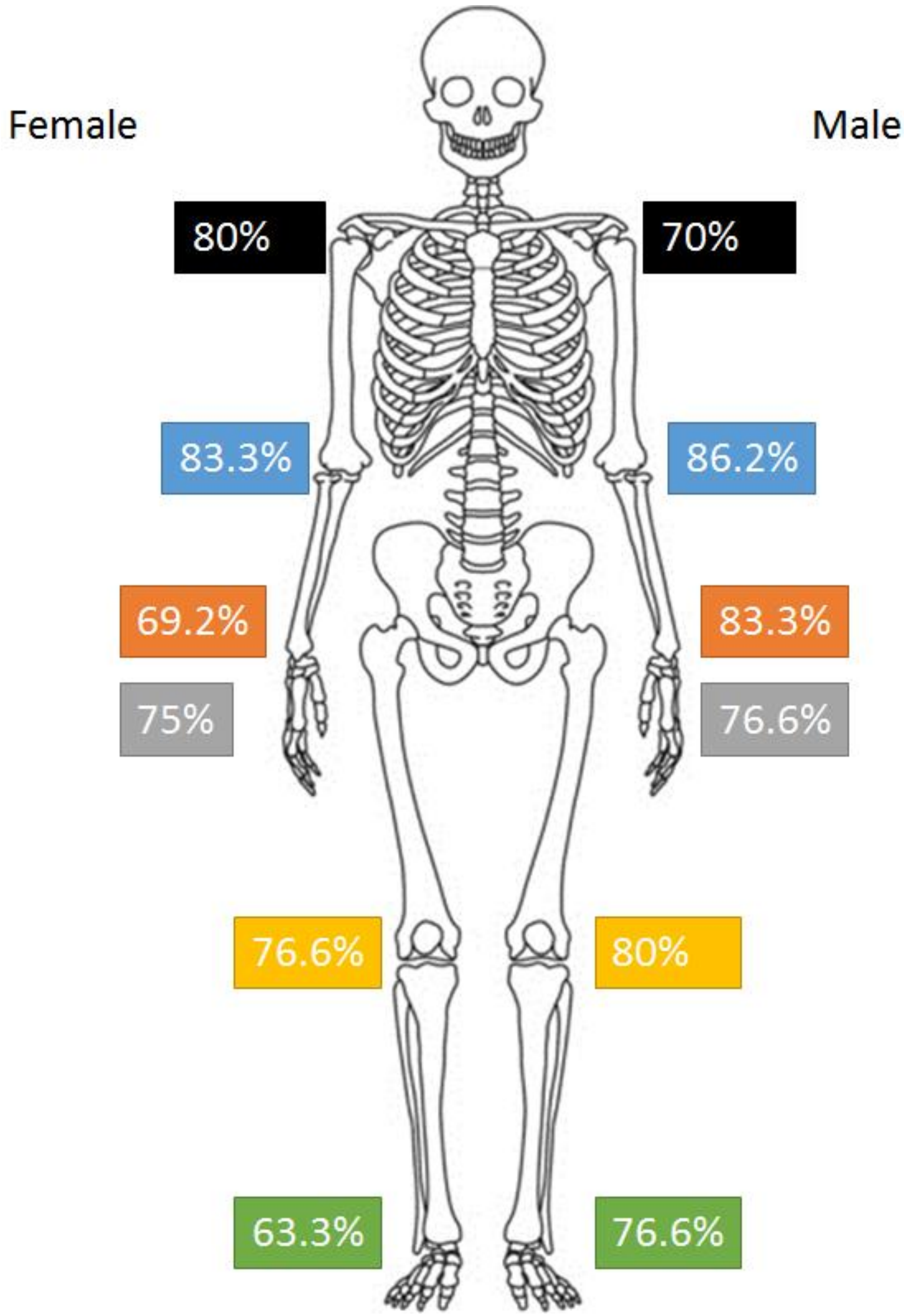


**Figure 12 Osteoarthritis prevalence comparisons by individual joints between sex cohorts from the Necropolis (Color indicators: black shoulder, blue elbow, orange wrist, gray hip, yellow knee, and green ankle).**

### *Between aged-sex cohorts*

The prevalence of osteoarthritis again does not significantly differ in either the upper or the lower limb joints when compared between females and males within the same age cohorts. Within the young adult cohort males have a higher prevalence in the upper limb joints and females have a higher prevalence in the lower limbs joints. While among middle-aged adults females have a higher prevalence in both the upper limb joints and the lower limb joints and among old adults, males have a higher prevalence in the upper and in the lower limb joints (Table 19). However, statistical analyses show that the severity of osteoarthritis was independent of the sex of individuals within same age cohorts in both the upper limb joints and the lower limb joints (Table 20). The variable differences for the prevalence of osteoarthritis and by severity between females and males within same age cohorts are mirrored by the crude prevalence rates (Figures C7 and D7).

**Table 20 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between aged-sex cohorts from the Necropolis.**

<table>
<tr><th>Cohort</th><th>ULJ %</th><th>ÔR</th><th>p-value</th><th>LLJ %</th><th>ÔR</th><th>p-value</th></tr>
<tr><td>YAF</td><td>30.0</td><td rowspan="2">0.85<br>YAM+</td><td rowspan="2">0.8760</td><td>40.0</td><td rowspan="2">1.55<br>YAF+</td><td rowspan="2">0.6401</td></tr>
<tr><td>YAM</td><td>33.3</td><td>33.3</td></tr>
<tr><td>MAF</td><td>90.0</td><td rowspan="2">3.00<br>MAF+</td><td rowspan="2">0.3784</td><td>60.0</td><td rowspan="2">1.07<br>MAF+</td><td rowspan="2">0.9369</td></tr>
<tr><td>MAM</td><td>75.0</td><td>58.3</td></tr>
<tr><td>OAF</td><td>70.0</td><td rowspan="2">0.29<br>OAM+</td><td rowspan="2">0.3302</td><td>80.0</td><td rowspan="2">0.17<br>OAM+</td><td rowspan="2">0.2880</td></tr>
<tr><td>OAM</td><td>88.8</td><td>100.0</td></tr>
</table>

**Table 21 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between aged-sex cohorts from the Necropolis.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| YAF | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | 1 |
| YAM | ULJ | 4/4 | 100.0 | 0/4 | 0.0 | 0/4 | 0 | |
| YAF | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | 1 |
| YAM | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | |
| MAF | ULJ | 9/9 | 100.0 | 0/9 | 0.0 | 0/9 | 0 | 1 |
| MAM | ULJ | 6/6 | 100.0 | 0/6 | 0.0 | 0/6 | 0 | |
| MAF | LLJ | 9/9 | 100.0 | 0/9 | 0.0 | 0/9 | 0 | 1 |
| MAM | LLJ | 7/7 | 100.0 | 0/7 | 0.0 | 0/7 | 0 | |
| OAF | ULJ | 6/7 | 85.7 | 1/7 | 14.2 | 0/7 | 0 | 0.4666 |
| OAM | ULJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0 | |
| OAF | LLJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0 | 1 |
| OAM | LLJ | 8/9 | 88.8 | 1/9 | 11.1 | 0/9 | 0 | |

## Osteoarthritis results for Crypt skeletal sample

### Prevalence comparisons between upper and lower limb joints

An examination of the data for the osteoarthritis presence among the Crypt individuals shows that the prevalence of this condition is relatively high in both the upper limb joints and the lower limb joints among individuals overall (Table 21). There are no significant differences in the prevalence of osteoarthritis between the upper limb joints and the lower limb joints among all Crypt individuals examined, but the prevalence is slightly higher in the upper limb joints (Table 21). Crude prevalence rates reflect similar patterns of osteoarthritis among these individuals (Figure C8). An examination of data by severity of osteoarthritis shows that the majority of the Crypt individuals affected by osteoarthritis have mild osteoarthritis in the upper limb joints with 14.2 % of these individuals with moderate form of this condition and 7.14 % of these individuals with the pronounced form of osteoarthritis. However, in the lower limb joints, all affected individuals have only the mild form of osteoarthritis. Furthermore, overall the severity of osteoarthritis was independent of joint location (Table 22). Figure D8 also demonstrates these patterns.

**Table 22 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints among all Crypt adults.**

| Sample | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| Overall | ULJ | 14/16 | 87.5 | 1.61 ULJ+ | 0.6284 |
| | LLJ | 13/16 | 81.2 | | |

**Table 23 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints among all Crypt adults.**

| Sample | Joints | MOA(n/N) | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| Overall | Upper | 11/14 | 78.5 | 2/14 | 14.2 | 1/14 | 7.14 | 0.2222 |
| | Lower | 13/13 | 100.0 | 0/13 | 0.0 | 0/13 | 0.00 | |

### *Within age cohorts*

The odds ratio results show that there are no significant differences in the prevalence of osteoarthritis between upper and lower limb joints within any age cohorts. While among young adults the prevalence is higher in the upper limb joints than the lower limb joints, among middle-aged adults and old adults the prevalence is exactly the same in the upper limb joints and the lower limb joints (Table 23). Figure C9 also reflects these patterns by crude prevalence. All affected individuals within all three age cohorts have only mild osteoarthritis in the lower limb joints. While young adults and middle -aged adults have only mild osteoarthritis in the upper limb joints, old adults also have moderate and pronounced forms of this condition in the upper limb joints. However, statistical analyses show that the severity of osteoarthritis did not correlate with the location of this condition among the affected old adults or any other age cohort (Table 24). Crude prevalence of osteoarthritis by severity also reflects these patterns of osteoarthritis among the Crypt age cohorts (Figure D9).

**Table 24 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within age cohorts from the Crypt.**

| Sample | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| YA | ULJ | 2/2 | 100.0 | 5.0 ULJ+ | 0.4049 |
| | LLJ | 1/2 | 50.0 | | |
| MA | ULJ | 5/6 | 83.3 | 1.00 Equal | 1 |
| | LLJ | 5/6 | 83.3 | | |
| OA | ULJ | 7/8 | 87.5 | 1.00 Equal | 1 |
| | LLJ | 7/8 | 87.5 | | |

**Table 25 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within age cohorts from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| YA | ULJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0.0 | 1 |
| | LLJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0.0 | |
| MA | ULJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | 1 |
| | LLJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | |
| OA | ULJ | 4/7 | 57.1 | 2/7 | 28.5 | 1/7 | 14.2 | 0.1923 |
| | LLJ | 7/7 | 100.0 | 0/7 | 0.0 | 0/7 | 0.0 | |

### *Within sex cohorts*

Within the female and male cohorts overall, the prevalence of osteoarthritis did not significantly differ between the upper and lower limbs joints. While females have an equal prevalence of osteoarthritis in the upper and lower limb joints, the prevalence of this condition is slightly higher in the upper limb joints than lower limb joints of males (Table 25). Furthermore, while females have only mild osteoarthritis in both the upper and the lower limb joints, males also have moderate and pronounced forms of this condition in the upper limb joints. Still, the statistical analyses show that the severity of osteoarthritis among any of these individuals and its location did not correlate (Table 26). Similar patterns for the presence of osteoarthritis and by its severity between the upper and lower limbs among the Crypt sex cohorts are reflected in crude prevalence rates (Figures C10 and D10).

**Table 26 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within sex cohorts from the Crypt.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| F | ULJ | 5/7 | 71.4 | 1.00 Equal | 1 |
| | LLJ | 5/7 | 71.4 | | |
| M | ULJ | 9/9 | 100.0 | 3.35 ULJ+ | 0.4766 |
| | LLJ | 8/9 | 88.8 | | |

**Table 27 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within sex cohorts from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| F | ULJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | 1 |
| | LLJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | |
| M | ULJ | 6/9 | 66.6 | 2/9 | 22.2 | 1/9 | 11.1 | 0.3294 |
| | LLJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0.0 | |

### *Within aged-sex cohorts*

An examination of prevalence rates for the presence of osteoarthritis within aged-sex cohorts shows that among all of these individuals there are no significant differences between the upper and the lower limb joints. While young adult females and old adult males have a higher prevalence in upper limb joints, old adult females have higher prevalence in the lower limb joints. However, young adult males and both the middle-aged females and males have a prevalence of osteoarthritis in both the upper limb joints and the lower limb joints (Table 27). An examination of results by severity of osteoarthritis indicates that all of these individuals have mild osteoarthritis in the upper limb joints except for the old adult males who also have moderate and pronounced forms of this condition in these joints. Finally, the statistical analyses show that for the old adult males the severity of osteoarthritis did not correlate with its location (Table 28). Crude prevalence data for the presence of osteoarthritis and by severity also show these similar patterns of osteoarthritis between the upper and lower limb joints among these individuals (Figure C11 and D11).

**Table 28 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within aged-sex cohorts from the Crypt.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| YAF | ULJ | 1/1 | 100.0 | 9.00 ULJ+ | 0.3414 |
| | LLJ | 0/1 | 0.0 | | |
| YAM | ULJ | 1/1 | 100.0 | 1.00 Equal | 1 |
| | LLJ | 1/1 | 100.0 | | |
| MAF | ULJ | 2/3 | 66.6 | 1.00 Equal | 1 |
| | LLJ | 2/3 | 66.6 | | |
| MAM | ULJ | 3/3 | 100.0 | 1.00 Equal | 1 |
| | LLJ | 3/3 | 100.0 | | |
| OAF | ULJ | 2/3 | 66.6 | 0.23 LLJ+ | 0.4332 |
| | LLJ | 3/5 | 60.0 | | |
| OAM | ULJ | 5/5 | 100.0 | 3.66 ULJ+ | 0.4584 |
| | LLJ | 4/5 | 80.0 | | |

**Table 29 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within aged-sex cohorts from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| YAF | ULJ | 1/1 | 100 | 0/1 | 0 | 0/1 | 0 | 1 |
| | LLJ | 0/0 | 0 | 0/0 | 0 | 0/0 | 0 | |
| YAM | ULJ | 1/1 | 100 | 0/1 | 0 | 0/1 | 0 | 1 |
| | LLJ | 1/1 | 100 | 0/1 | 0 | 0/1 | 0 | |
| MAF | ULJ | 2/2 | 100 | 0/2 | 0 | 0/2 | 0 | 1 |
| | LLJ | 2/2 | 100 | 0/2 | 0 | 0/2 | 0 | |
| MAM | ULJ | 3/3 | 100 | 0/3 | 0 | 0/3 | 0 | 1 |
| | LLJ | 3/3 | 100 | 0/3 | 0 | 0/3 | 0 | |
| OAF | ULJ | 2/2 | 100 | 0/2 | 0 | 0/2 | 0 | 1 |
| | LLJ | 3/3 | 100 | 0/3 | 0 | 0/3 | 0 | |
| OAM | ULJ | 2/5 | 40 | 2/5 | 40 | 1/5 | 20 | 0.1666 |
| | LLJ | 4/4 | 100 | 0/4 | 0 | 0/4 | 0 | |

## Prevalence comparisons for upper limb joints and lower limb joints

### *Between age cohorts*

There are no significant differences in the prevalence of osteoarthritis in either the upper limb joints or the lower limb joints between the three age cohorts. Interestingly, according to the results in upper limb joint, the prevalence is the highest in young adults and lowest in middle-aged adults. In lower limb joints, the prevalence increases with age, but not at the level of significance (Table 29). While moderate and pronounced forms of osteoarthritis are only evident among old adult individuals and only in the upper limb joints, statistical analyses show that the severity of this condition did not correlate with age (Table 30). Crude prevalence data for the presence of osteoarthritis mirror similar patterns between age cohorts (Figure C12). Furthermore, crude prevalence by severity of osteoarthritis also mirrors relatively small differences in severity of osteoarthritis between age cohorts (Figure D12).

**Table 30 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between age cohorts from the Crypt.**

| Cohort | ULJ % | ÔR | p-value | LLJ % | ÔR | p-value |
|---|---|---|---|---|---|---|
| YA | 100.0 | 1.36 YA+ | 0.8634 | 50.0 | 0.20 MAA+ | 0.3683 |
| MAA | 81.8 | | | 83.3 | | |
| YA | 100.0 | 1 Equal | 1 | 50.0 | 0.14 OA+ | 0.2724 |
| OA | 87.5 | | | 87.5 | | |
| MAA | 81.8 | 0.71 OA+ | 0.826 | 83.3 | 0.71 OA+ | 0.8260 |
| OA | 87.5 | | | 87.5 | | |

**Table 31 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between age cohorts from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| YA | ULJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0.0 | 1 |
| MAA | ULJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | |
| YA | ULJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0.0 | 1 |
| OA | ULJ | 4/7 | 57.1 | 2/7 | 28.5 | 1/7 | 14.2 | |
| MAA | ULJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | 0.4696 |
| OA | ULJ | 4/7 | 57.1 | 2/7 | 28.5 | 1/7 | 14.2 | |
| YA | LLJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0.0 | 1 |
| MAA | LLJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | |
| YA | LLJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0.0 | 1 |
| OA | LLJ | 7/7 | 100.0 | 0/7 | 0.0 | 0/7 | 0.0 | |
| MAA | LLJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | 1 |
| OA | LLJ | 7/7 | 100.0 | 0/7 | 0.0 | 0/7 | 0.0 | |

### *Between sex cohorts*

The prevalence of osteoarthritis did not significantly differ in either the upper or the lower limb joints between females and males overall. However, in both the upper and the lower limb joints the prevalence of this condition is higher among males (Table 31). While moderate and pronounced forms of osteoarthritis are only evident in the upper limb joints of males, the severity of osteoarthritis does not correlate with sex (Table 32). These similar patterns of osteoarthritis presence and by severity between females and males are also reflected in crude prevalence rates (Figures C13 and D13). Figure 13 shows the prevalence of osteoarthritis by individual joints of females and males, but the rates of prevalence between these cohorts do not significantly differ for any of these joints (Table 34).

**Table 32 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between sex cohorts from the Crypt.**

| Cohort | ULJ % | ÔR | p-value | LLJ J% | ÔR | p-value |
|---|---|---|---|---|---|---|
| F | 71.4 | 0.11 M+ | 0.1884 | 71.4 | 0.31 M+ | 0.3892 |
| M | 100 | | | 88.8 | | |

**Table 33 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between sex cohorts from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| F | ULJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | 0.6703 |
| M | ULJ | 6/9 | 66.6 | 2/9 | 22.2 | 1/9 | 11.1 | |
| F | LLJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | 1 |
| M | LLJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0.0 | |

**Table 34 Odds ratio results, osteoarthritis prevalence comparisons by individual joints between sex cohorts from the Crypt.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| F | Shoulder | 5/6 | 83.3 | 0.21 M+ | 0.3731 |
| M | Shoulder | 8/8 | 100 | | |
| F | Elbow | 6/7 | 85.7 | 0.25 M+ | 0.4252 |
| M | Elbow | 8/8 | 100 | | |
| F | Wrist | 4/4 | 100 | 2.07 F+ | 0.6752 |
| M | Wrist | 6/7 | 85.7 | | |
| F | Hip | 7/7 | 100 | 5.76 F+ | 0.2850 |
| M | Hip | 6/8 | 75 | | |
| F | Knee | 5/7 | 71.4 | 0.11 M+ | 0.1884 |
| M | Knee | 9/9 | 100 | | |
| F | Ankle | 5/7 | 71.4 | 0.11 M+ | 0.1884 |
| M | Ankle | 9/9 | 100 | | |

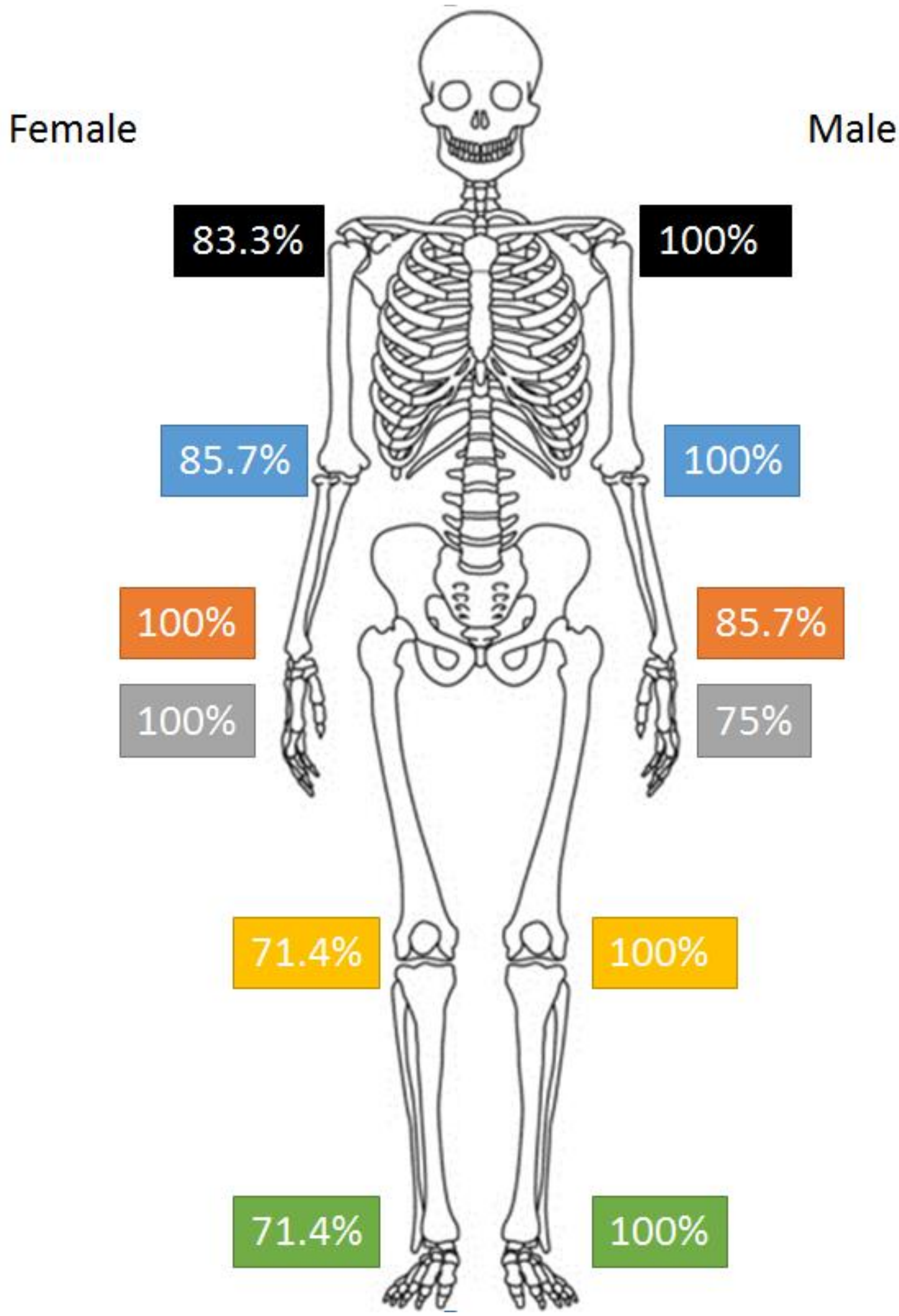


**Figure 13 Osteoarthritis prevalence comparisons by individual joints between sex cohorts from the Crypt (Color indicators: black shoulder, blue elbow, orange wrist, gray hip, yellow knee, and green ankle).**

### *Between aged-sex cohorts*

When the prevalence of osteoarthritis is compared between sex cohorts of the same age, these reveal that the differences between females and males were not significant in either the upper limb joints or the lower limb joints. However, the prevalence of osteoarthritis was higher in males within the middle-aged and old adult cohorts in upper limb joints and within the young adult and middle-aged adult cohorts in the lower limb joints (Table 33). In the upper limbs, mild osteoarthritis affects 100% of affected females. Although moderate and pronounced forms of osteoarthritis are only evident in the upper limb joints of old adult males, the severity of this condition did not correlate with the aged- sex cohorts (Table 34). Crude prevalence data for osteoarthritis presence and severity also show small differences between females and males within same age cohort (Figures C14 and D14).

**Table 35 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between aged-sex cohorts from the Crypt.**

| Cohort | ULJ% | ÔR | p-value | LLJ% | ÔR | p-value |
|---|---|---|---|---|---|---|
| YAF | 100.0 | 1 Equal | 1 | 50.0 | 0.11 YAM+ | 0.3414 |
| YAM | 100.0 | | | 83.3 | | |
| MAF | 66.6 | 0.23 MAM+ | 0.4332 | 50.0 | 0.23 MAM+ | 0.4332 |
| MAM | 100.0 | | | 87.5 | | |
| OAF | 66.6 | 0.15 OAM+ | 0.2951 | 83.3 | 2.33 OAF+ | 0.6344 |
| OAM | 100.0 | | | 87.5 | | |

**Table 36 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between aged-sex cohorts from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| YAF | ULJ | 1/1 | 100 | 0/1 | 0 | 0/1 | 0 | 1 |
| YAM | ULJ | 1/1 | 100 | 0/1 | 0 | 0/1 | 0 | |
| YAF | LLJ | 0/0 | 0 | 0/0 | 0 | 0/0 | 0 | 1 |
| YAM | LLJ | 1/1 | 100 | 0/1 | 0 | 0/1 | 0 | |
| MAF | ULJ | 2/2 | 100 | 0/2 | 0 | 0/2 | 0 | 1 |
| MAM | ULJ | 3/3 | 100 | 0/3 | 0 | 0/3 | 0 | |
| MAF | LLJ | 2/2 | 100 | 0/2 | 0 | 0/2 | 0 | 1 |
| MAM | LLJ | 3/3 | 100 | 0/3 | 0 | 0/3 | 0 | |
| OAF | ULJ | 2/2 | 100 | 0/2 | 0 | 0/2 | 0 | 0.6190 |
| OAM | ULJ | 2/5 | 40 | 2/5 | 40 | 1/5 | 20 | |
| OAF | LLJ | 3/3 | 100 | 0/3 | 0 | 0/3 | 0 | 1 |
| OAM | LLJ | 4/4 | 100 | 0/4 | 0 | 0/4 | 0 | |

Osteoarthritis comparisons between Necropolis and Crypt samples

**Prevalence comparisons between upper and lower limb joints**

Overall, both the Necropolis and the Crypt individuals have a higher prevalence for the presence of osteoarthritis in the upper limb joints than the lower limb joints, but these are not significant in both groups (Table 35). Furthermore, for either group, the prevalence of osteoarthritis by severity does not correlate with the location of this condition (Table 36). Similar patterns of osteoarthritis between upper and lower limb joints among both the Necropolis and Crypt skeletons are also reflected in crude prevalence rates for the presence of osteoarthritis and by its severity (Figures C15 and D15).

**Table 37 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints among all Necropolis and all Crypt adults.**

| Sample | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| N | ULJ | 39/60 | 65.0 | 1.15<br>ULJ+ | 0.7049 |
| | LLJ | 37/60 | 61.6 | | |
| C | ULJ | 14/16 | 87.5 | 1.61<br>ULJ+ | 0.6284 |
| | LLJ | 13/16 | 81.2 | | |

**Table 38 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints among all Necropolis and all Crypt adults.**

| Sample | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| N | ULJ | 38/39 | 97.4 | 1/39 | 2.56 | 0/39 | 0.00 | 1 |
| | LLJ | 36/37 | 97.2 | 1/37 | 2.7 | 0/37 | 0.00 | |
| C | ULJ | 11/14 | 78.5 | 2/14 | 14.2 | 1/14 | 7.14 | 0.2222 |
| | LLJ | 13/13 | 100.0 | 0/13 | 0.0 | 0/13 | 0.00 | |

### *Within same age cohorts*

An examination of crude prevalence of osteoarthritis suggests varied patterns in this condition between the same age cohorts from the two burial locations. While young adults from the Necropolis have a higher prevalence of osteoarthritis in the lower limb joints than the upper limbs, the opposite is true for their Crypt counterparts. While the middle-aged adults from the Necropolis have a higher prevalence of this condition in the upper limbs, their Crypt counterparts are equally affected by osteoarthritis in the upper and lower limbs. Finally, while the old adults from the Necropolis have a higher prevalence of osteoarthritis in the lower limbs, the old adults from the Crypt are equally affected by this condition in the upper and lower limbs. However, the prevalence of osteoarthritis between the upper limb joints and the lower limbs joints did not significantly differ in any age cohorts from either the Necropolis or the Crypt (Table 37). Furthermore, an examination of the osteoarthritis prevalence by severity shows that for any of the three age cohorts from either burial location, the severity of this condition did not correlate with its location (Table 38). Crude prevalence rates mirror similar patterns of osteoarthritis between the same age cohorts from the Necropolis and the Crypt (Figure C16). Crude prevalence rates by severity of osteoarthritis also mirror small difference between the upper and lower limb joints among both the Necropolis and Crypt groups (Figure D16).

**Table 39 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within age cohorts from the Necropolis and from the Crypt.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| NYA | ULJ | 6/19 | 31.5 | 0.79 LLJ+ | 0.7326 |
| | LLJ | 7/19 | 36.8 | | |
| CYA | ULJ | 2/2 | 100.0 | 5.00 ULJ+ | 0.4049 |
| | LLJ | 1/2 | 50.0 | | |
| NMA | ULJ | 18/22 | 81.8 | 3.11 ULJ+ | 0.1058 |
| | LLJ | 13/22 | 59.0 | | |
| CMA | ULJ | 5/6 | 83.3 | 1.00 Equal | 1 |
| | LLJ | 5/6 | 83.3 | | |
| NOA | ULJ | 15/19 | 78.9 | 0.44 LLJ+ | 0.3818 |
| | LLJ | 17/19 | 89.4 | | |
| COA | ULJ | 7/8 | 87.5 | 1.00 Equal | 1 |
| | LLJ | 7/8 | 87.5 | | |

**Table 40 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within age cohorts from the Necropolis and from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| NYA | ULJ | 6/6 | 100.0 | 0/6 | 0.00 | 0/6 | 0.0 | 1 |
| | LLJ | 7/7 | 100.0 | 0/7 | 0.00 | 0/7 | 0.0 | |
| CYA | ULJ | 2/2 | 100.0 | 0/2 | 0.00 | 0/2 | 0.0 | 1 |
| | LLJ | 1/1 | 100.0 | 0/1 | 0.00 | 0/1 | 0.0 | |
| NMA | ULJ | 18/18 | 100.0 | 0/18 | 0.00 | 0/18 | 0.0 | 1 |
| | LLJ | 13/13 | 100.0 | 0/13 | 0.00 | 0/13 | 0.0 | |
| CMA | ULJ | 5/5 | 100.0 | 0/5 | 0.00 | 0/5 | 0.0 | 1 |
| | LLJ | 5/5 | 100.0 | 0/5 | 0.00 | 0/5 | 0.0 | |
| NOA | ULJ | 14/15 | 93.3 | 1/15 | 6.66 | 0/15 | 0.0 | 1 |
| | LLJ | 16/17 | 94.1 | 1/17 | 5.88 | 0/17 | 0.0 | |
| COA | ULJ | 4/7 | 57.1 | 2/7 | 28.5 | 1/7 | 14.2 | 0.1923 |
| | LLJ | 7/7 | 100.0 | 0/7 | 0.00 | 0/7 | 0.0 | |

### *Within same sex cohorts*

Further examination of the prevalence of osteoarthritis suggests that while the Necropolis females have a higher prevalence of osteoarthritis in the upper limb joints than the lower limb joints, their Crypt counterparts are equally affected by this condition in the both joints' locations. Both males from the Necropolis and the Crypt have a higher prevalence of osteoarthritis in the upper limb joints than the lower limb joints. However, statistical analyses show that there were no significant differences in the prevalence of this condition between the upper and the lower limb joints among females and males from both burial locations (Table 39). Moreover, for any of the sex cohorts from either burial location, the severity of osteoarthritis did not correlate with its location (Table 40). Crude prevalence rates mirror similar patterns of osteoarthritis between same sex cohorts from the Necropolis and Crypt (Figure C17). Crude prevalence rates by severity of osteoarthritis also mirror small difference between upper and lower limb joints among both the Necropolis and Crypt sex cohorts (Figure D17).

**Table 41 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within sex cohorts from the Necropolis and from the Crypt.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| NF | ULJ | 19/30 | 63.3 | 1.15 ULJ+ | 0.7907 |
| | LLJ | 18/30 | 60.0 | | |
| CF | ULJ | 5/7 | 71.4 | 1.00 Equal | 1 |
| | LLJ | 5/7 | 71.4 | | |
| NM | ULJ | 20/30 | 66.6 | 1.15 ULJ+ | 0.7867 |
| | LLJ | 19/30 | 63.3 | | |
| CM | ULJ | 9/9 | 100.0 | 3.35 ULJ+ | 0.4766 |
| | LLJ | 8/9 | 88.8 | | |

**Table 42 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within sex cohorts from the Necropolis and from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| NF | ULJ | 18/19 | 94.7 | 1/19 | 5.26 | 0/19 | 0.0 | 1 |
| | LLJ | 18/18 | 100.0 | 0/18 | 0.00 | 0/18 | 0.0 | |
| CF | ULJ | 5/5 | 100.0 | 0/5 | 0.00 | 0/5 | 0.0 | 1 |
| | LLJ | 5/5 | 100.0 | 0/5 | 0.00 | 0/5 | 0.0 | |
| NM | ULJ | 20/20 | 100.0 | 0/20 | 0.00 | 0/20 | 0.0 | 0.4870 |
| | LLJ | 18/19 | 94.7 | 1/19 | 5.26 | 0/19 | 0.0 | |
| CM | ULJ | 6/9 | 66.6 | 2/9 | 22.2 | 1/9 | 11.1 | 0.3294 |
| | LLJ | 8/8 | 100.0 | 0/8 | 0.00 | 0/8 | 0.0 | |

### *Within same age and same sex cohorts*

The examination of the prevalence of osteoarthritis suggests that the osteoarthritis patterns varied among some same age and same sex cohorts from two burial locations (e.g. young adult females and males, middle-aged females and males, and old adult males). Still, the osteoarthritis prevalence between the upper and the lower limb joints did not significantly differ among any aged-sex cohorts from either burial location (Table 41). Also, for none of these cohorts the severity of this condition did not correlate with its location (Table 42). Crude prevalence rates for the presence of osteoarthritis and by severity also show that patterns of osteoarthritis were similar between upper and lower limb joints among all aged-sex cohorts from both the Necropolis and the Crypt (Figures C18and D18).

**Table 43 Odds ratio results, osteoarthritis prevalence comparisons between upper limb joints and lower limb joints within aged-sex cohorts from the Necropolis and from the Crypt.**

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| NYAF | ULJ | 3/10 | 30.0 | 0.64 LLJ+ | 0.6401 |
| | LLJ | 4/10 | 40.0 | | |
| CYAF | ULJ | 1/1 | 100.0 | 9.00 ULJ+ | 0.3414 |
| | LLJ | 0/1 | 0.0 | | |
| NYAM | ULJ | 3/9 | 33.3 | 1.07 ULJ+ | 0.9304 |
| | LLJ | 3/9 | 33.3 | | |
| CYAM | ULJ | 1/1 | 100.0 | 1.00 Equal | 1 |
| | LLJ | 1/1 | 100.0 | | |
| NMAF | ULJ | 9/10 | 90.0 | 6.00 ULJ+ | 0.1472 |
| | LLJ | 6/10 | 60.0 | | |
| CMAF | ULJ | 2/3 | 66.6 | 1.00 Equal | 1 |
| | LLJ | 2/3 | 66.6 | | |
| NMAM | ULJ | 9/12 | 75.0 | 2.14 ULJ+ | 0.3904 |
| | LLJ | 7/12 | 58.3 | | |

| Cohort | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| CMAM | ULJ | 3/3 | 100.0 | 1.00 Equal | 1 |
| | LLJ | 3/3 | 100.0 | | |
| NOAF | ULJ | 7/10 | 70.0 | 0.58 LLJ+ | 0.6075 |
| | LLJ | 8/10 | 80.0 | | |
| COAF | ULJ | 2/3 | 66.6 | 0.23 LLJ+ | 0.4332 |
| | LLJ | 3/5 | 60.0 | | |
| NOAM | ULJ | 8/9 | 88.8 | 0.29 LLJ+ | 0.4766 |
| | LLJ | 9/9 | 100.0 | | |
| COAM | ULJ | 5/5 | 100.0 | 3.66 ULJ+ | 0.4584 |
| | LLJ | 4/5 | 80.0 | | |

**Table 44 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity between upper limb joints and lower limb joints within aged-sex cohorts from the Necropolis and from the Crypt.**

| Cohort | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| NYAF | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | 1 |
| | LLJ | 4/4 | 100.0 | 0/4 | 0.0 | 0/4 | 0 | |
| CYAF | ULJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0 | 1 |
| | LLJ | 0/0 | 0.0 | 0/0 | 0.0 | 0/0 | 0 | |
| NYAM | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | 1 |
| | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | |
| CYAM | ULJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0 | 1 |
| | LLJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0 | |
| NMAF | ULJ | 9/9 | 100.0 | 0/9 | 0.0 | 0/9 | 0 | 1 |
| | LLJ | 6/6 | 100.0 | 0/6 | 0.0 | 0/6 | 0 | |
| CMAF | ULJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0 | 1 |
| | LLJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0 | |
| NMAM | ULJ | 9/9 | 100.0 | 0/9 | 0.0 | 0/9 | 0 | 1 |
| | LLJ | 7/7 | 100.0 | 0/7 | 0.0 | 0/7 | 0 | |
| CMAM | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | 1 |
| | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | |
| NOAF | ULJ | 6/7 | 85.7 | 1/7 | 14.2 | 0/7 | 0 | 1 |
| | LLJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0 | |
| COAF | ULJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0 | 1 |
| | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0 | |
| NOAM | ULJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0 | 1 |
| | LLJ | 8/9 | 88.8 | 1/9 | 11.1 | 0/9 | 0 | |
| COAM | ULJ | 2/5 | 40.0 | 2/5 | 40.0 | 1/5 | 20 | 0.1666 |
| | LLJ | 4/4 | 100.0 | 0/4 | 0.0 | 0/4 | 0 | |

### Prevalence comparisons for upper limb joints and lower limb joints

There were no significant differences in the prevalence of osteoarthritis in either the upper limb joints or the lower limb joints between the Necropolis and Crypt individuals overall, but the Crypt individuals have a higher prevalence of osteoarthritis in both the upper and the lower limbs (Table 43). Examination of the results by severity of osteoarthritis suggests that the pronounced forms of osteoarthritis were only found in the upper limb joints of the Crypt individuals, but that the severity of osteoarthritis for these joints did not correlate with the individuals' location of the burial (Table 44). Similar osteoarthritis effects between the Necropolis and Crypt individuals are also reflected in crude prevalence rates for osteoarthritis presence and severity (Figures C19 and D19). Figure 14 shows prevalence of osteoarthritis for individual joints of these groups, but the prevalence rates of this condition do not significantly differ for any of these joints between the Necropolis and Crypt skeletons (Table 47).

**Table 45 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between Necropolis and Crypt individuals overall.**

| Sample | ULJ % | ÔR | p-value | LLJ % | ÔR | p-value |
|---|---|---|---|---|---|---|
| N | 65 | 0.26 C+ | 0.0984 | 61.5 | 0.22 C+ | *0.0665* |
| C | 87.5 | | | 81.2 | | |

**Table 46 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between Necropolis and Crypt individuals overall.**

| Sample | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| N | ULJ | 38/39 | 97.4 | 1/39 | 2.56 | 0/39 | 0.00 | *0.0510* |
| C | ULJ | 11/14 | 78.5 | 2/14 | 14.2 | 1/14 | 7.14 | |
| N | LLJ | 36/37 | 97.2 | 1/37 | 2.7 | 0/37 | 0.00 | 1 |
| C | LLJ | 13/13 | 100.0 | 0/13 | 0.0 | 0/13 | 0.00 | |

**Table 47 Odds ratio results, osteoarthritis prevalence comparisons by individual joints between Necropolis and Crypt individuals overall.**

| Sample | Joints | n/N | % | ÔR | p-value |
|---|---|---|---|---|---|
| N | Shoulder | 45/60 | 75 | 0.23 C+ | 0.1744 |
| C | Shoulder | 13/14 | 92.8 | | |
| N | Elbow | 50/59 | 84.7 | 0.39 C+ | 0.3993 |
| C | Elbow | 14/15 | 93.3 | | |
| N | Wrist | 43/56 | 76.7 | 0.33C+ | 0.3126 |
| C | Wrist | 10/11 | 90.9 | | |
| N | Hip | 44/58 | 75.8 | 0.48 C+ | 0.3750 |
| C | Hip | 13/15 | 86.6 | | |
| N | Knee | 47/60 | 78.3 | 0.51 C+ | 0.4194 |
| C | Knee | 14/16 | 87.5 | | |
| N | Ankle | 42/60 | 70 | 0.33 C+ | 0.1733 |
| C | Ankle | 14/16 | 87.5 | | |

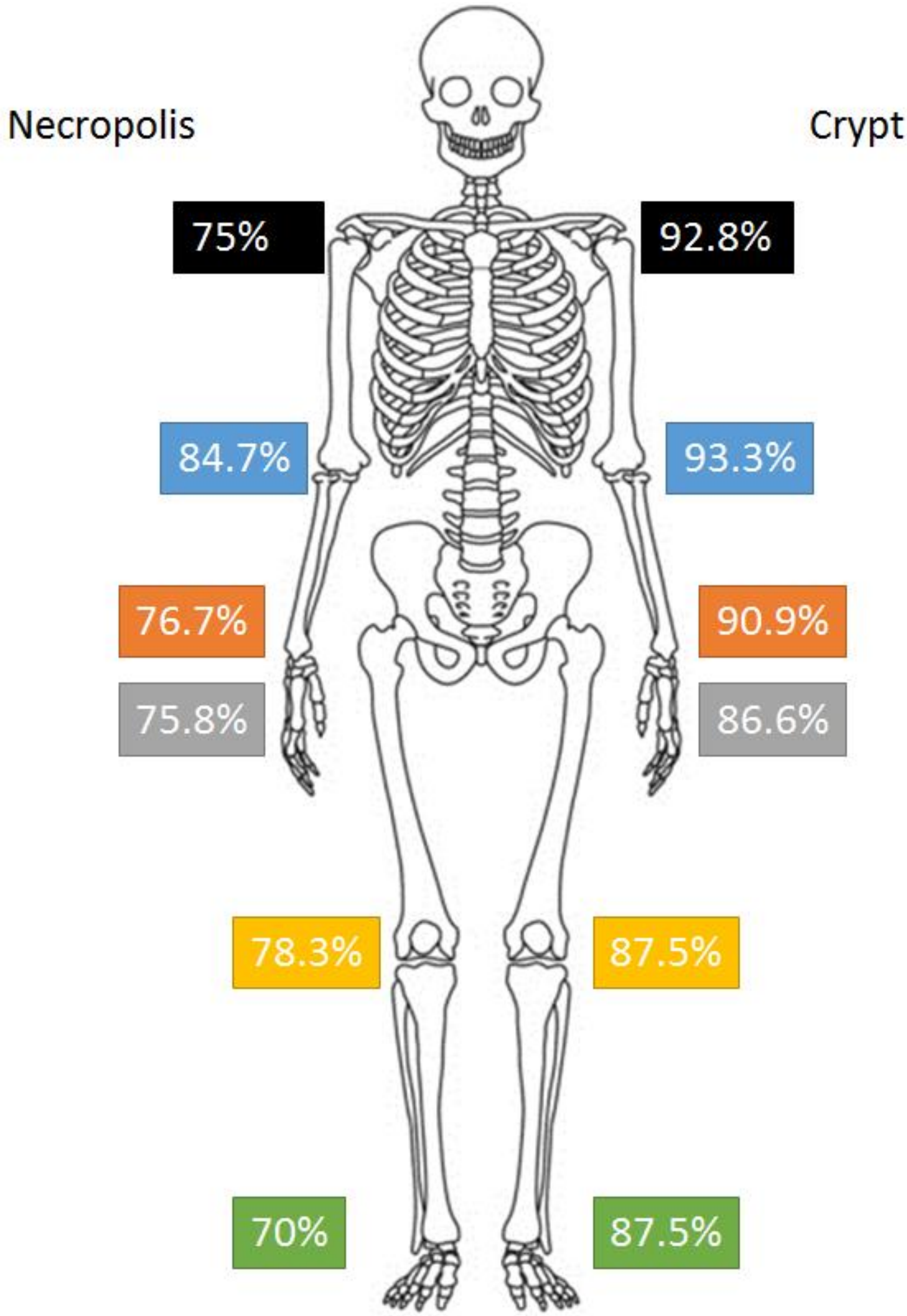


**Figure 14 Osteoarthritis prevalence comparisons by individual joints between Necropolis and Crypt individuals overall (Color indicators: black shoulder, blue elbow, orange wrist, gray hip, yellow knee, and green ankle).**

### *Between same age cohorts*

The prevalence of osteoarthritis did not significantly differ between individuals within same age cohorts from the Necropolis and the Crypt in either the upper limb joints or the lower limb joints. However, the Crypt individuals have a higher prevalence in both the upper and the lower limb joints than their Necropolis counterparts except in the lower limb joints among old adults (Table 45). While in the upper limb joints old adults from the Crypt have a higher prevalence of moderate and pronounced osteoarthritis than their Necropolis counterparts, statistical analyses show that the individuals' location of the burial did not correlate with the severity of this condition among old adults (Table 46). Similar osteoarthritis effects between the same age cohorts from the Necropolis and Crypt are also reflected in crude prevalence rates for osteoarthritis presence and severity (Figures C20 and D20).

**Table 48 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between same age cohorts from the Necropolis and Crypt.**

| Sample | ULJ % | ÔR | p-value | LLJ % | ÔR | p-value |
|---|---|---|---|---|---|---|
| NYA | 31.5 | 0.09 CYA+ | 0.1488 | 36.8 | 0.58 CYA+ | 0.7179 |
| CYA | 100.0 | | | 50.0 | | |
| NMA | 81.8 | 0.90 CMAA+ | 0.9316 | 59.0 | 0.28 CMAA+ | 0.2919 |
| CMA | 83.3 | | | 83.3 | | |
| NOA | 78.9 | 0.53 COA+ | 0.6054 | 89.4 | 1.21 NOA+ | 0.8817 |
| COA | 87.5 | | | 87.5 | | |

**Table 49 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between same age cohorts from the Necropolis and Crypt.**

| Sample | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| NYA | ULJ | 6/6 | 100 | 0/6 | 0.0 | 0/6 | 0.0 | 1 |
| CYA | ULJ | 2/2 | 100 | 0/2 | 0.0 | 0/2 | 0.0 | |
| NYA | LLJ | 7/7 | 100 | 0/7 | 0.0 | 0/7 | 0.0 | 1 |
| CYA | LLJ | 1/1 | 100 | 0/1 | 0.0 | 0/1 | 0.0 | |
| NMA | ULJ | 18/18 | 100 | 0/18 | 0.0 | 0/18 | 0.0 | 1 |
| CMA | ULJ | 5/5 | 100 | 0/5 | 0.0 | 0/5 | 0.0 | |
| NMA | LLJ | 13/13 | 100 | 0/13 | 0.0 | 0/13 | 0.0 | 1 |
| CMA | LLJ | 5/5 | 100 | 0/5 | 0.0 | 0/5 | 0.0 | |
| NOA | ULJ | 14/15 | 93.3 | 1/15 | 6.7 | 0/15 | 0.0 | *0.0765* |
| COA | ULJ | 4/7 | 57.1 | 2/7 | 28.5 | 1/7 | 14.2 | |
| NOA | LLJ | 16/17 | 94.1 | 1/17 | 5.9 | 0/17 | 0.0 | 1 |
| COA | LLJ | 7/7 | 100 | 0/7 | 0.0 | 0/7 | 0.0 | |

### *Between same sex cohorts*

Both females and males from the Crypt have a higher prevalence of osteoarthritis in both the upper and the lower limb joints than their Necropolis counterparts, but statistical analyses show that these differences are not significant (Table 47). While the Necropolis females also have moderate osteoarthritis, statistical analyses show that the severity of this condition among these individuals does not correlate with their burial location. However, statistical analyses show that the severity of osteoarthritis in the upper limb joints between males correlates with the location of their burial. In fact, besides mild osteoarthritis, only the Crypt males have moderate and pronounced forms of this condition in these joints (Table 48). Similar osteoarthritis effects between same sex cohorts from the Necropolis and Crypt are reflected in crude prevalence rates for the presence of osteoarthritis (Figure C21). Also crude prevalence rates by severity of osteoarthritis in upper limb joints between the Necropolis and Crypt males reflect differences between these individuals (Figure D21).

**Table 50 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between same sex cohorts from the Necropolis and Crypt.**

| Sample | ULJ % | ÔR | p-value | LLJ % | ÔR | p-value |
|---|---|---|---|---|---|---|
| NF | 63.3 | 0.69 CF+ | 0.6873 | 60.0 | 0.60 CF+ | 0.5770 |
| CF | 71.4 | | | 71.4 | | |
| NM | 66.6 | 0.10 CM+ | 0.1292 | 63.3 | 0.21 CM+ | 0.1735 |
| CM | 100 | | | 88.8 | | |

**Table 51 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between same sex cohorts from the Necropolis and Crypt.**

| Sample | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| NF | ULJ | 18/19 | 94.7 | 1/19 | 5.3 | 0/19 | 0.0 | 1 |
| CF | ULJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | |
| NF | LLJ | 18/18 | 100.0 | 0/18 | 0.0 | 0/18 | 0.0 | 1 |
| CF | LLJ | 5/5 | 100.0 | 0/5 | 0.0 | 0/5 | 0.0 | |
| NM | ULJ | 20/20 | 100.0 | 0/19 | 0.0 | 0/19 | 0.0 | *0.0229* |
| CM | ULJ | 6/9 | 66.6 | 2/9 | 22.2 | 1/9 | 11.1 | |
| NM | LLJ | 18/19 | 94.7 | 1/19 | 5.3 | 0/19 | 0.0 | 1 |
| CM | LLJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0.0 | |

### *Between same age and same sex cohorts*

The prevalence of osteoarthritis did not significantly differ between the Necropolis and Crypt same age cohorts in either the upper or the lower limb joints (Table 49). However, statistical analyses show that among the old adult males from the Necropolis and Crypt the severity of osteoarthritis in the upper limb joints correlates with their burial location. In fact, while the Necropolis old adult males only have the mild forms of osteoarthritis in the upper limb joints, 40% of the Crypt old adult males have moderate osteoarthritis and 20% have pronounced osteoarthritis in these joints (Table 50). Again, similar osteoarthritis effects between same aged-sex cohorts from the Necropolis and Crypt are reflected in crude prevalence rates for the presence of osteoarthritis (Figures C22, C23 and C24). Also crude prevalence rates by severity of osteoarthritis in upper limb joints between the Necropolis and Crypt old adult males reflect differences between these individuals (Figures D22, D23and D24).

**Table 52 Odds ratio results, osteoarthritis prevalence comparisons in upper limb joints and lower limb joints between same aged-sex cohorts from the Necropolis and Crypt.**

| Sample | ULJ % | ÔR | p-value | LLJ % | ÔR | p-value |
|---|---|---|---|---|---|---|
| NYAF | 30.0 | 0.15 CYAF+ | 0.2895 | 40.0 | 2.07 NYAF+ | 0.6752 |
| CYAF | 100.0 | | | 0.0 | | |
| NMAF | 90.0 | 4.50 NMAF+ | 0.3520 | 60.0 | 0.75 CMAF+ | 0.8354 |
| CMAF | 66.6 | | | 66.6 | | |
| NOAF | 70.0 | 1.16 NOAF+ | 0.9127 | 80.0 | 0.48 COAF+ | 0.6663 |
| COAF | 66.6 | | | 100.0 | | |
| NYAM | 33.3 | 0.17 CYAM+ | 0.3298 | 33.6 | 0.17 CYAM+ | 0.3298 |
| CYAM | 100.0 | | | 100.0 | | |
| NMAM | 75.0 | 0.38 CMAM+ | 0.5625 | 58.3 | 0.19 CMAM+ | 0.3104 |
| CMAM | 100.0 | | | 100.0 | | |
| NOAM | 88.8 | 0.51 COAM+ | 0.7001 | 100.0 | 0.15 COAM+ | 0.2861 |
| COAM | 100.0 | | | 80.0 | | |

**Table 53 Freeman-Holton extension of Fisher Exact test results, osteoarthritis prevalence comparisons by severity in upper limb joints and in lower limb joints between same aged-sex cohorts from the Necropolis and Crypt.**

| Sample | Joints | MOA n/N | MOA % | MDOA n/N | MDOA % | POA n/N | POA % | p-value |
|---|---|---|---|---|---|---|---|---|
| NYAF | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0.0 | 1 |
| CYAF | ULJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0.0 | |
| NYAF | LLJ | 4/4 | 100.0 | 0/4 | 0.0 | 0/4 | 0.0 | 1 |
| CYAF | LLJ | 0/0 | 0.0 | 0/0 | 0.0 | 0/0 | 0.0 | |
| NMAF | ULJ | 9/9 | 100.0 | 0/9 | 0.0 | 0/9 | 0.0 | 1 |
| CMAF | ULJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0.0 | |
| NMAF | LLJ | 6/6 | 100.0 | 0/6 | 0.0 | 0/6 | 0.0 | 1 |
| CMAF | LLJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0.0 | |
| NOAF | ULJ | 6/7 | 85.7 | 1/7 | 14.2 | 0/7 | 0.0 | 1 |
| COAF | ULJ | 2/2 | 100.0 | 0/2 | 0.0 | 0/2 | 0.0 | |
| NOAF | LLJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0.0 | 1 |
| COAF | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0.0 | |
| NYAM | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0.0 | 1 |
| CYAM | ULJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0.0 | |
| NYAM | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0.0 | 1 |
| CYAM | LLJ | 1/1 | 100.0 | 0/1 | 0.0 | 0/1 | 0.0 | |
| NMAM | ULJ | 9/9 | 100.0 | 0/9 | 0.0 | 0/9 | 0.0 | 1 |
| CMAM | ULJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0.0 | |
| NMAM | LLJ | 7/7 | 100.0 | 0/7 | 0.0 | 0/7 | 0.0 | 1 |
| CMAM | LLJ | 3/3 | 100.0 | 0/3 | 0.0 | 0/3 | 0.0 | |
| NOAM | ULJ | 8/8 | 100.0 | 0/8 | 0.0 | 0/8 | 0.0 | *0.0349* |
| COAM | ULJ | 2/5 | 40.0 | 2/5 | 40.0 | 1/5 | 20.0 | |
| NOAM | LLJ | 8/9 | 88.8 | 1/9 | 11.1 | 0/9 | 0.0 | 1 |
| COAM | LLJ | 4/4 | 100.0 | 0/4 | 0.0 | 0/4 | 0.0 | |

## Summary

This chapter presented results for sex and age cohorts of examined individuals from Mistihalj. Also, this chapter presented osteoarthritis comparisons between upper and lower limb joints within cohorts from both burial contexts. Furthermore, osteoarthritis prevalence comparisons in upper and lower limb joints between age and sex cohorts for both burial contexts and between the same age and sex cohorts from two burial contexts were examined.

# CHAPTER 5: DISCUSSION

This chapter will discuss the results of this study in order to demonstrate how they answer this study's research questions. Specifically, similarities and differences in osteoarthritis prevalence rates and severity among and between examined individuals are discussed in order to infer whether the Mistihalj population used differentially the upper and the lower limb joints, whether the division of labor existed by age or sex, and whether the lifestyles differed for the people of Mistihalj from the two time periods. Since a variety of local and systemic factors can play a role in the prevalence and location of osteoarthritis, including by severity, these factors are also discussed in this chapter. Furthermore, this discussion also explores the ethnographic and historical correlates about the activities and subsistence strategies of both the Late Medieval populations and the 19th century populations in Trebinje with the goal of better understanding the possible effects of lifestyles on the etiology of osteoarthritis among these individuals.

As suggested by other researchers, the interpretation of osteoarthritis prevalence rates among past populations continues to be a difficult task due not only to the multifactorial etiology of this condition, but also the lack of comparative material due to different diagnostic methods for osteoarthritis data collection and analyses between bioarchaeological studies (e.g., Palmer et al. 2016), and between these studies and clinical and epidemiological studies (e.g., Corti and Rigon, 2003). However, many researchers agree that general comparisons of osteoarthritis patterns between populations can offer insight about the effects of this condition (e.g., Bridges, 1991; Waldron, 1992) and potential roles different factors played in its etiology (Jurmain, 1980). This discussion follows these precedents.

## <u>Lifestyles of Late Medieval Necropolis Individuals</u>

### Activity Patterns

According to historical studies, the subsistence economy of free peasants in Trebinje region during the rule of Kingdom of Bosnia (A.D. 1377 – 1463), which the Necropolis individuals are inferred to be, was not defined by occupational specialization and clearly defined division of labor but rather focused on small- scale family agro-pastoralism where children and adults of both sexes were expected to participate as a labor force (Tošić, 1995a:78-81; 1995b). Thus, it was expected that the effects of osteoarthritis, if activity-related stresses and loading played a role in the development of this condition among these individuals, would be expressed in both the upper and the lower limb joints and among individuals of different adult age and sex cohorts.

As expected, the prevalence of osteoarthritis among the Necropolis individuals are fairly high as more than half of these individuals have this condition in both the upper limb joints and the lower limb joints. In fact, the osteoarthritis prevalence rates are much higher in both the upper and lower limb joints of these individuals when compared to osteoarthritis prevalence rates for the upper limb joints (shoulder, elbow, and wrist/hand) and the lower limb joints (hip, knee, ankle, foot) of other archaeological populations where composite scores for upper limb joints and lower limb joints were scored (e.g., Eng, 2016) (Table 51). Moreover, the prevalence of osteoarthritis among the Necropolis individuals are comparable to both the combined upper limb joints' and the combined lower limb joints' prevalence rates among the ancient Egyptian Amarna builders who are assumed to have participated in hard laboring (Kemp et al., 2013) (Table 51).

However, this comparison does not suggest that the Necropolis individuals participated in hard labor. As discussed above, since each of these studies uses different methods for data collection and analyses, the specific osteoarthritis prevalence rates cannot be directly compared between these groups. At the same time, almost all the Necropolis individuals with osteoarthritis have a mild form of this condition.

**Table 54 Osteoarthritis prevalence rates in upper and lower limb joints among Necropolis individuals compared with reported osteoarthritis prevalence rates in upper and lower limb joints of other archaeological populations.**

| Study | Time period | Region | Subsistence Economy | Age | Sex | Upper limb joints osteoarthritis prevalence | Lower limb joints osteoarthritis prevalence |
|---|---|---|---|---|---|---|---|
| Eng, 2016 | Bronze Age and Iron Age | China and Mongolia | Pastoralism | Young adults (20-35 years), Middle adults (35-50 years), Old adults (50+ years) | Females and males | 9.3% | 8.6% |
| Kemp et al., 2013 | c. 1349-1331 B.C. | Egypt | Urban workers | Skeletally mature adults | Females and males | 65.9% | 47.7% |
| Manoni, present study | AD 1377-1463 | Bosnia and Herzegovina | Agro-pastoralists | Young adults, middle-aged adults and old adults | Females and males | 65% | 61.6% |

Data analyses do not support the hypothesis that the Necropolis individuals overall and individuals of different ages and sexes had different functional impacts from osteoarthritis in their upper and lower body extremities. Interestingly, among modern day populations, osteoarthritis in the weight bearing joints of the lower limbs seems to be more common than osteoarthritis of the upper limb joints. For example, the incidence rates of osteoarthritis are higher in the knee and the hip, among both men and women, than osteoarthritis of the hand (Oliveria et al., 1995). A review of clinical studies shows that the prevalence of osteoarthritis in shoulder joints, even among the cadavers who died over the age of 60 years, is relatively low (Kerr et al, 1985), and that the incidence of elbow osteoarthritis is quite rare at about 2% (Stanley, 1994). Other studies show that when osteoarthritis does occur in the upper limb joints among modern day populations, it is most often due to micro trauma from specific activities involving heavy manual labor. For example, individuals with an increased risk of osteoarthritis in shoulder joints are those that perform activities involving heavy lifting using the upper limbs (Stenlund et al., 1992). Furthermore, individuals with an increased risk of osteoarthritis in the elbow and wrist joints among modern day populations are those that perform strenuous activities involving these joints, such as the use of vibrating power tools (Bovenzi et al., 1987; Mintz and Fraga, 1973). High osteoarthritis prevalence in the upper limb joints among the Necropolis skeletons overall and among both sexes within all three age cohorts is likely an indicator of upper limb joint stress due to activities performed by these individuals including during early adulthood.

An increase in the incidence rates of osteoarthritis in weight bearing joints of the lower extremities is also seen among individuals involved in certain occupations that require extensive use of the lower limb joints, including farming (Croft et al., 1992; Sandmark et al., 2000). If such activity-related stress played a role in the development of osteoarthritis among these Necropolis skeletons, then the lack of significant differences in the prevalence rates of this condition in the upper and the lower limb joints of these individuals might be a consequence of a similar extent of stress and loading imposed on these joints during these individuals' lifetimes. Historical sources describe Late Medieval Trebinje peasants, including children and young adults, involved in agricultural activities, such as fruit, grain, and vegetable farming (Tošić, 1995a:77-81), that would have involved carrying heavy loads and the extensive use of both the upper and lower limb joint systems during soil shoveling, grain thrashing, and fruit, grain, and vegetable collection. Moreover, among these peasants, both men and women are described as being involved in heavy lifting and the local transport of charcoal and stone (Tošić, 1995a:81).

Notably, despite the differences in the methods for data collection and their analyses, the patterning of osteoarthritis is similar between the Necropolis individuals and other past populations with similar subsistence regimes from the Late Medieval Balkans as there are no significant differences in osteoarthritis prevalence between the upper and lower limb joints among these samples. For example, findings from a study of a Late Medieval rural adult population in Croatia neighboring the Trebinje region also suggest similar a prevalence of osteoarthritis between any of the upper and lower limb joints examined (Novak, 2011). Also, osteoarthritis results from the Late Medieval and later periods rural adult population from Nova Rača, in present day Croatia, suggest that the differences in the prevalence of osteoarthritis between upper and lower limb joints were insignificant (Šlaus, 2000).

However, it is important to note that the similar prevalence of osteoarthritis in the upper and the lower limb joints of the Necropolis individuals might be due to a number of other factors that play a role in the development of osteoarthritis. Clinical studies show that the prevalence rates of osteoarthritis in both the upper and the lower limb joints increases among individuals of any age and gender that are obese (Blagojevic et al. 2010), have suffered previous joint trauma

(Franklin et al., 2010), have anatomical variances that affect the joint's alignment (Hunter et al., 2005) and that have a genetic predisposition to development of osteoarthritis (Kraus et al., 2007; Palotie et al., 1989). Elimination of obesity as a factor that could have played a role in the development of osteoarthritis among these late medieval individuals is difficult. Most bioarchaeological studies of osteoarthritis (e.g., Eng, 2016) assume that obesity would not have been prevalent among past populations in general due to their active lifestyles (Eaton et al., 1988). Furthermore, historical sources describe frequent and intermittent famines affecting the Trebinje population suring the time period in which these individuals would have lived, thus it is unlikely that individuals from this skeletal sample would have been regularly obese (Tošić, 1995a:82).

During the collection of data for this study, trauma and genetic abnormalities in either the upper or lower limb bones were not observed among any of the Necropolis individuals. However, individuals with long tibiae have been shown to have an increased prevalence of osteoarthritis in lower limb joints, particularly the knee joint (Hunter et al., 2005). Other studies show that Mistihalj female and male skeletons from the Necropolis have a significantly higher crural index than other Late Medieval European skeletons (Ruff, 2017: 402). It is possible that the high prevalence rates of osteoarthritis in the lower limb joints of these individuals might be due to their anatomical variance. High prevalence rates in the upper and the lower limb joints among Necropolis individuals might also indicate a relationship to other systemic factors, such as genetic predisposition, for the development of osteoarthritis. For example, it is argued that genetic inheritability for osteoarthritis is about 50%, although the percentages vary between joint locations that have been examined thus far (Spector and MacGregor, 2004). Furthermore, certain mitochondrial DNA haplogroups, specifically the H haplogroup, which is the most prevalent in Bosnian and Herzegovinian populations (Cvjetan et al., 2004), have a significantly higher decrease in cartilage integrity than other haplogroups examined, and the highest, although nonsignificant, prevalence rates of joints space narrowing, osteophytes and subchondral sclerosis in knee joints relative to other haplogroups examined (Soto-Hermida et al., 2014). However, the elimination of genetic factors that might have played a role in the development of osteoarthritis among the Necropolis individuals is beyond the scope of this study.

### Division of labor by age and sex

According to epidemiological studies, an age-related increase in the prevalence of osteoarthritis, including more severe forms, is expected, as age is a major non-genetic host factor that increases the risk of the development of osteoarthritis (Loeser, 2010; Murphy et al., 2008). This is primarily due to the fact that with age, cellular ability to respond to stress decreases in the superficial zones of cartilage where osteoarthritic changes are likely to begin (Loeser et al., 2012). Bioarchaeological studies also show an age-related increase in the prevalence of osteoarthritis among past populations (e.g., Jurmain, 1980) including Late Medieval Balkan populations (e.g., Šlaus 2000; 2002). Osteoarthritis results for the Necropolis sample support the results of these studies. In fact, among the Necropolis individuals, the prevalence of osteoarthritis in the upper limb joints is significantly higher among the middle-aged adults and old adults than young adults, and in the lower limb joints, the prevalence of osteoarthritis is significantly higher among old adults than both the middle-aged adults and the young adults. Furthermore, although age does not positively correlate with the severity of osteoarthritis among these individuals, in both the upper and lower limb joints only the old adults from the Necropolis have a more severe form of this condition, while all young adults and middle-aged adults affected have a mild form of osteoarthritis.

An epidemiological data review of osteoarthritis shows that in modern day populations, women, particularly after 55 years of age, tend to have higher prevalence rates of osteoarthritis and more severe forms of this condition in the knee, than men (Srikanth et al. 2005). However, most previous findings concerning archaeological populations, including agro-pastoralist groups, show that males from different age cohorts have a generally significantly higher prevalence of osteoarthritis than their female counterparts due to more physically demanding lifestyles (e.g., Eng, 2007; Klaus et al., 2009). Comparisons of osteoarthritis results for females and male individuals from the Necropolis show that, both overall and when examined within same age cohorts, females and males are similarly affected by osteoarthritis. Moreover, results of statistical analyses show that the severity of osteoarthritis did not positively correlate with either sex, or sexed age cohorts. These results agree with the results of other Late Medieval Balkan populations that show no significant differences in the prevalence of osteoarthritis between females and males (Šlaus, 2000; 2002).

Similarities in osteoarthritis rates between the sexes in this study might be due to different factors including the same, perhaps genetic, predisposition to the development of osteoarthritis or a similar extent of workload or activities performed by these individuals. As explained above, the examination of genetic factors that might have played a role in the development of this condition among these individuals is beyond the scope of this study, but a worthy factor that could be examined in future studies of this population. If mechanical stresses and loading played a significant role in the development of osteoarthritis among the Necropolis individuals, then these results might suggest a similar extent of involvement of males and females in the labor force or, perhaps, in the performance of similar activities by these individuals in the Late Medieval Trebinje region which would agree with historical accounts. In fact, historical studies suggest, as discussed earlier, that both men and women, including from a young age, would have been involved in similar farming activities, transport of charcoal and stone, and that the division of labor between sexes was loosely defined (Tošić, 1995b:37).

## Lifestyles of the Crypt Individuals

### Activity patterns

The results of this study show that the osteoarthritis prevalence in both the upper and the lower limb joints were higher among the Crypt individuals when compared to those of other archaeological populations where composite prevalence rates were examined (Eng, 2016; Kemp et al., 2013) (Table 51). However, most of the Crypt individuals with osteoarthritis demonstrate a mild form of this condition in both the upper and the lower limb joints. Moreover, the small sample size for Crypt might increase the chance of a false positive. Thus, it is difficult to ascertain whether differences in osteoarthritis rates between the Crypt skeletons and these other archaeological skeletal series reflect difference in risk factors for this condition between these individuals.

Osteoarthritis data examination for the Crypt sample overall shows that osteoarthritis prevalence rates between their upper and lower limb joints did not significantly differ. Additionally, there are no significant differences in the prevalence rates of osteoarthritis between the upper and lower limb joints among affected individuals within age, sex and aged-sex cohorts. The upper and lower limb joints among middle-aged and old adults from the Crypt are equally likely to be affected by osteoarthritis. Moreover, data examination by sex shows that osteoarthritis equally affects the upper and lower limb joints of young adult males and middle-aged females and males. Furthermore, for all of these individuals the severity of osteoarthritis did not positively correlate with its location. These patterns of osteoarthritis agree with the osteoarthritis patterns among Mistihalj's Necropolis individuals and among other archaeological Balkan populations (Novak, 2011; Šlaus, 2000). Thus, if activity- related stresses and loading played a role in the development of osteoarthritis among the Crypt individuals it is likely that the majority of them would have been engaged in activities that required the similar use of upper and lower body limbs.

Although the results of the statistical analyses in this study suggest that the location of osteoarthritis did not positively correlate with its severity, it is important to note that the moderate and pronounced forms of this condition are observed in the upper limb joints of older adults and not in the lower limb joints. A more detailed examination of osteoarthritis results by upper and lower limb joints within age groups of the Crypt skeletal sample shows a higher, but insignificant, likelihood that young adults will be affected by this condition in the upper limb joints than the lower. This is contrary to the majority of findings in the modern populations which show that osteoarthritis is most common in weight bearing joints of the lower limbs and among older individuals (Arden and Nevitt, 2006). However, the development of osteoarthritis in the upper limb joints of the modern day populations, as discussed previously, is rare and found to be most often a consequence of continuous mechanical stress and loading of these joints

(Bovenzi et al., 1987; Mintz and Fraga, 1973). Thus, the development of osteoarthritis in the upper limb joints of the Crypt individuals probably suggests a lifestyle, including from a young age that would have involved the strenuous use of upper body joints.

As discussed above, the effects of osteoarthritis in the joints of Crypt individuals might be due to a number of systemic factors. During the collection of data, skeletal examinations did not suggest any visibly evident injuries or bone abnormalities in either the upper or the lower limb bones of Crypt individuals. In historical and ethnographic studies, 18th and 19th century Trebinje peasants are described as involved in agricultural activities similar to those performed by Late Medieval Trebinje peasants (Zorić, 1989). It is plausible that these individuals used both the upper and the lower body limbs during these activities. Therefore, generally similar prevalence rates of osteoarthritis between the upper limb joints and the lower limb joints might indicate a similar extent of stress and loading in these joints.

### Division of labor by age and sex

The results of osteoarthritis prevalence among the Crypt individuals do not support the results of previous findings among archaeological populations (Jurmain, 1980) and those for past Balkan populations (Novak, 2011; Šlaus, 2000; Šlaus, 2002), including the Mistihalj Necropolis sample, that the prevalence of osteoarthritis overall increases with age. Although the prevalence of osteoarthritis is higher in old adults than middle-aged adults and young adults in the lower limb joints, these results are insignificant. Moreover, the prevalence of osteoarthritis in the upper limb joints among the Crypt individuals, although insignificant, is the highest in young adults. Higher prevalence rates among these young adult individuals might be related to an intense use of the upper limb joints during early life as it is the case in some other archeological populations (e.g. Jurmain, 1977). A possible explanation for this is that those individuals from the Crypt that lived to an old age might have led less stressful lifestyles than those that died young. However, this pattern might also be the consequence of sampling bias, as there are fewer young adults from this group than middle-aged and old adults (Wood et al., 1992).

Overall, the males have a higher prevalence of osteoarthritis in both the upper and lower limb joints among the Crypt individuals. While affected females are observed only with a mild form of this condition in both the upper and the lower limb joints, affected males are observed with moderate and pronounced forms of this condition in the upper limb joints. However, osteoarthritis rates do not significantly differ between the Crypt females and males overall, nor when examined within the same age cohorts, and the severity of osteoarthritis does not correlate with the age or sex of these individuals. Thus, inferences about the differences in the effects of osteoarthritis between sexes cannot be offered.

If the development of osteoarthritis among Crypt skeletons is due to activity-related stresses and loading, then it is likely that the females and males from the Crypt were involved to a similar extent in the labor force throughout their lives, which would agree with the compiled ethnographic data about peasants' lives in 19th century Trebinje (Zorić, 1989). In fact, both young boys and girls are described as taking animals to the pastures and back daily, while men and women are described as equally involved in agricultural and pastoralist activities. The loosely based division of labor between men and women is only suggested, but not supported by these data, in that men were solely involved in hunting and military activities (Radović, 2002:36; Zorić, 1989).

## Similarities and differences in lifestyles of the Late Medieval Necropolis individuals and the 19th century Crypt individuals

### Activity patterns over time at Mistihalj

Hundreds of years separate the Late Medieval and 19th century and it was expected that the lifestyles of the Necropolis skeletons and Crypt skeletons would differ. Therefore it was also expected that if biomechanical stresses and loading from activities played a role in the development of osteoarthritis among individuals from these two time periods, there would be significant differences in the effects of osteoarthritis between these two skeletal samples. However, the general patterns of osteoarthritis within both samples are similar to one another. Thus, if subsistence economy-related activities played a role in the effects of osteoarthritis among these individuals, the results of this study largely support historical and ethnographic sources that the subsistence economy-related activities did not generally differ between these two time periods in Trebinje (Tošić, 1995a; 1995b; Zorić, 1989).

It is important to note that the severity of osteoarthritis in the upper limb joints positively correlates with the burial location among men overall and within the old adult cohort where 19th century Crypt males have more severe forms of osteoarthritis than their Late Medieval Necropolis counterparts. This pattern of more severe osteoarthritis in upper limb joints of the Crypt individuals might be related to a number of factors that play a role in the development of this condition such as genetic predisposition (Palotie et al., 1989), trauma (Buckwalter and Lane, 1997), older age (Murphy et al., 2008) and more intense activity-related stresses and loading (Croft et al., 1992). Greater genetic predisposition for osteoarthritis among Crypt individuals than Necropolis individuals is not verifiable by this study, but there is no reason to assume that there is no genetic continuation between these two groups and thus such a factor would play a similar role in the development of osteoarthritis between the men from the two time periods. However, future bioarchaeological studies of these two skeletal samples could clarify such assumptions, either through dental genetic analyses of inherited traits, or other genetic tests, that allow for the examination of genetic sequence diversity between populations. Severe bone trauma was not observed among any of these individuals. If the Crypt males, particularly among old adult cohort, lived longer lives, than their Necropolis counterparts, then Crypt males' more severe forms of osteoarthritis might be due to longer exposure to stresses, including behavioral stress, and decrease in joints' ability to respond to such stresses due to senescence in the upper limb joints. If lifestyles played a role in the development of osteoarthritis among these males, then these results might suggest that the upper limb joints of the Crypt males were exposed to more strenuous mechanical stresses and loadings than the upper limb joints of their Necropolis counterparts. Interestingly, as stated earlier, available historical and ethnographic sources do not seem to indicate differences in subsistence strategy-related activities between men in Late Medieval and 19th century Trebinje. In fact, men from both time periods in Trebinje are described as involved in similar activities (e.g., Tošić, 1995a:81; Zorić, 1989). However, the ethnographic sources describe 19th century peasant men as participants in guerilla warfare against the Ottoman and Austro-Hungarian soldiers throughout the 19th century. The warfare consisted of precision and remote shooting by these men using the common Džeferdar rifles

(Radović, 2002:36). Whether the Crypt males were participants in such warfare and whether such activities played a role in the development of osteoarthritis in their upper limb joints is uncertain, but if that is the case then the differences in severity of osteoarthritis among these men and their Necropolis counterparts might be due to differences in their military histories.

## Summary

This chapter discussed the effects of osteoarthritis among and between the Necropolis and Crypt skeletons from the Mistihalj site in Bosnia and Herzegovina in order to infer the potential role of activity- related stresses that might have contributed to the development of osteoarthritis among these individuals. Although a positive relationship with age and osteoarthritis is predicted, such a correlation is only evident among the Necropolis individuals. The role of other systemic factors such as obesity, anatomical variances, and genetic predisposition to osteoarthritis that might have played a role in these results is beyond the scope of this study and future research is needed for clarification. However, if lifestyles and activity-related stresses played a role in the development of this condition among Mistihalj individuals, then overall similarities in the prevalence, patterning, and severity of osteoarthritis among these skeletons agree with historical and ethnographic sources that describe similar lifestyles and labor of adult men and women living in Late Medieval times and 19th century and later centuries Trebinje.

# CHAPTER 6: CONCLUSION

In some past anthropological studies, the focus on examining osteoarthritis as a consequence of specific activities led to criticism emphasizing its multifactorial etiology (Weiss and Jurmain, 2007). However, many epidemiological and clinical studies demonstrate that extensive behavioral stresses and loading imposed on joints might play a role in the development of osteoarthritis (Bovenzi et al., 1987; Gelber et al., 2000; Honkonen, 1995; Mintz and Fraga, 1973; Stenlund et al., 1992). Thus the examination of osteoarthritis resulting from biomechanical stresses (with a careful examination of other factors that could confound this condition's development, e.g., age, sex, and trauma) can provide important information about culturally defined behaviors and activity patterns. In fact, bioarchaeological research shows that such analyses, in conjunction with social and mortuary data, can also provide relevant information about socio-economic inequalities and their impact on the health of individuals in complex societies (Klaus et al., 2009; Schrader, 2012; Sperduti, 1997). This study follows these precedents and provides evidence of the effects of osteoarthritis and what role culturally defined behavioral stresses might have played in the development of this condition among and between skeletons of inferred peasants from a Late Medieval Necropolis and the 19$^{th}$ century church Crypt at the Mistihalj site in the Trebinje region of the Balkans.

The particular aim of this thesis was to explore the similarities and differences among osteoarthritis effects between the upper and lower limb joints and between individuals of different age and sex cohorts in order to explore whether their activity levels and patterns suggest a specialization or division of labor among these individuals. This information is important because, by comparing the results with ethnographic and historical data descriptions of their culturally defined behaviors, it can illuminate whether these individuals were in fact of peasant status, as inferred through mortuary data analyses. This study also examined whether the effects of osteoarthritis are different or similar between individuals that lived in different time periods, specifically between the Late Medieval and the 19th century in Trebinje. The reason for this was to examine whether these results suggest similar or different activity levels and patterns between these individuals in order to explore whether this information agrees with historical data about lifestyles of Late Medieval Trebinje's peasants and ethnographic and historic data about 19th and later centuries Trebinje's peasant lifestyles. In order to answer these questions a set of hypotheses was developed and tested via the statistical analyses of osteoarthritis results.

The hypothesis that there would be differences in the effects, i.e. the rates of prevalence and severity, of osteoarthritis between the upper and lower limb joints among any of these individuals is rejected. The absence of both significant differences between the prevalence in these joints and any correlation between the severity of osteoarthritis and its location might reflect similar stresses and loading on these joints during these individuals' lifetimes. Thus, it is probable that these individuals did not practice labor specialization and were most likely peasants involved in varied agro-pastoralist activities described by ethnographic and historical sources.

This study fails to reject the hypothesis that there will be varied prevalence rates of osteoarthritis between different age cohorts among the Necropolis individuals, but does reject such a hypothesis for the Crypt individuals. The hypothesis that the severity of osteoarthritis will correlate with age is also rejected for both samples. The fact that older individuals have significantly higher prevalence rates than middle-aged and young adults among Necropolis individuals, might be due to older individuals longer exposure to activities, but also as a result of regular age- related processes. The lack of significant differences in the prevalence rates of osteoarthritis among the Crypt individuals of different ages might suggest more strenuous lifestyles among those that died young than those that lived to an old age which might point to a division of labor by age among the Crypt individuals where young adults would have been the active labor force.

The hypothesis that there will be significant differences in the effects of osteoarthritis between the sexes is rejected. These results might suggest that both men and women from these two time periods in Trebinje were involved to a similar extent in the labor force or performed similar activities, which would again agree with ethnographic and historical accounts about peasants living in Late Medieval and 19$^{th}$ and later centuries in Trebinje.

The hypothesis that there will be significant differences in prevalence rates among individuals of the same age and sex from the Late Medieval Necropolis and 19$^{th}$ century church Crypt is rejected. However, the hypothesis that the severity will correlate with the location of burial among these cohorts is only partially rejected, because such correlation is evident among men overall and within the old adult cohort.  The general lack of significant differences between the Necropolis and Crypt individuals might indicate that peasants in Trebinje led similar lifestyles for centuries.

Ethnographic and historical studies suggest that the lifestyles and activities of the Trebinje peasant populations during these periods was fairly homogenous, with a majority of individuals involved primarily in general agro-pastoralist activities that would have put both the upper and lower limb joints under similar stresses and loading. Moreover, these sources describe a subsistence economy with a loosely defined division of labor by age and sex within both time periods in this region (Tošić, 1995a:78-81; 1995b; Zorić, 1989). However, these studies also suggest that there were only minor differences in the lifestyles of peasants in Trebinje between these two times, separated by hundreds of years, particularly among men (Radović, 2002:36; Tošić, 1995a:78-81).

## Limitations and future research directions

While controlling for age and sex is essential in the examination of the data in order to provide more specific information about osteoarthritis effects among and between populations, such categorizations can result in small sample sizes that might increase the chance of a false positive. In this study, such an error might have played a role in the examinations, particularly among the Crypt skeletons. I propose that in future research on osteoarthritis among Mistihalj individuals, data should be collected for more skeletons from both burial locations. In this study, further examinations were not possible due to time constraints.

Due to the multifactorial etiology of osteoarthritis, future research should control for non-activity related factors that might play a role in the development of this condition, particularly body size and mass among individuals of different ages and sexes. For example, Weiss (2004) found that when controlling for age in Euro-American and Amerindian populations, body mass and size correlated with osteoarthritis. Interestingly, smaller individuals had more osteoarthritis than larger individuals. Since smaller individuals in this sample were women, the author concluded that the differences in osteoarthritis prevalence rates among sexes might be due to anatomical differences between females and males rather than behavioral differences during their lifetimes. Thus, I propose that another study of osteoarthritis among Mistihalj skeletons should be conducted that would control for body mass and size in order to examine what role these factors might have played in the development of this condition among these individuals. A study shows that Mistihalj males have moderately (5%), but significantly, higher BMI (body mass index) than pooled pan-European Late Medieval skeletons (Ruff, 2017:402). If there is sexual dimorphism between the Mistihalj females and males, and females are significantly smaller than their male counterparts, then similarities in osteoarthritis prevalence rates between sexes in this study might be due to a combination of biological factors and cultural factors, and this proposition must be examined.

A genetic predisposition for osteoarthritis can result in generalized effects of this condition among individuals. However, an examination of this factor was beyond the scope of this study.  Relevant future research on Mistihalj samples concerning this issue is necessary to verify this study's conclusions. I propose that future research should focus in particular on genotyping Mistihalj skeletons in order to examine if they belong to mitochondrial haplogroup H, which might be a likely biomarker of osteoarthritis and is the most prevalent mitochondrial haplogroup among Bosnians and Herzegovinians.

Although this study examined agglomerated data, time constraints prevented the examination and comparison of osteoarthritis scores for individual joints in both the upper and lower limbs. However, I would like to conduct such detailed examinations of the data in the future, because differences between specific joints are more likely to reflect the effects of activity related stresses and loading than systemic factors such as age and genetic predisposition (Weiss and Jurmain, 2007). Furthermore, this future study would compare the data to that collected on other Balkan peasant populations in the Late Medieval and later centuries. Of particular interest would be to compare osteoarthritis data from  the Necropolis individuals and the Late Medieval rural Koprivno population examined by Dr. Mario Novak in Croatia.

## Contributions

As the first study of osteoarthritis among past populations from Bosnia and Herzegovina, this study provides initial bioarchaeological information about the possible effects of lifestyles on the joint health of individuals living in the past in this geographic territory. As such, this study's data also provide comparative material for future bioarchaeological research of past populations in the territories of Bosnia and Herzegovina and archaeological populations from other Balkan and European regions that lived in either the Late Medieval or 19$^{th}$ and later centuries. Such comparative studies between past populations are important, because they have the potential to reveal extrinsic factors, such as culturally-defined behaviors, that might play a role in the development of osteoarthritis

Finally, this study contributes to a broader anthropological understanding of questions concerning the culturally-defined activities and labor inequalities among and between individuals of low social status of different ages and sexes within socio-economically complex societies.

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Date__5/2/18____________________________
Requestor Name__Zorina Manoni____________________
Organization ____________________________________

Address __534 E. Esther St.________________________
City __Orlando___________________________________
State__FL_______________________________________
Country____________________ Zip Code__32806____________
Phone___________________________
Email__zorinamanoni@knights.ucf.edu_______________

**MATERIAL REQUESTED**

Peabody Museum - Harvard Image Number(s) :

| Peabody ID# | Title | Digital file # |
|---|---|---|
| **2012.12.1.1.2.2.1** | **Sketch of graves, crypts from notebook II** | **TBD** |
| **2012.12.3.4** | **Maps relating to Mistihalj excavation, 1967, and Trebisnjica Project** | **TBD** |

**USE TO BE MADE OF MATERIAL REQUESTED:**

___ Book (cover)____Book (interior) (print edition) ___ eBook (term of 10 years)
___ Related ancillaries (book)
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_x__ Dissertation/thesis

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___Online/ web site: up to 1 year___ 1-5 years___ 5-10 years___
___Smartphone /iPhone or Android Application (app): up to 1 year___ 1-5 years___ 5-10 years___
___Exhibition: Temporary___ Traveling___ Permanent (10 years)___
___Exhibition promotional materials
___PowerPoint - for classroom or conference use only
___Associated Promotional materials
___Calendar

**Title/Description:** __Working title: A bioarchaeological study of osteoarthritis among and between agro-pastoralists_______________________________________________

**Author/Producer/Curator:** __Zorina Manoni_____________________________________________

**Editor(s):**_____________________________________________________________

**Publisher/ Production Co./Venue** ______________________________________________

**Publication/Broadcast/Opening Date:**__2018_______________________

**Image(s):** B/W____ Color__x___
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PEABODY MUSEUM
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Harvard University, 11 Divinity Avenue, Cambridge, Massachusetts, 02138-2019

May 30, 2018

Zorina Manoni
534 E. Esther St
Orlando, FL 32806

Dear Zorina Manoni,

This letter sets forth the terms and conditions under which President and Fellows of Harvard College, on behalf of the Peabody Museum of Archeology and Ethnology ("Harvard"), agree to publication of four photographs of the following objects in thesis entitled "A bioarchaeological study of osteoarthritis of agro-pastoralists from Mistihalj, Bosnia and Herzegovina: a lifestyle set in time" by Zorina Manoni to be published by University of Central Florida in 2018:

| | |
|---|---|
| 968-10-40/N8959.0 | Homo sapiens sapiens |
| 968-10-40/N9054.0 | Homo sapiens sapiens |
| 968-10-40/N9164.0 | Homo sapiens sapiens |
| 968-10-40/N9228.0 | Homo sapiens sapiens |

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Arthur J. Marks
PRESIDENT AND FELLOWS OF
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THE PEABODY MUSEUM OF ARCHEOLOGY
AND ETHNOLOGY

ZManoni
**Zorina Manoni**

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JT

J. Marla Toyne <J.Marla.Toyne@ucf.edu>

Today, 9:26 AM

Zorina Manoni

Dear Zorina

I give you permission to use my photo of the Bosnia grave marker in your thesis.

Best
Dr Toyne

******

J. Marla Toyne, PhD
Associate Professor
Department of Anthropology
University of Central Florida
4000 Central Florida Blvd
Howard Phillips Hall, rm 309
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USA, 32816
(407) 823-1927
(407) 823 3498 (fax)

# APPENDIX B: DATA COLLECTION SHEET

| **JOINT** | **BONE** | **BONE AREA** | **LIPPING DEGREE** | | **LIPPING EXTENT** | | **POROSITY DEGREE** | | **POROSITY EXTENT** | | **EBURNATION DEGREE** | | **EBURNATION EXTENT** | | **OA** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | - | - | L | R | L | R | L | R | L | R | L | R | L | R | L | R |
| **ACROMIOCLAVICULAR** | SCAPULA | ACROMION | | | | | | | | | | | | | | |
| **ACROMIOCLAVICULAR** | CLAVICLE | LATERAL END OF CLAVICLE | | | | | | | | | | | | | | |
| **GLENOHUMERAL** | SCAPULA | GLENOID FOSSA | | | | | | | | | | | | | | |
| **GLENOHUMERAL** | HUMERUS | HEAD OF HUMERUS | | | | | | | | | | | | | | |
| **HUMEROULNAR** | HUMERUS | TROCHLEA OF HUMERUS | | | | | | | | | | | | | | |
| **HUMEROULNAR** | ULNA | TROCHLEAR NOTCH OF ULNA | | | | | | | | | | | | | | |
| **HUMERORADIAL** | HUMERUS | CAPITULUM OF HUMERUS | | | | | | | | | | | | | | |
| **HUMERORADIAL** | RADIUS | HEAD OF RADIUS | | | | | | | | | | | | | | |
| **PROXIMAL RADIOULNAR** | RADIUS | HEAD OF RADIUS | | | | | | | | | | | | | | |
| **PROXIMAL RADIOULNAR** | ULNA | RADIAL NOTCH OF ULNA | | | | | | | | | | | | | | |
| **RADIOCARPAL** | RADIUS | DISTAL END OF RADIUS | | | | | | | | | | | | | | |
| **ACETABULOFEMORAL** | OS COXAE | ACETABULUM | | | | | | | | | | | | | | |
| **ACETABULOFEMORAL** | FEMUR | HEAD OF FEMUR | | | | | | | | | | | | | | |
| **TIBIOFEMORAL** | FEMUR | MEDIAL AND LATERAL CONDYLES OF FEMUR | | | | | | | | | | | | | | |

| JOINT | BONE | BONE AREA | LIPPING DEGREE | | LIPPING EXTENT | | POROSITY DEGREE | | POROSITY EXTENT | | EBURNATION DEGREE | | EBURNATION EXTENT | | OA | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TIBIOFEMORAL** | TIBIA | MEDIAL AND LATERAL CONDYLES OF TIBIA | | | | | | | | | | | | | | |
| **PATELLOFEMORAL** | FEMUR | PATELLAR SURFACE OF FEMUR | | | | | | | | | | | | | | |
| **PATELLOFEMORAL** | PATELLA | POSTERIOR ASPECT OF PATELLA | | | | | | | | | | | | | | |
| **PROXIMAL TIBIOFIBULAR** | TIBIA | LATERAL CONDYLE OF TIBIA | | | | | | | | | | | | | | |
| **PROXIMAL TIBIOFIBULAR** | FIBULA | HEAD OF FIBULA | | | | | | | | | | | | | | |
| **TALOCRUCAL** | TIBIA | MEDIAL MALLEOUS OF TIBIA | | | | | | | | | | | | | | |
| **TALOCRUCAL** | FIBULA | LATERAL MALLEOUS FIBULA | | | | | | | | | | | | | | |
| **TALOCRUCAL** | TALUS | TALAR DOME | | | | | | | | | | | | | | |
| **TALOCRUCAL** | TALUS | LATERAL PROCESS | | | | | | | | | | | | | | |

# APPENDIX C: CRUDE PREVALENCE FOR THE PRESENCE OF OSTEARTHRITIS FIGURES

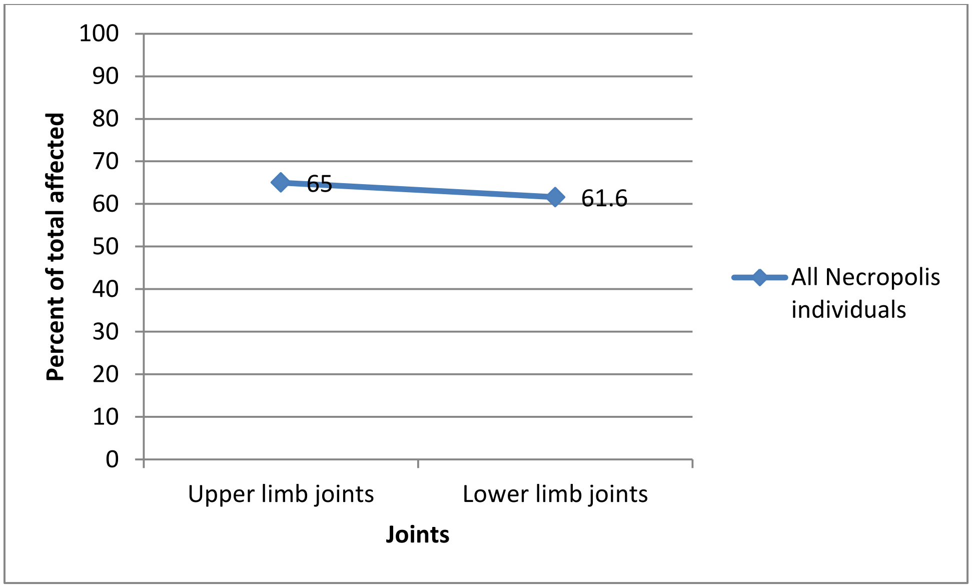


Figure C1 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - all Necropolis individuals.

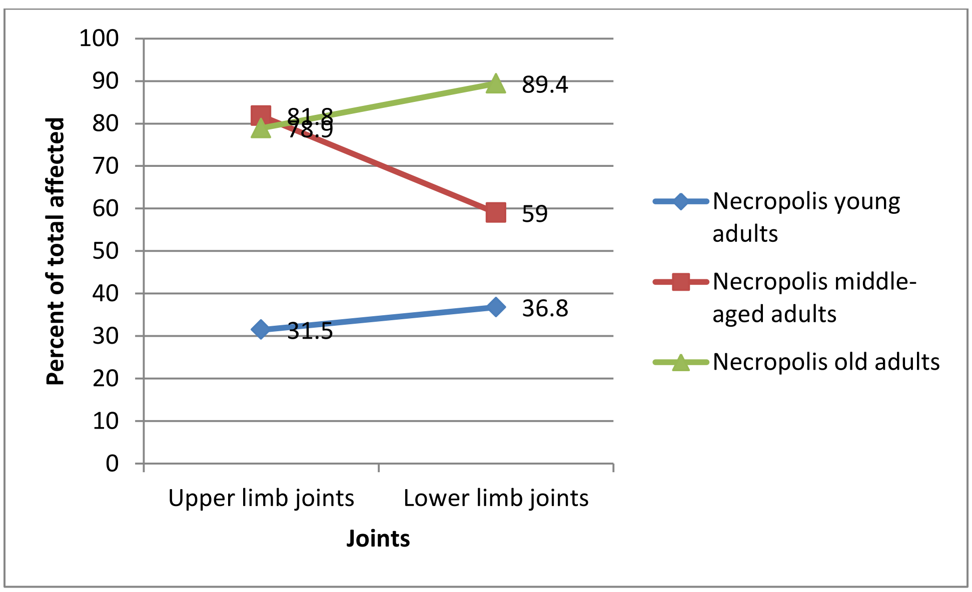


Figure C2 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis young adults, middle-aged adults and old adults.

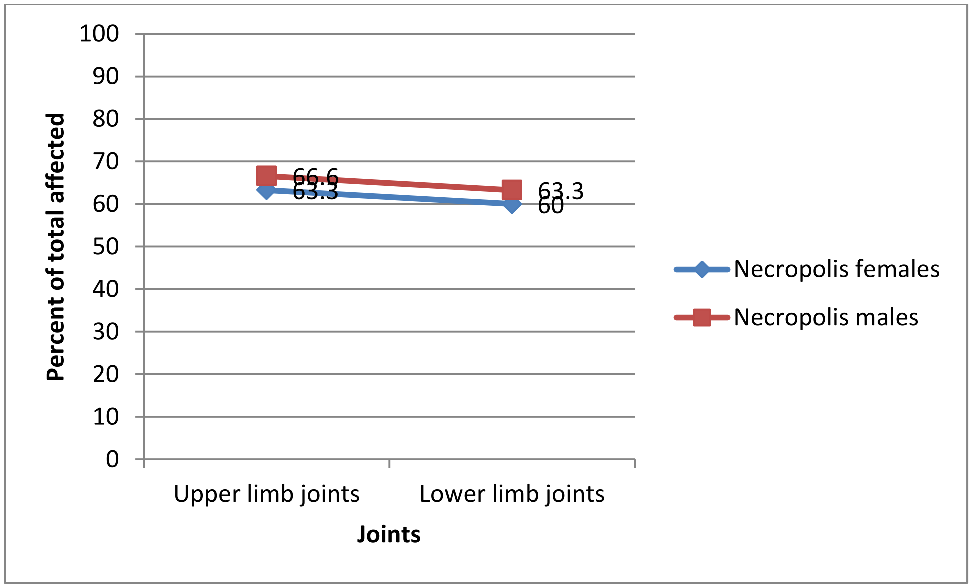


Figure C3 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis females and Necropolis males.

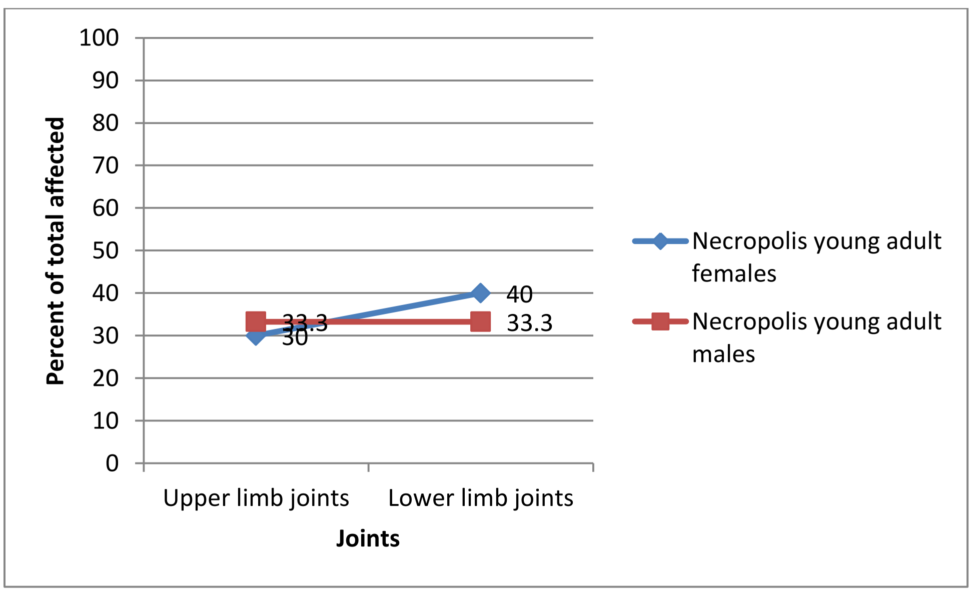


Figure C4 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis young adult females and Necropolis young adult males.

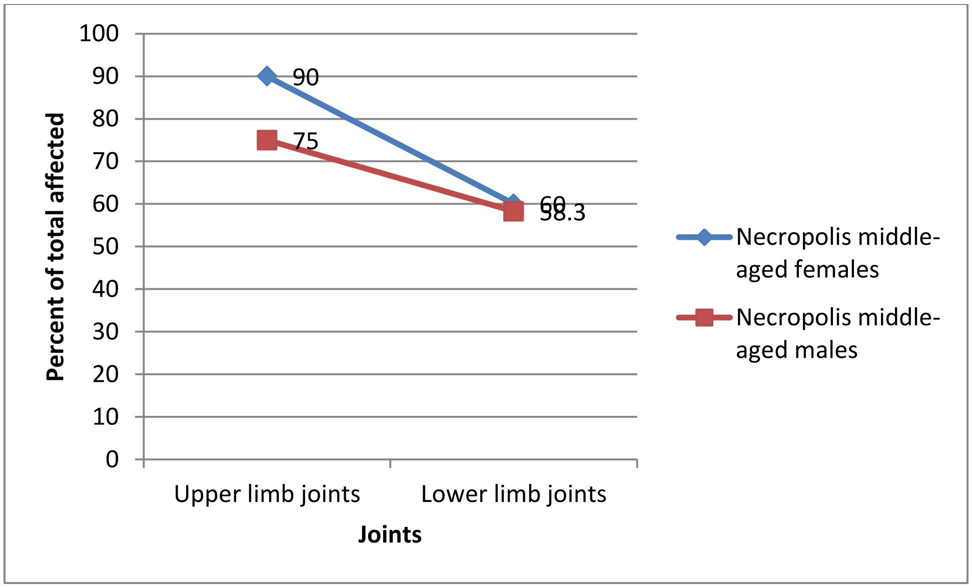


Figure C5 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis middle-aged females and Necropolis middle-aged males.

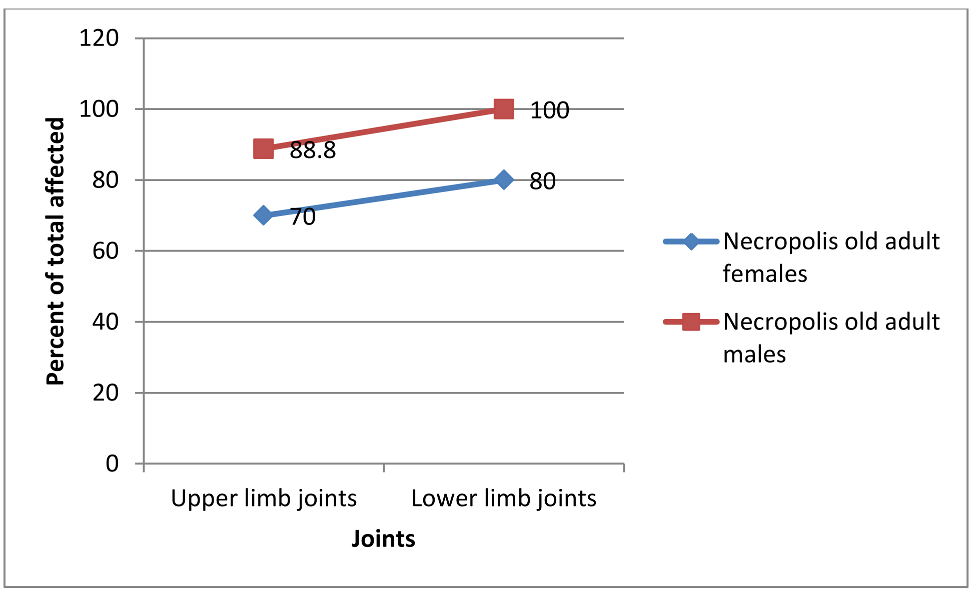


Figure C6 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis old adult females and old adult males.

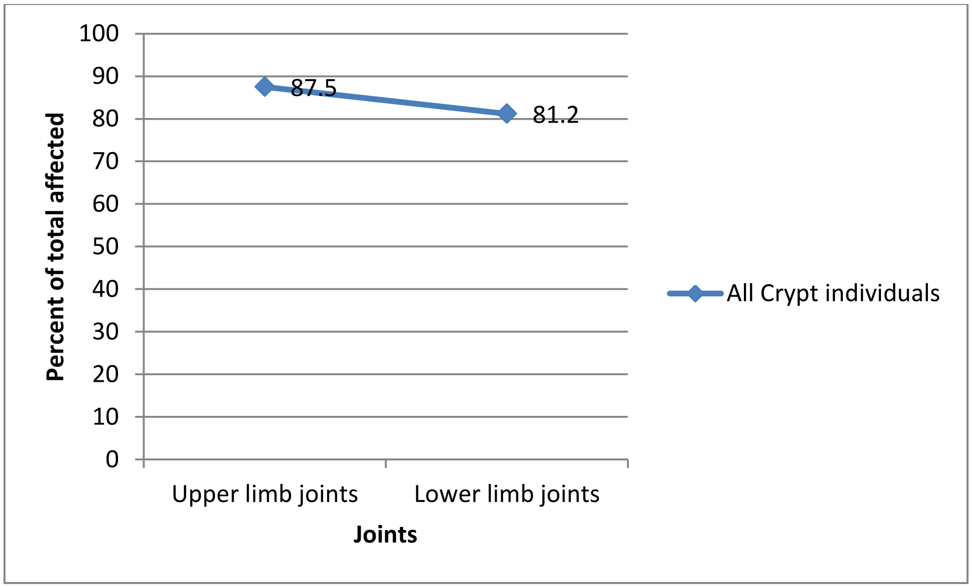


Figure C7 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - all Crypt individuals.

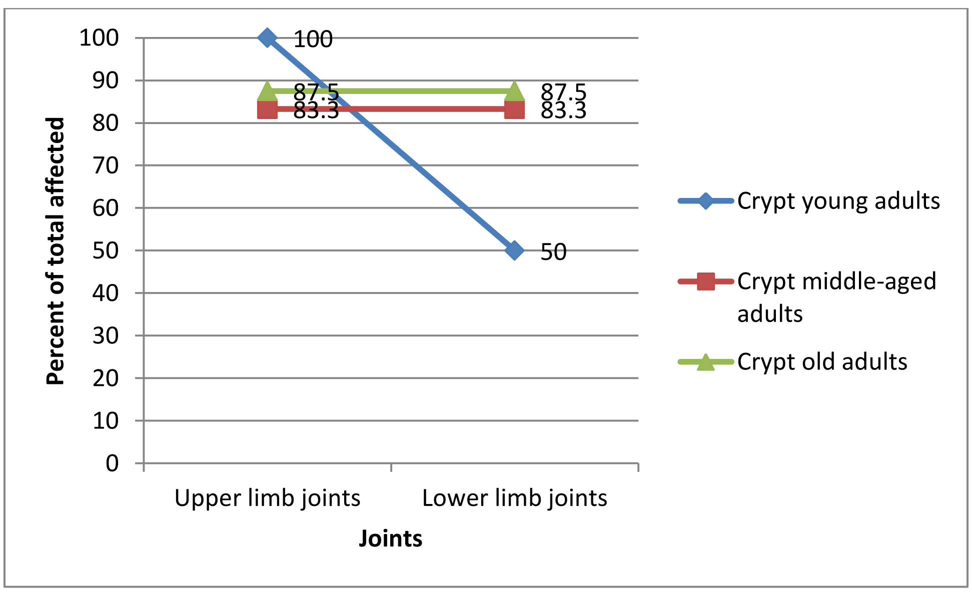


Figure C8 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Crypt young adults, Crypt middle-aged adults, and Crypt old adults.

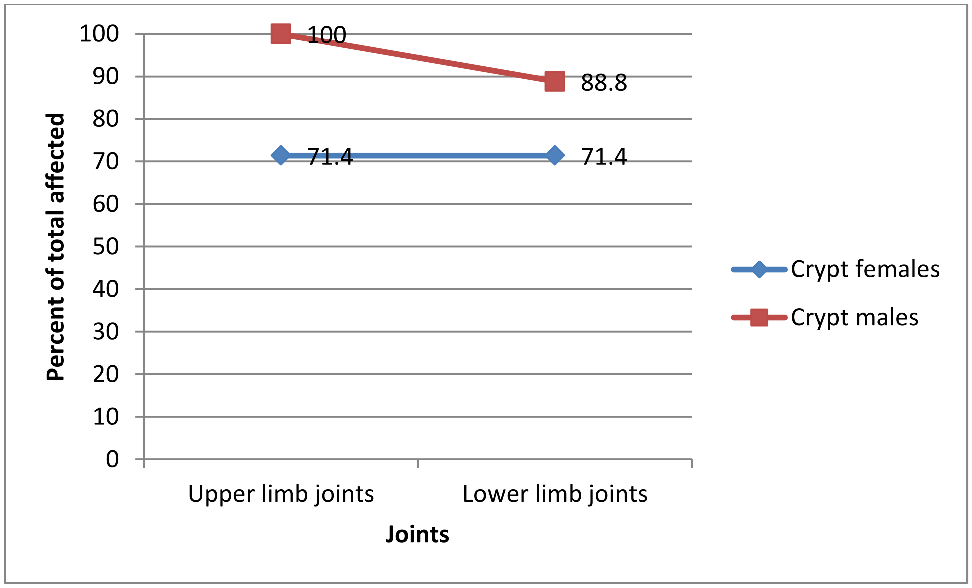


Figure C9 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Crypt females and Crypt males.

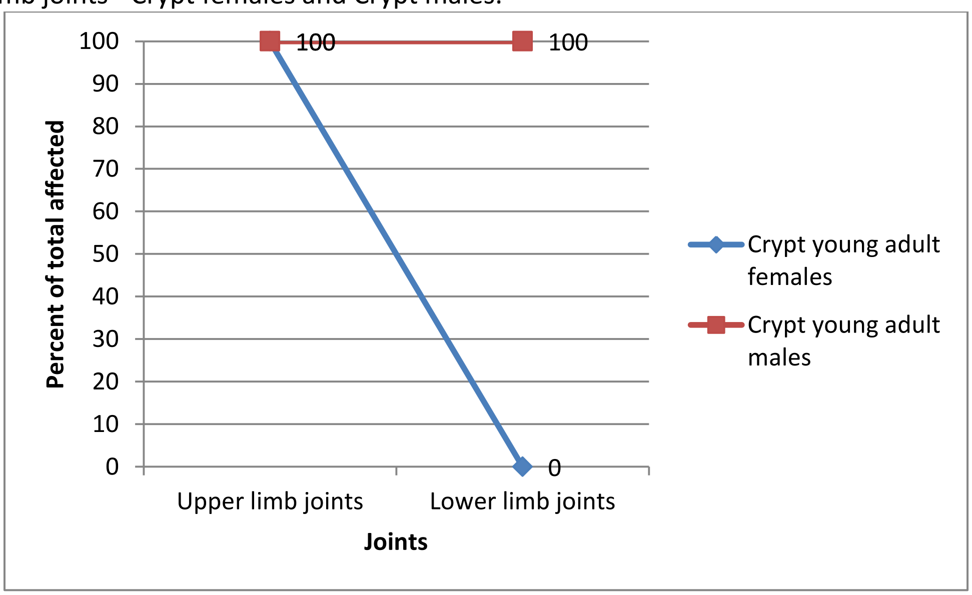


Figure C10 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Crypt young adult females and Crypt young adult males.

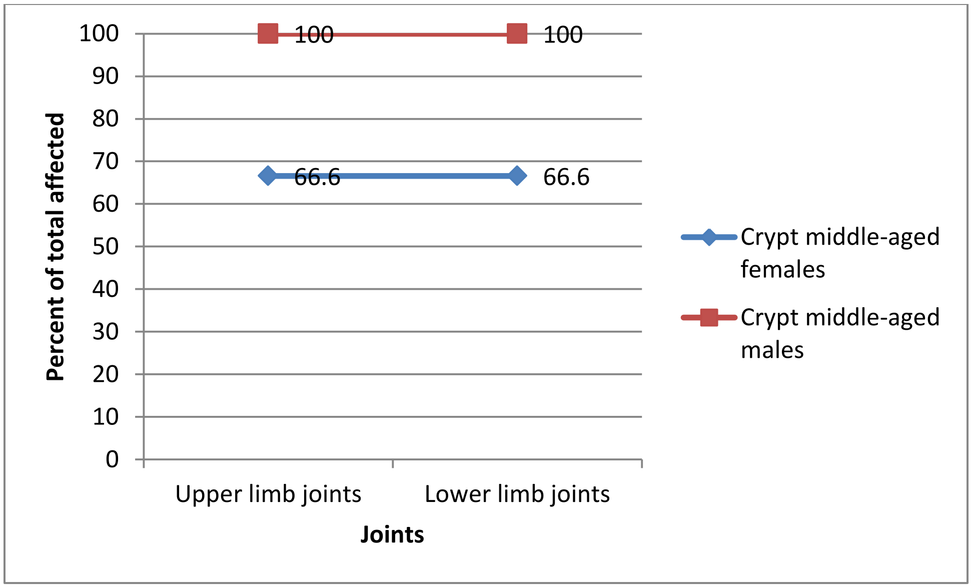


Figure C11 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Crypt middle-aged females and Crypt middle-aged males.

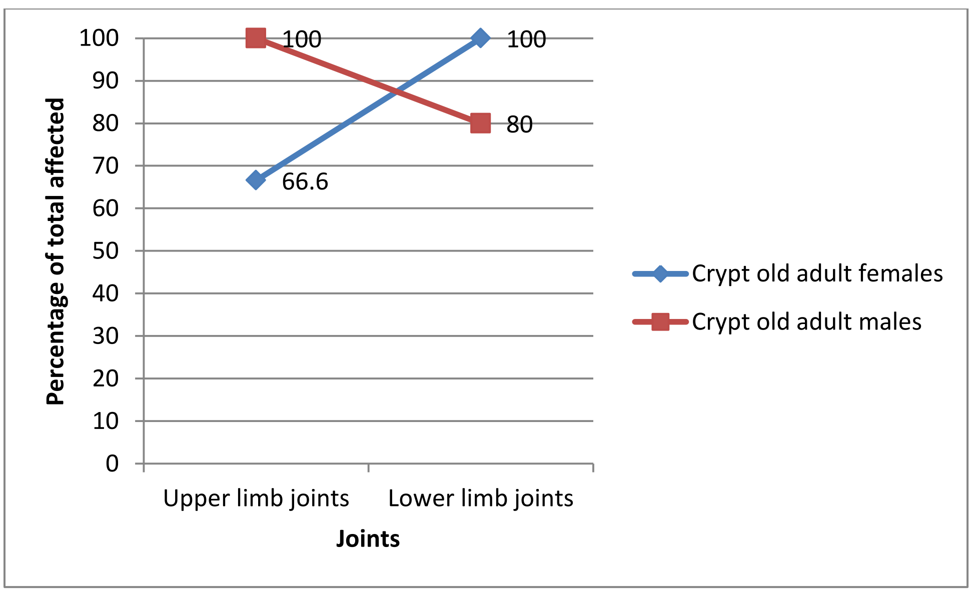


Figure C12 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Crypt old adult females and Crypt old adult males.

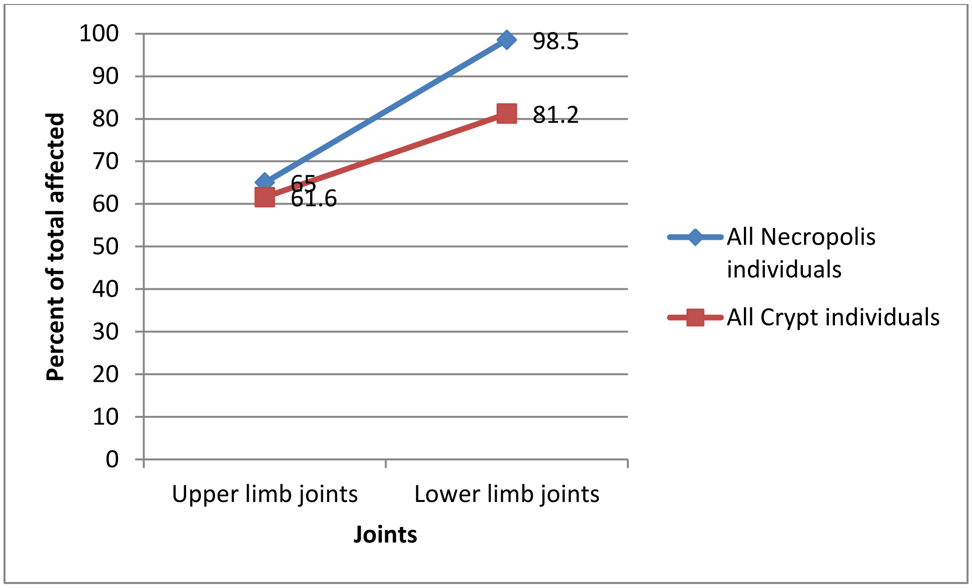


Figure C13 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - all Necropolis individuals and all Crypt individuals.

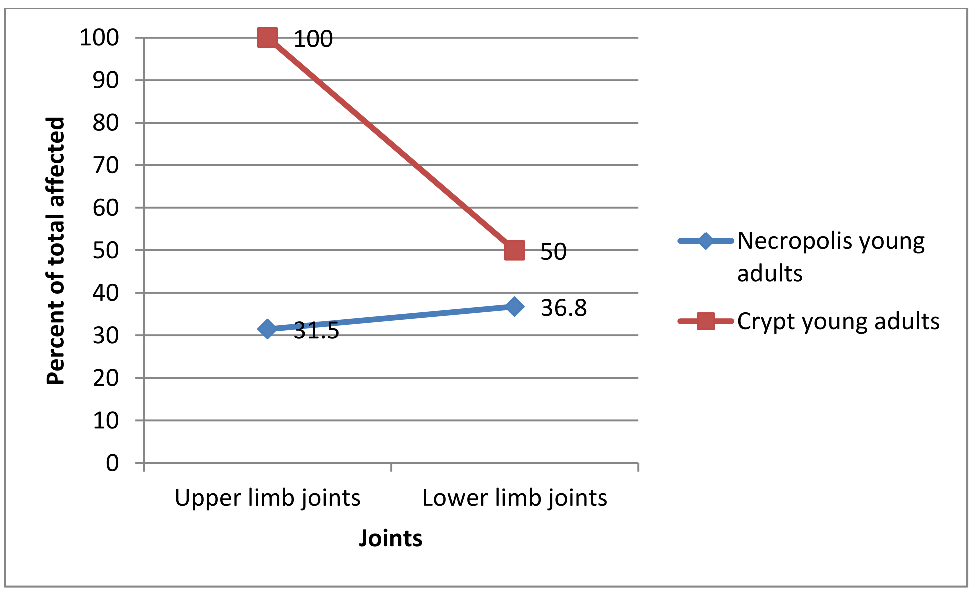


Figure C14 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt young adults.

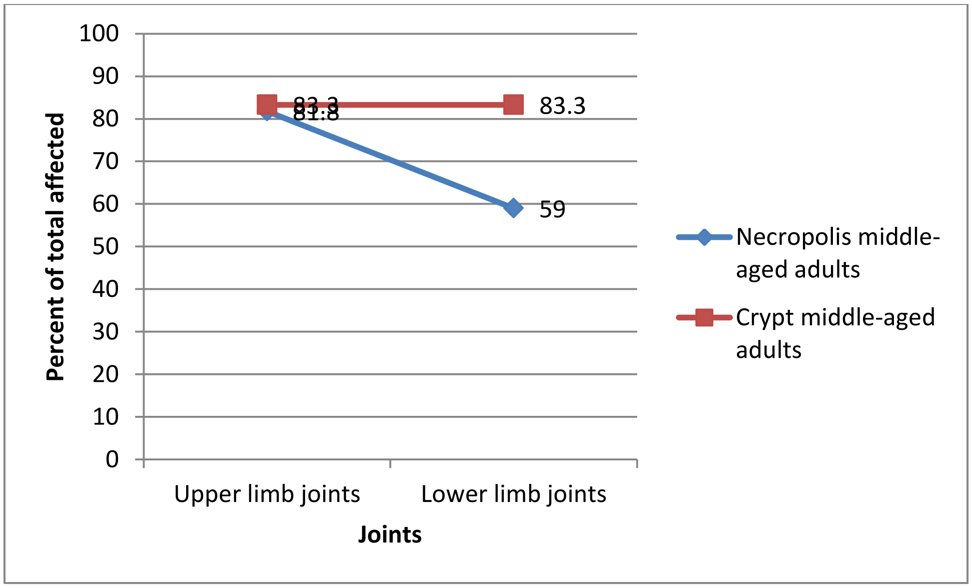


Figure C15 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt middle-aged adults.

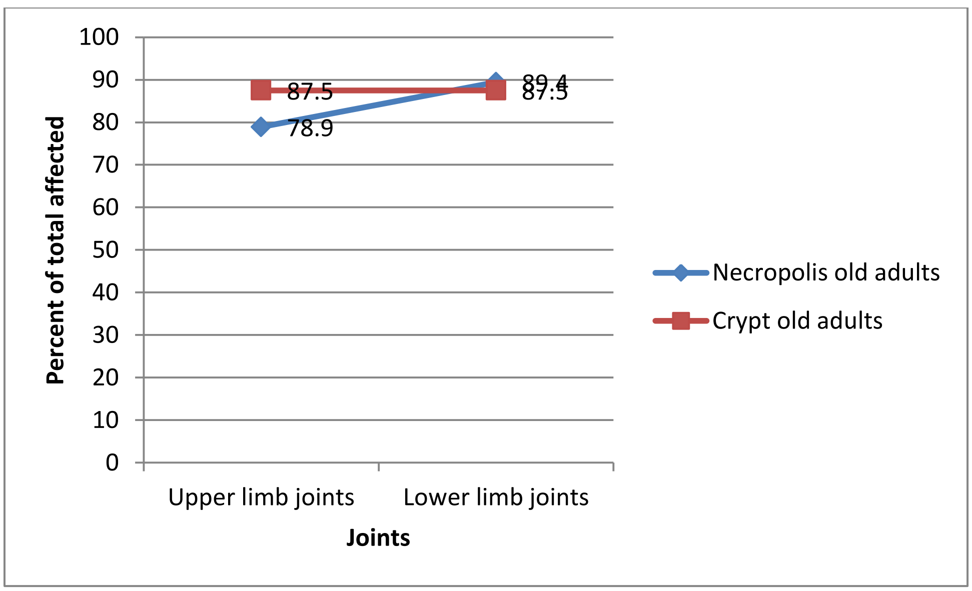


Figure C16 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt old adults.

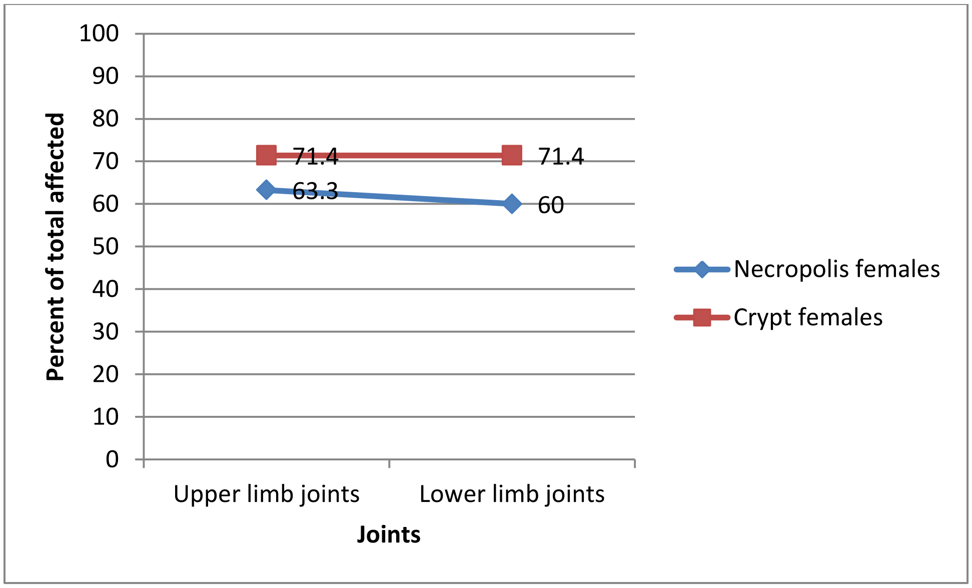


Figure C17 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt females.

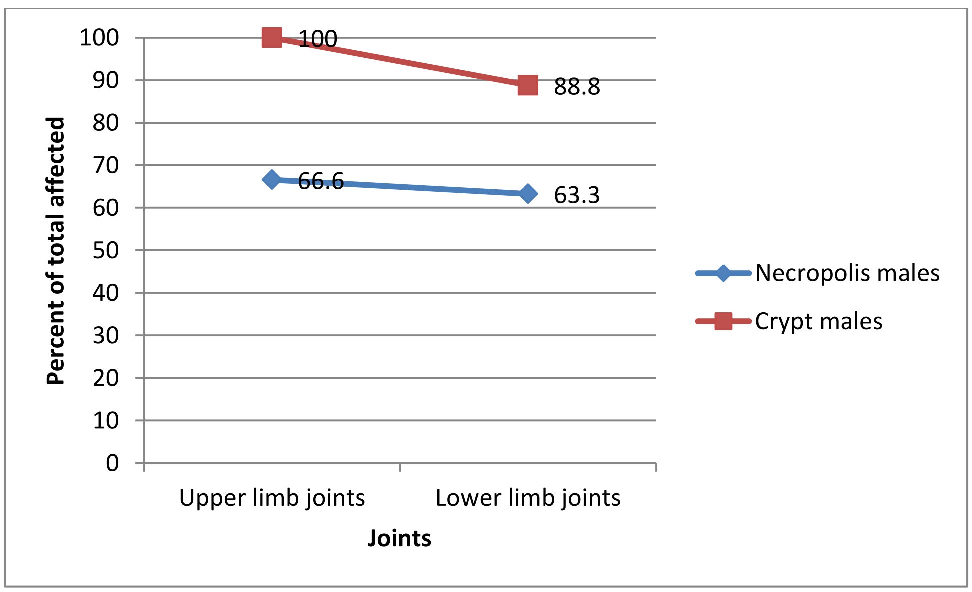


Figure C18 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt males.

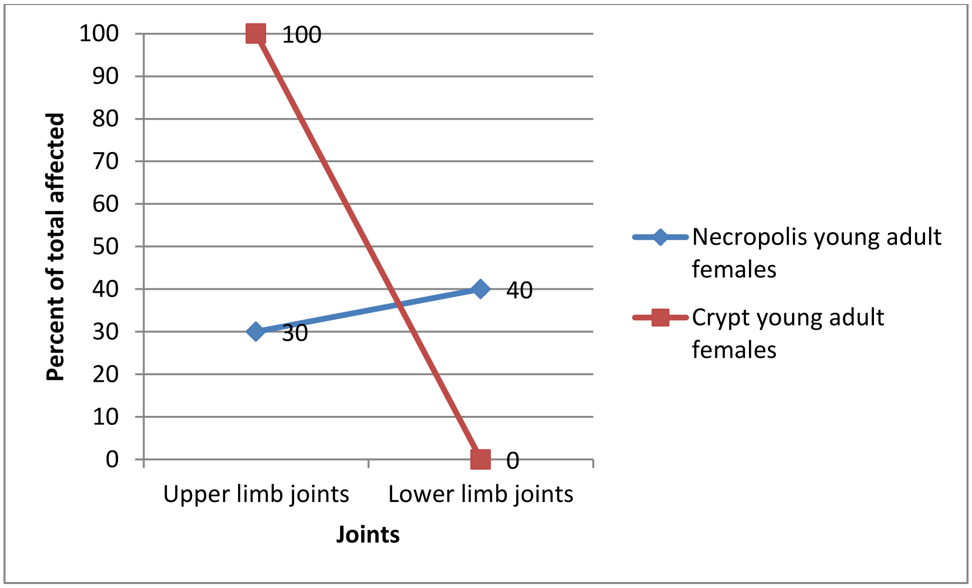


Figure C19 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt young adult females.

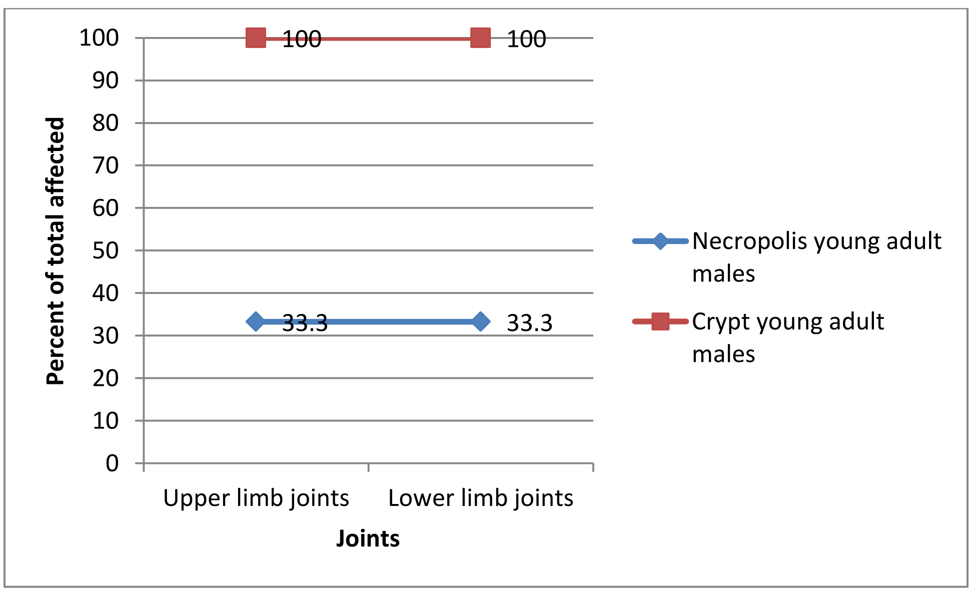


Figure C20 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt young adult males.

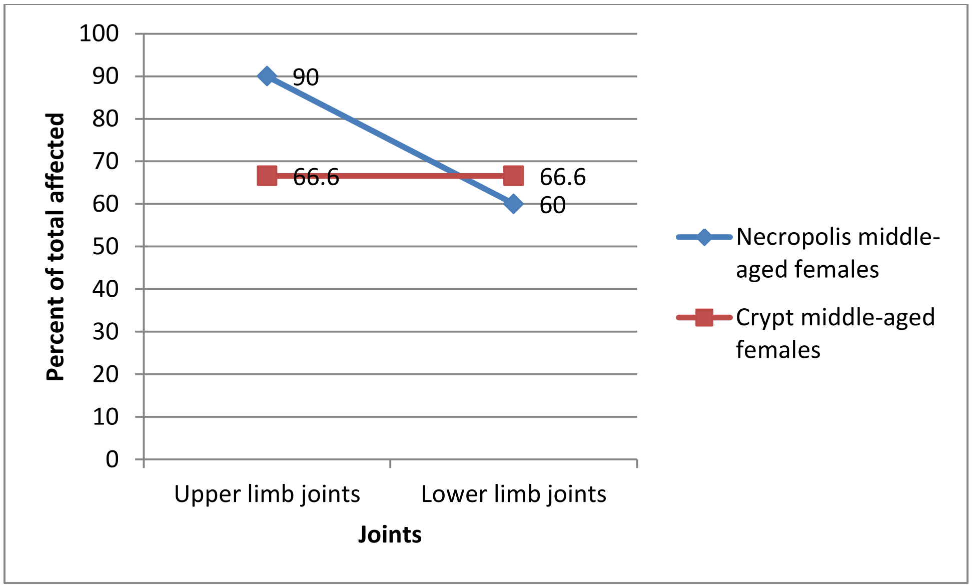


Figure C21 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt middle-aged females.

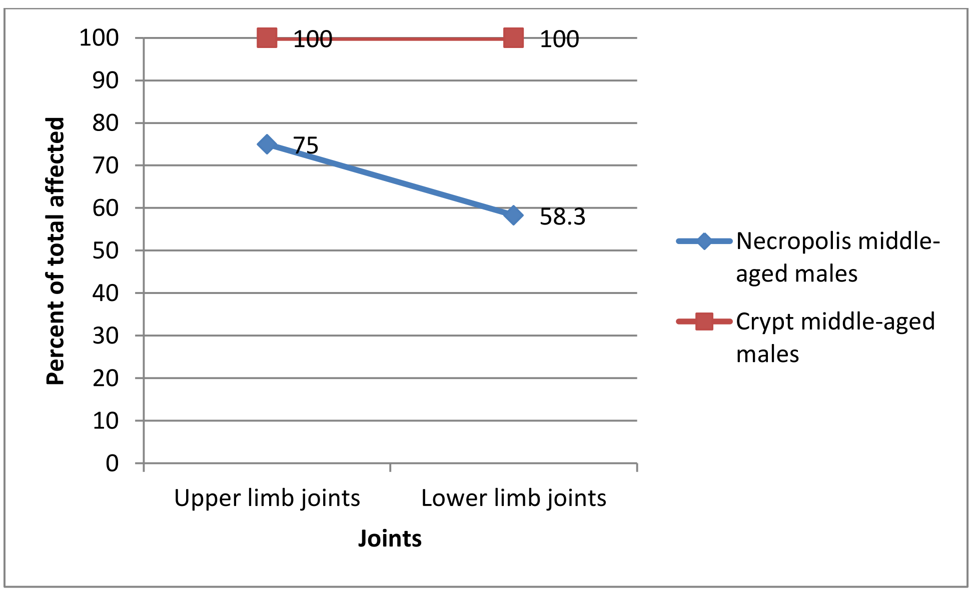


Figure C22 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt middle-aged males.

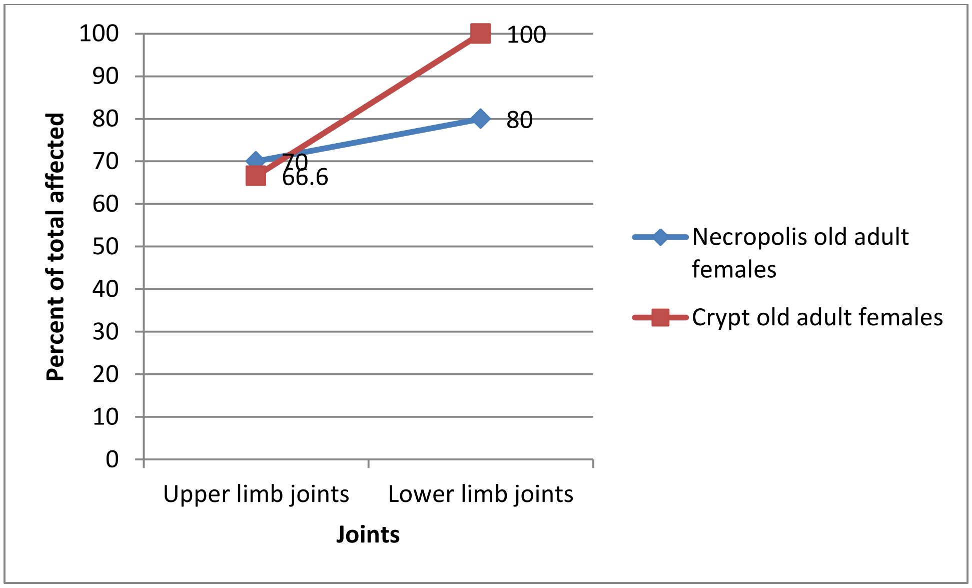


Figure C23 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt old adult females.

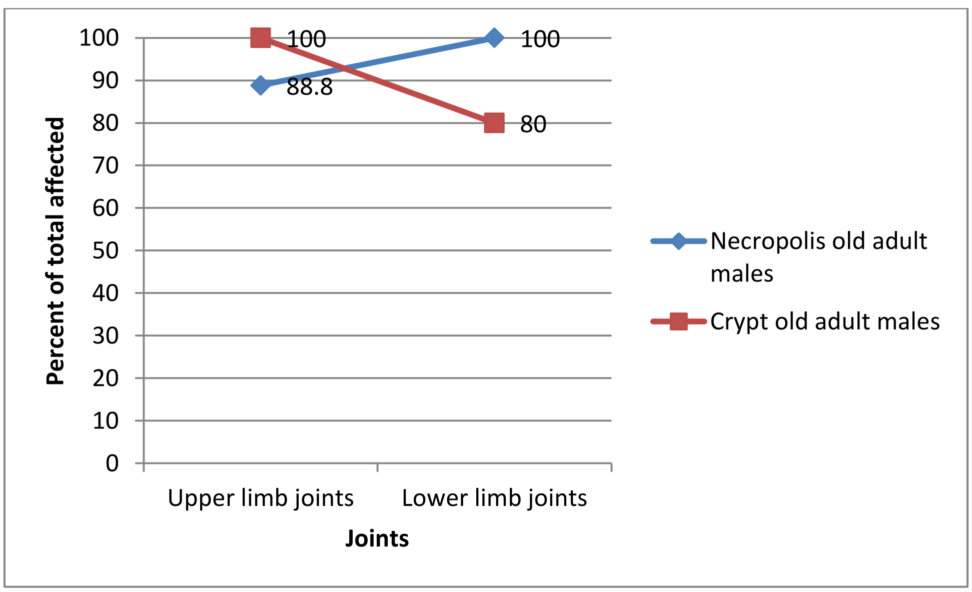


Figure C24 Crude prevalence comparison of osteoarthritis frequency in upper limb joints and lower limb joints - Necropolis and Crypt old adult males.

# APPENDIX D: CRUDE PREVALENCE OF OSTEARTHRITIS BY SEVERITY FIGURES

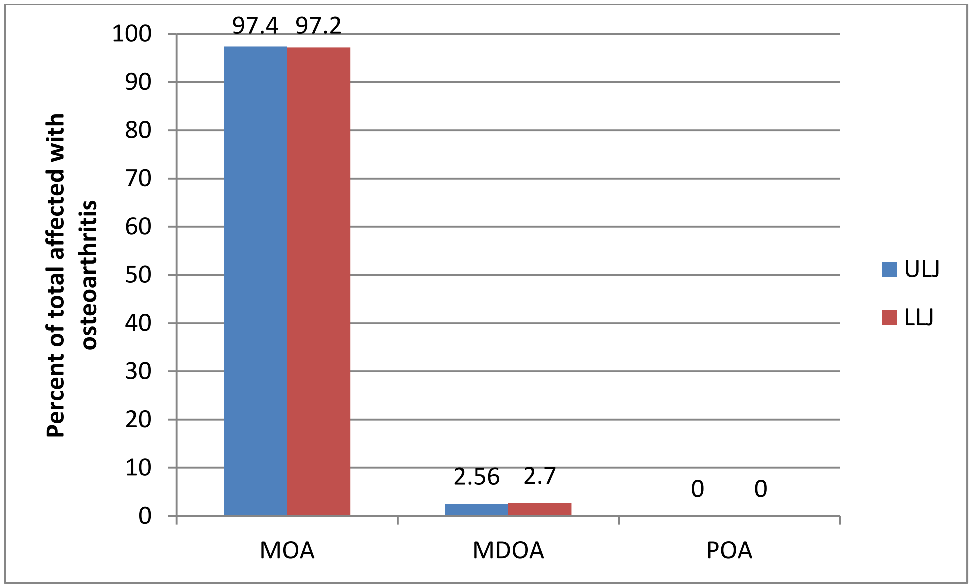


Figure D1 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis individuals.

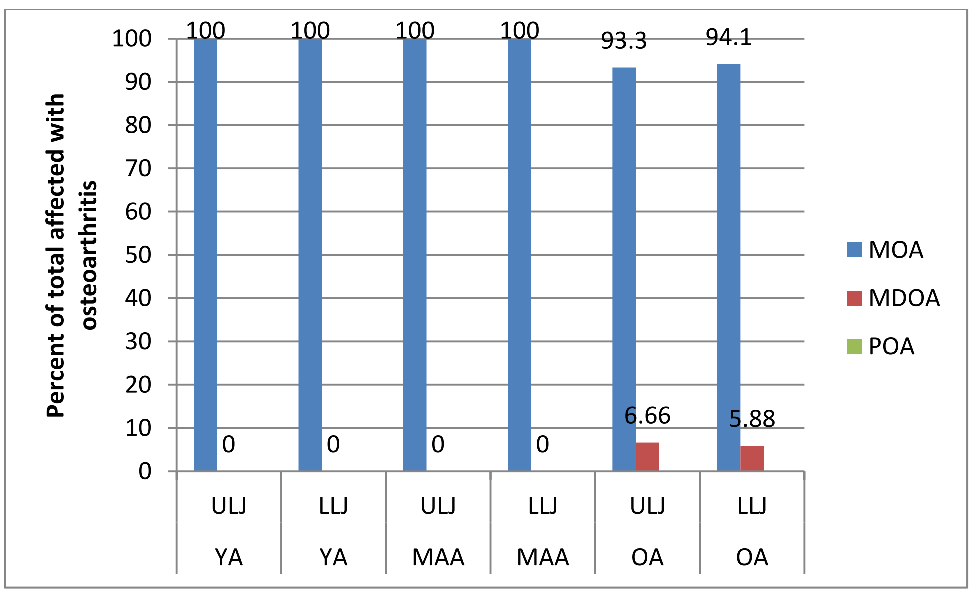


Figure D2 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis young adults, middle-aged adults, and old adults.

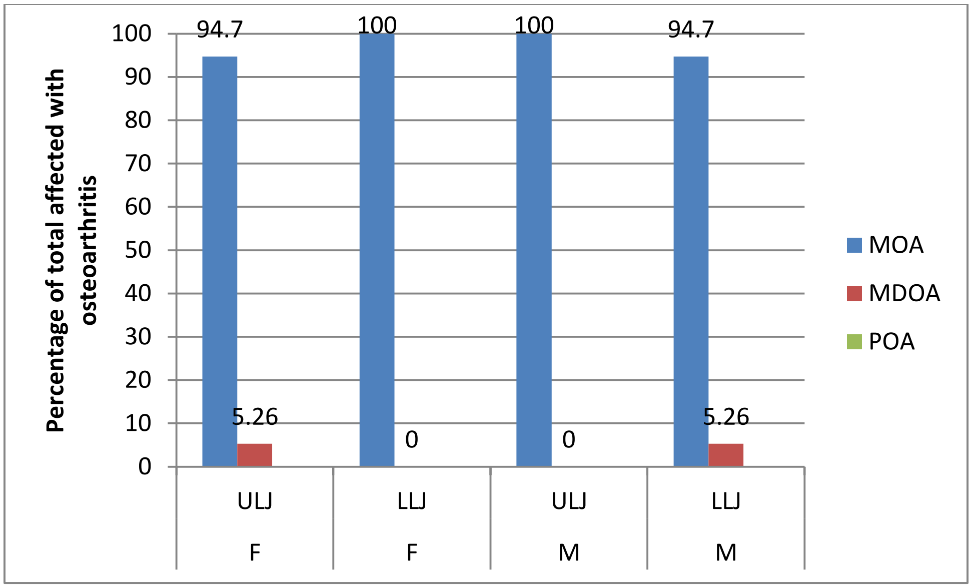


Figure D3 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis females and males.

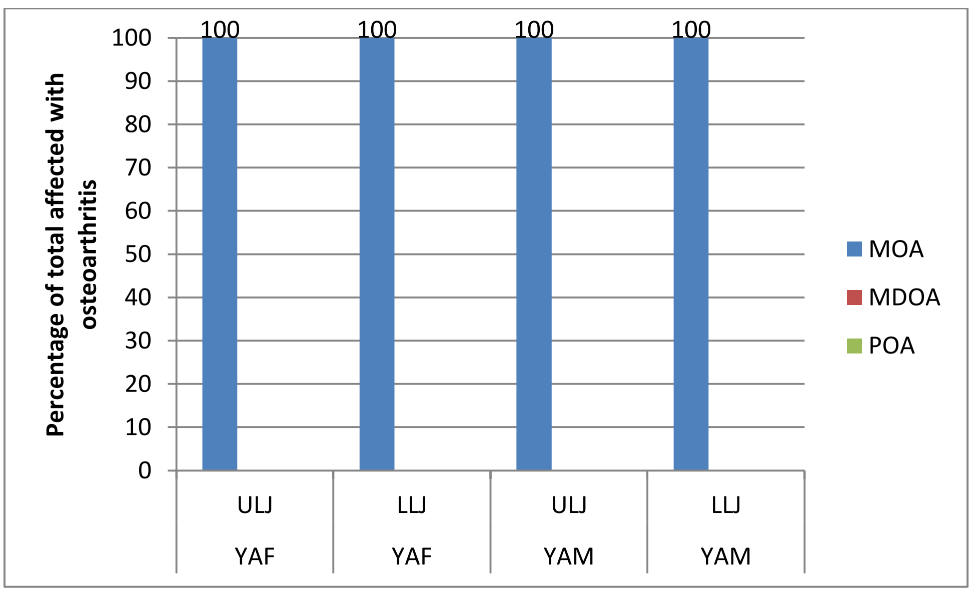


Figure D4 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis young adult females and young adult males.

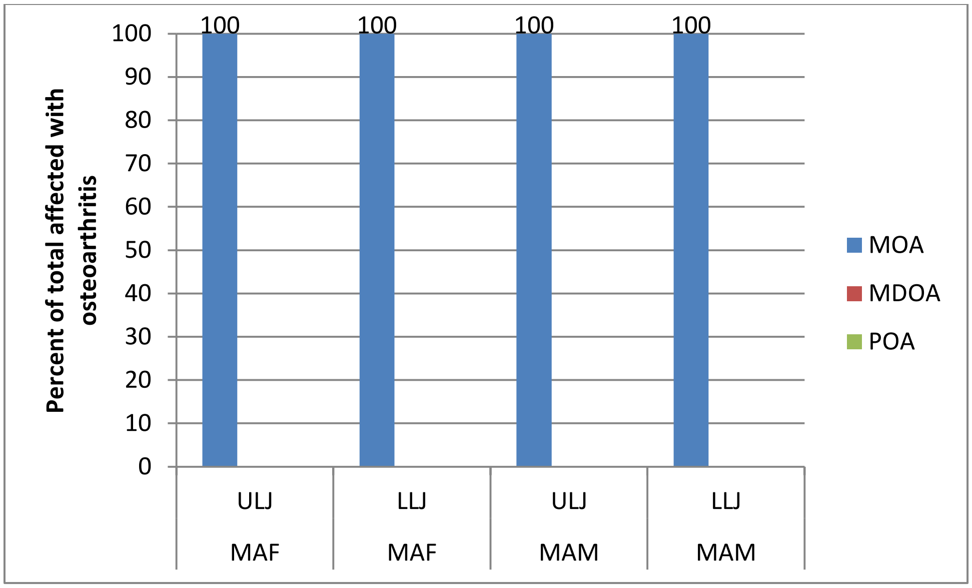


Figure D5 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis middle-aged females and middle-aged males.

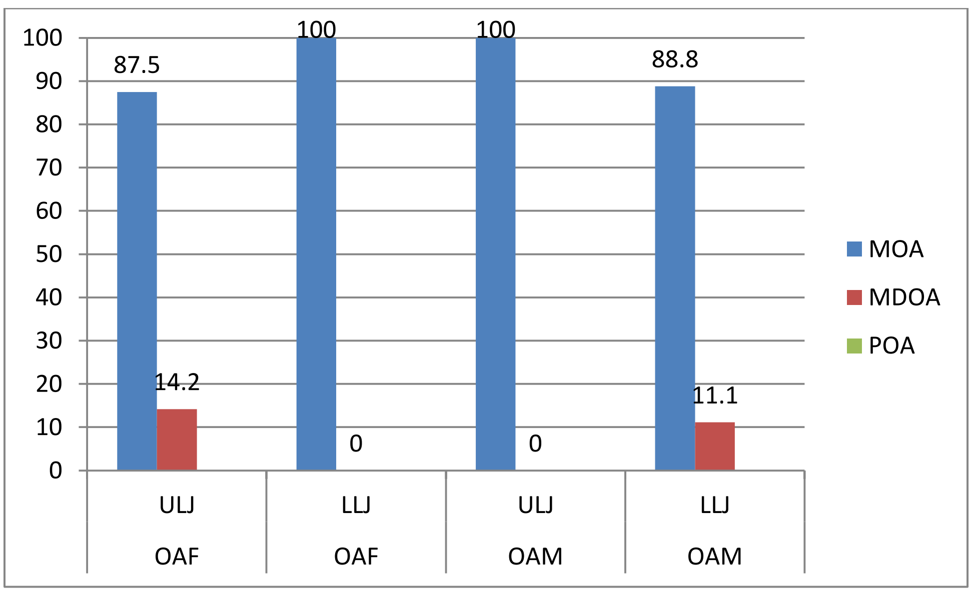


Figure D6 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis old adult females and old adult males.

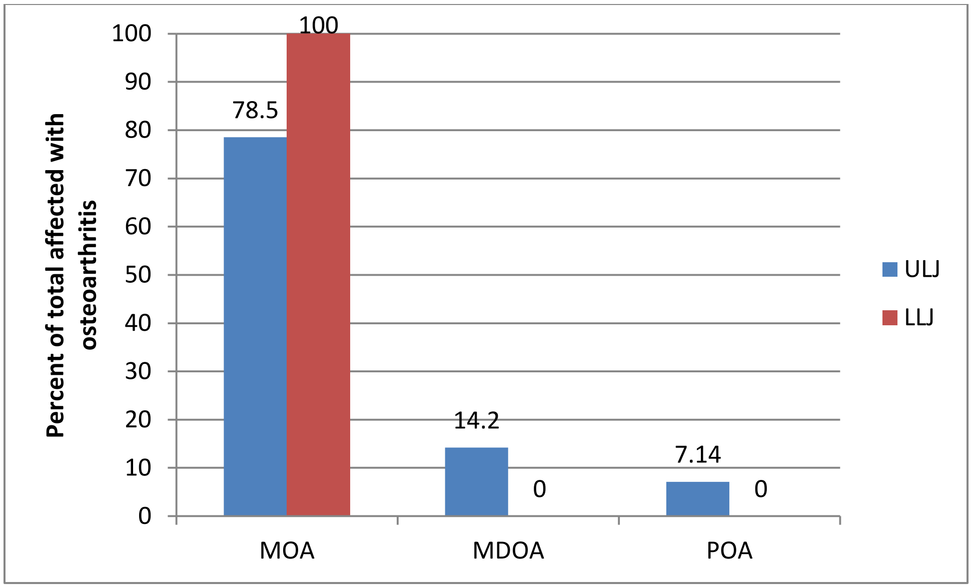


Figure D7 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Crypt individuals.


Figure D8 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Crypt young adults, middle-aged adults, and old adults.

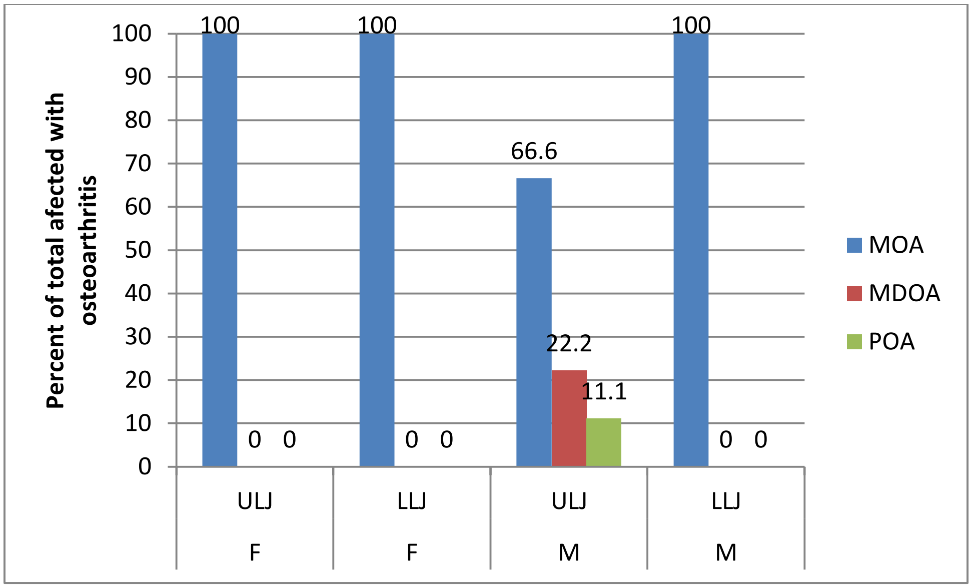


Figure D9 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Crypt females and males.

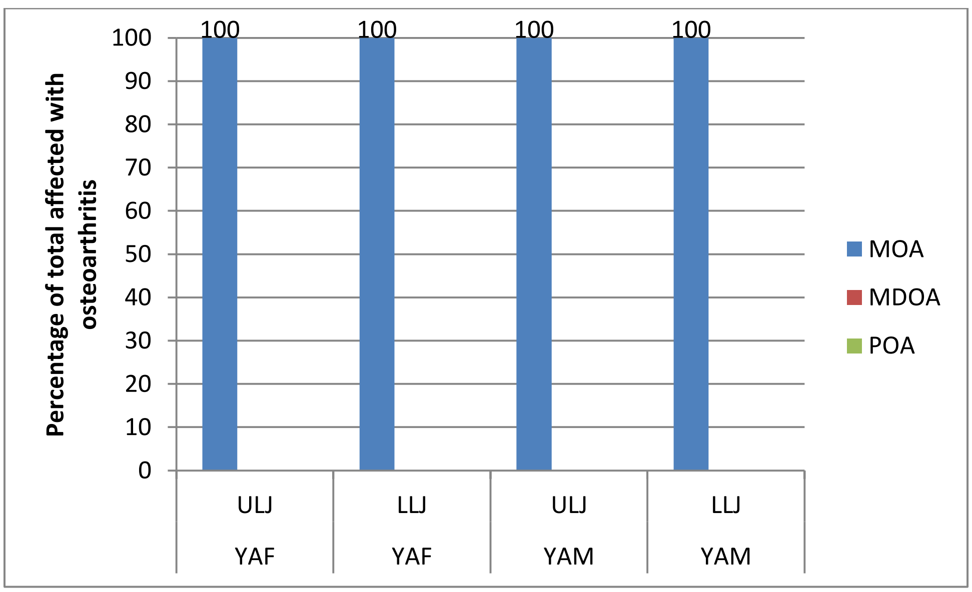


Figure D10 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Crypt young adult females and young adult males.

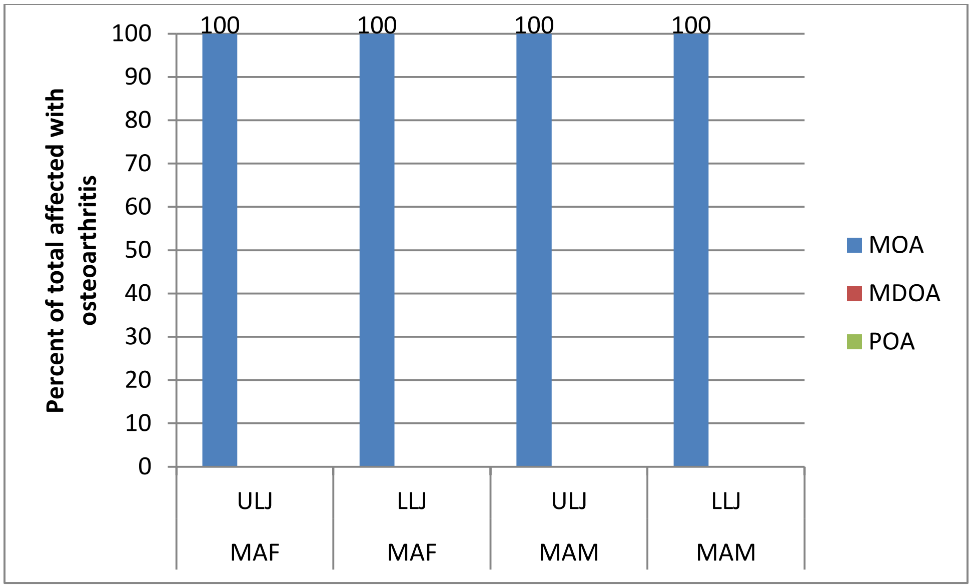


Figure D11 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Crypt middle-aged females and middle-aged males.

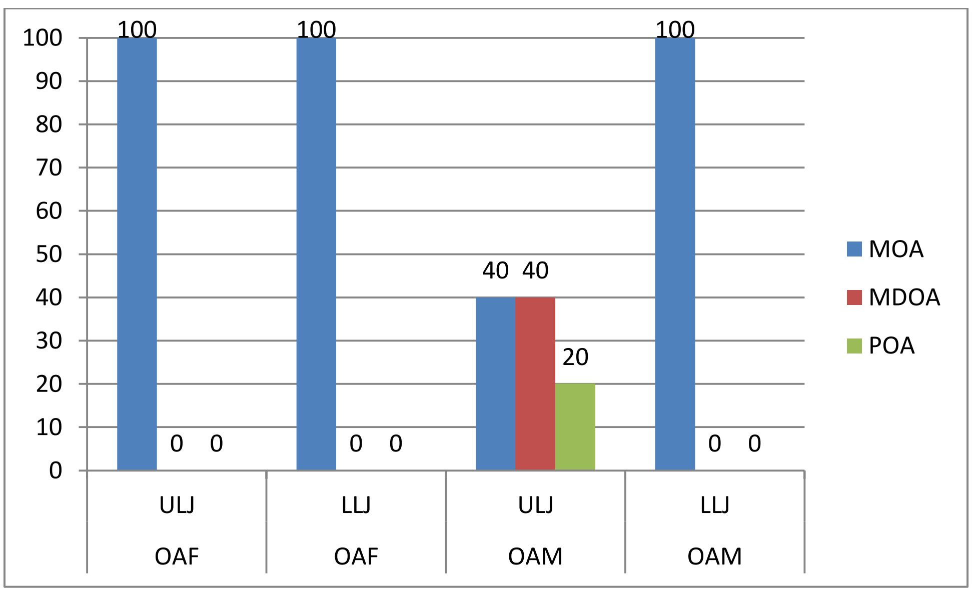


Figure D12 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Crypt old adult females and old adult males.

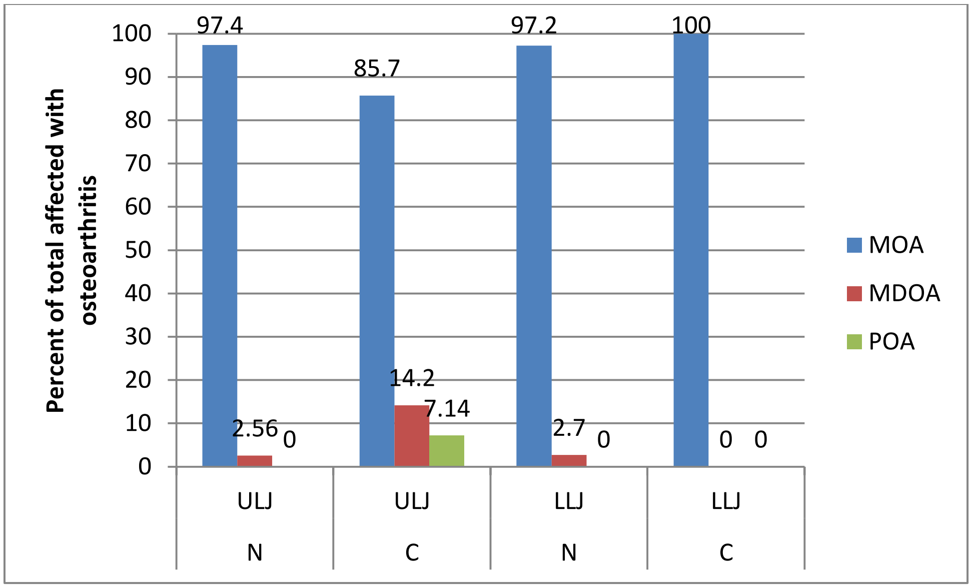


Figure D13 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and Crypt individuals.

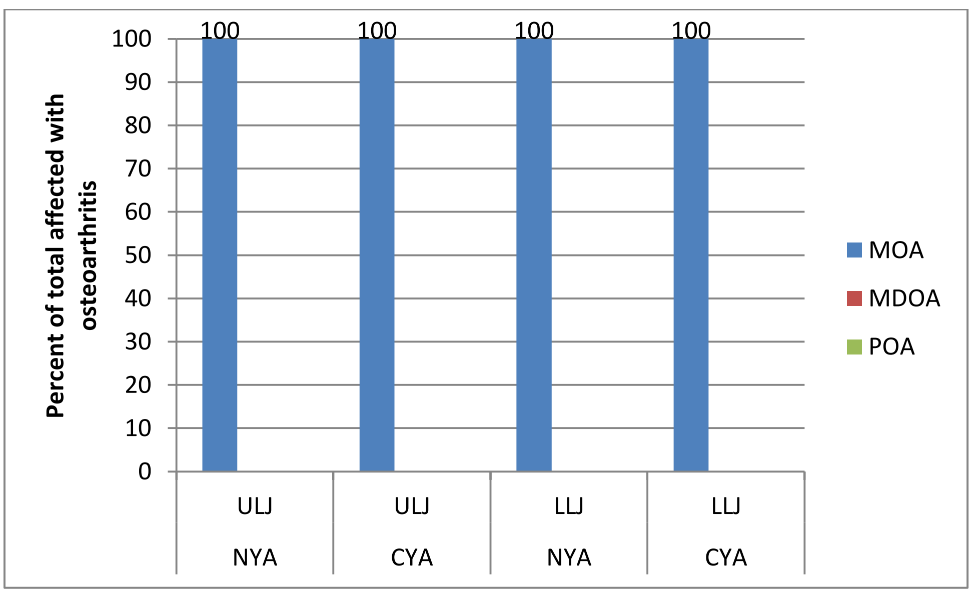


Figure D14 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and Crypt young adults.

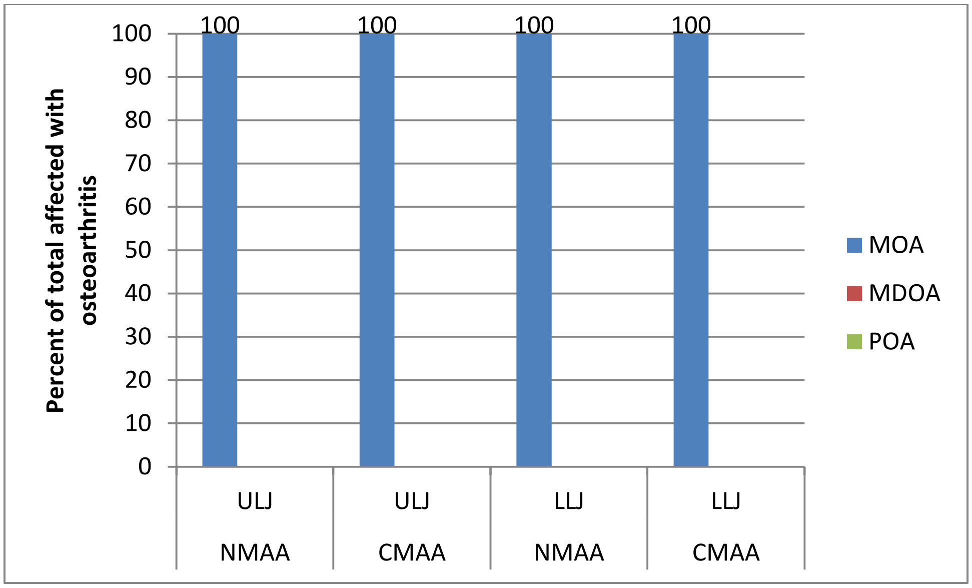


Figure D15 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt middle-aged adults.

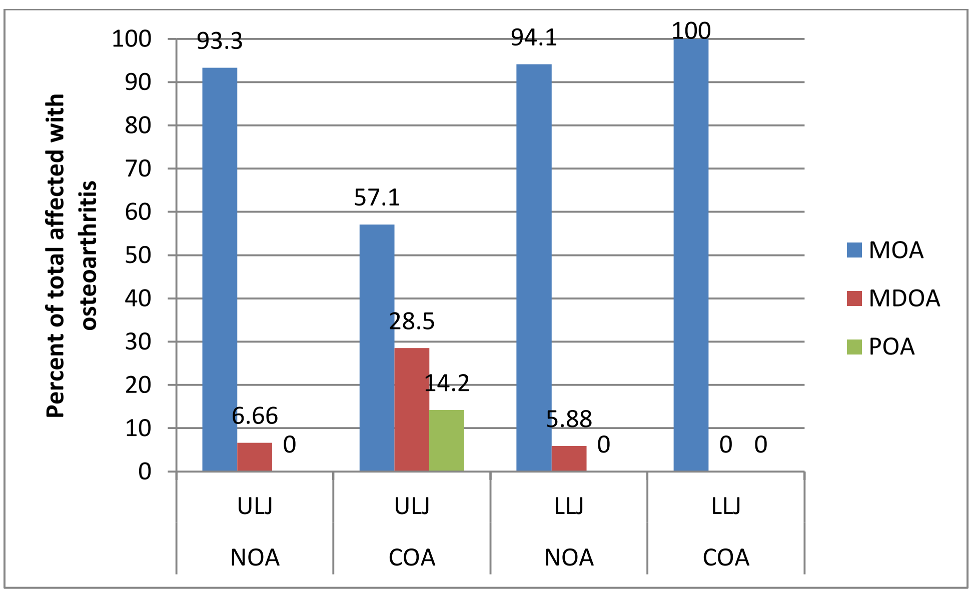


Figure D16 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt old adults.

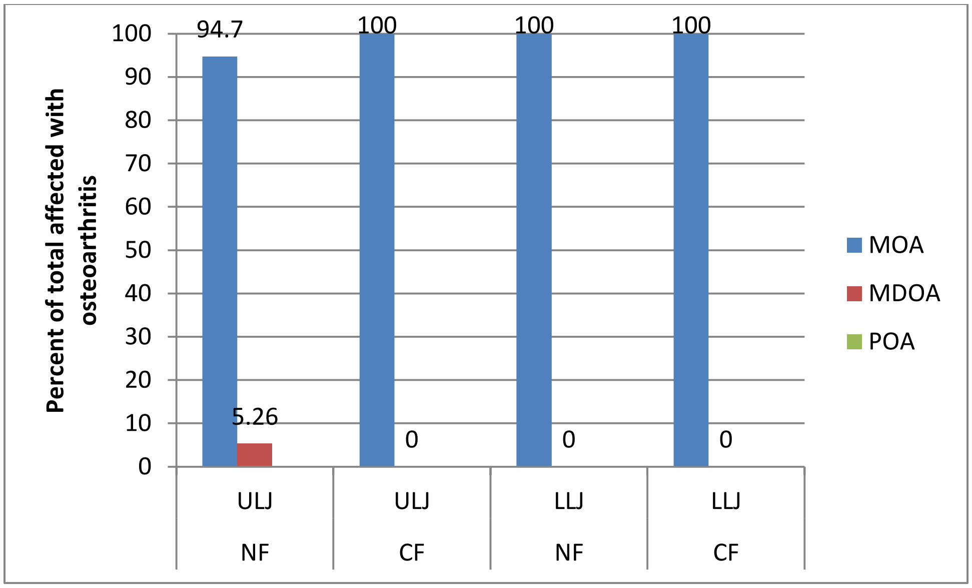


Figure D17 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt females.

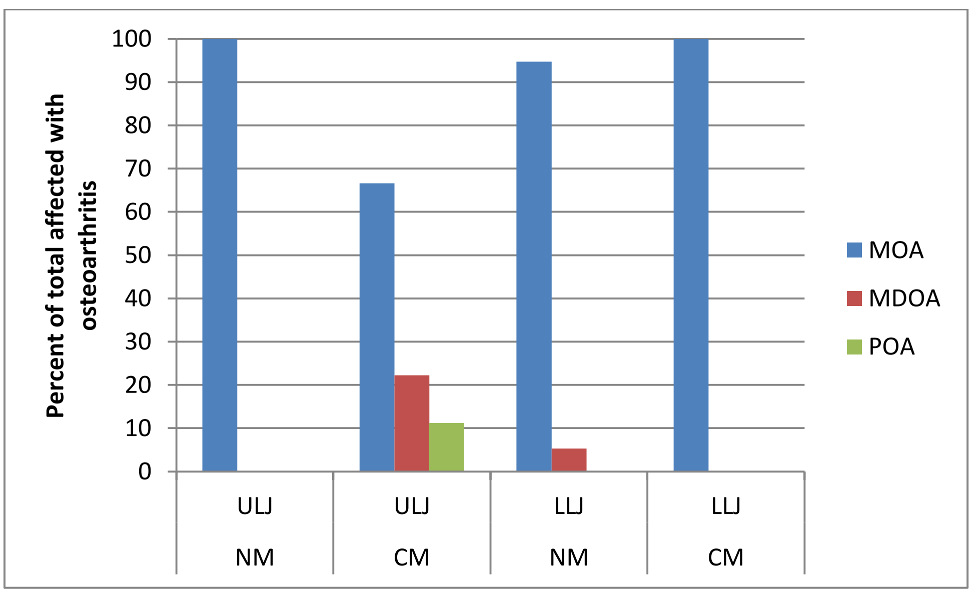


Figure D18 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt males.

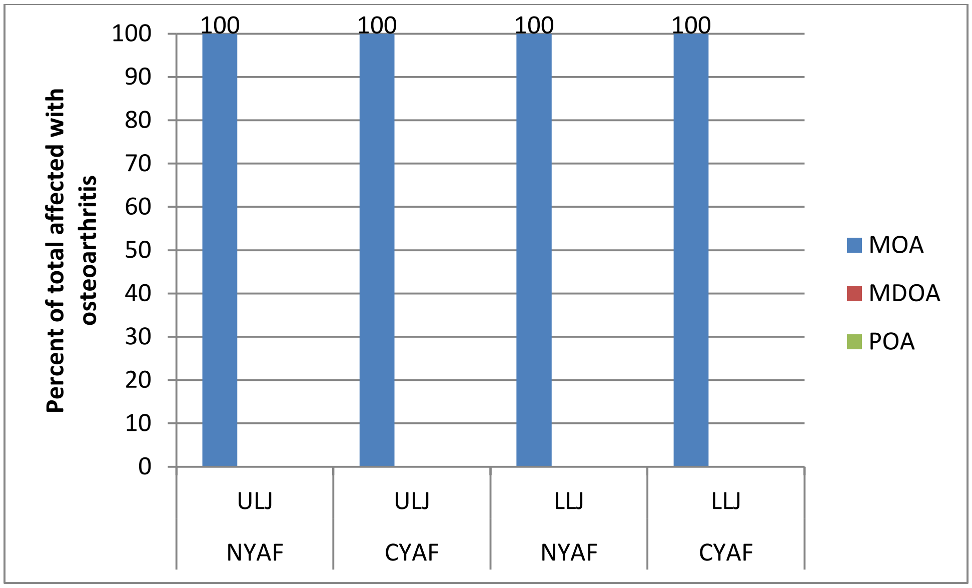


Figure D19 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt young adult females.

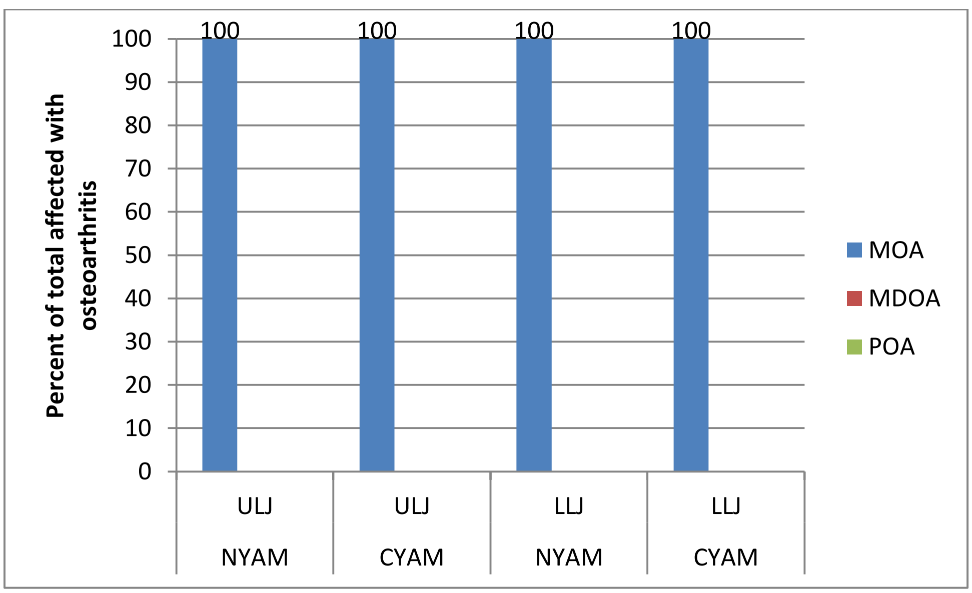


Figure D20 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt males.

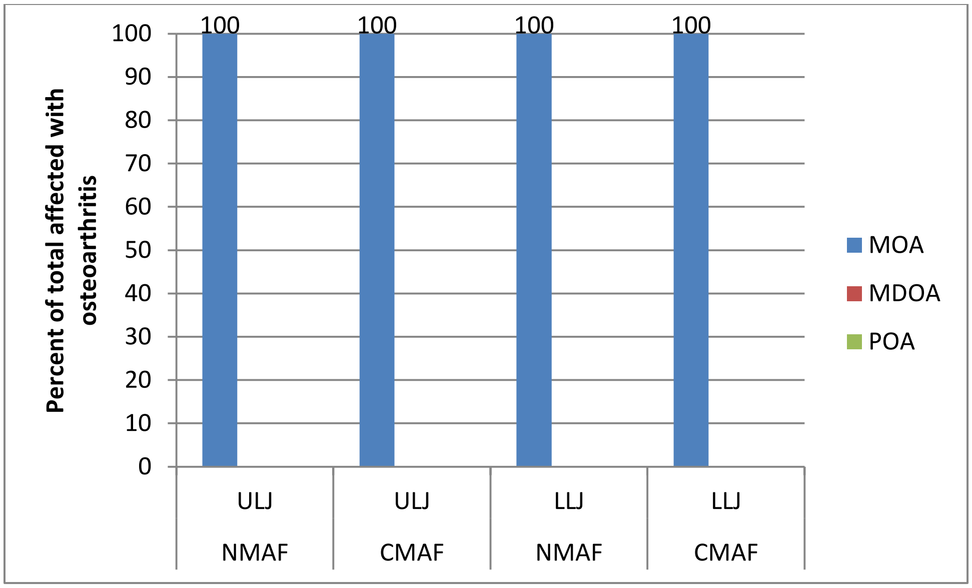


Figure D21 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt middle-aged females.

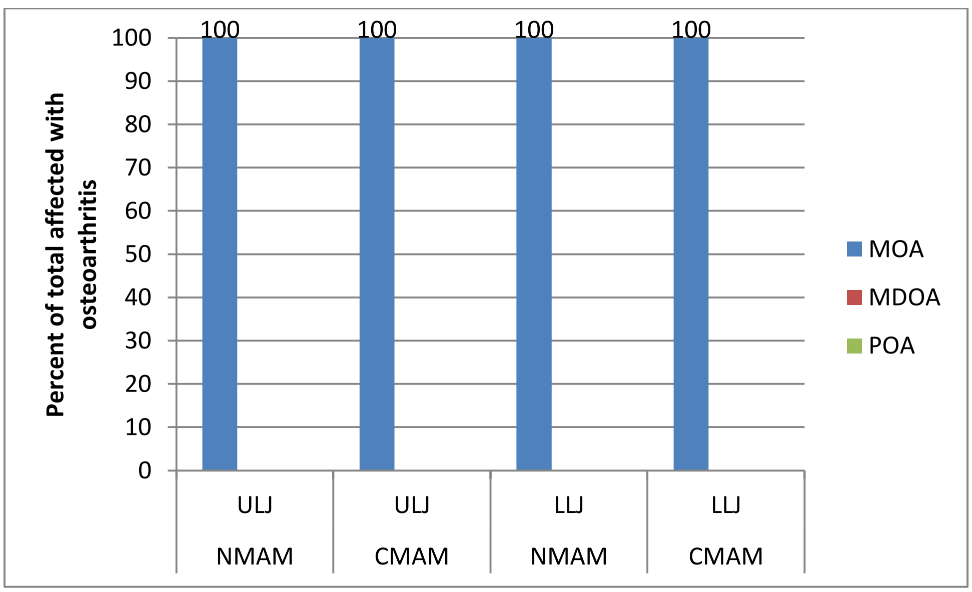


Figure D22 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt middle-aged males.

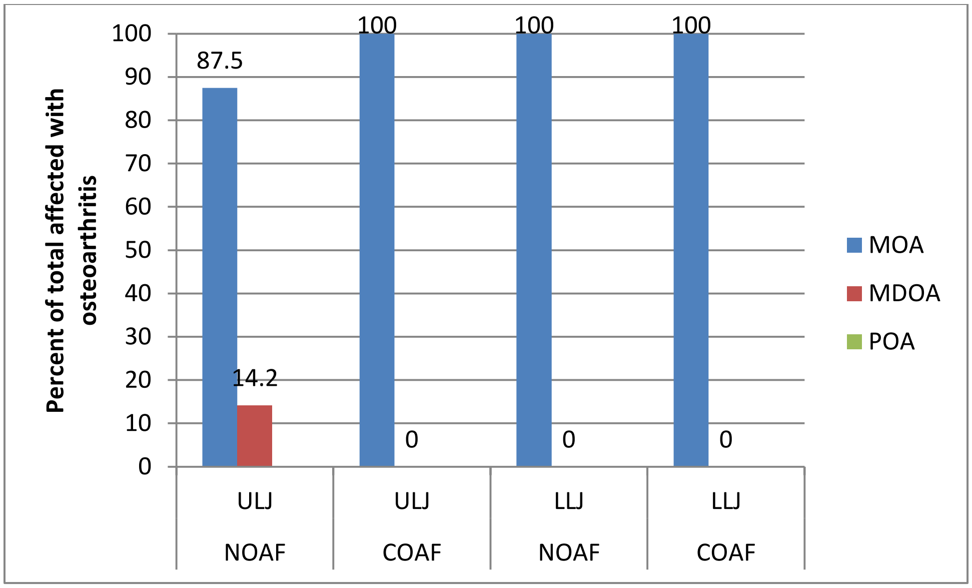


Figure D23 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt old adult females.

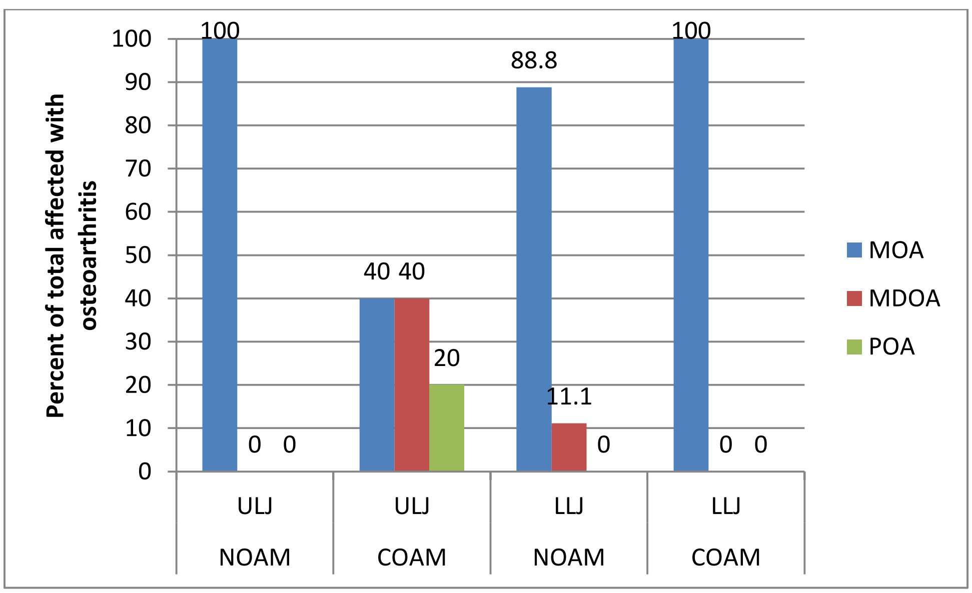


Figure D24 Crude prevalence comparison of osteoarthritis frequency by severity in upper limb joints and lower limb joints - all affected Necropolis and all affected Crypt old adult males.

# APPENDIX E: OSTEOARTHRITIS SCORES FOR MISTIHALJ INDIVIDUALS

(See abbreviations for definitions)

| Site | Individual | Sex | Age | SL | SR | S | EL | ER | E | WL | WR | W | ULJ | HL | HR | H | KL | KR | K | AL | AR | A | LLJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 968-10-40/N8936 | M | YA | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| N | 968-10-40/N9227 | F | OA | MD | MD | MD | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| N | 968-10-40/N9228 | F | MA | M | P | MD | N | N | N | N | N | N | N | N | M | N | N | N | N | N | N | N | N |
| N | 968-10-40/N9166 | M | MA | N | N | N | M | M | M | X | M | M | N | N | N | N | N | N | N | N | N | N | N |
| N | 968-10-40/N9163 | F | YA | N | N | N | M | M | M | X | X | X | N | X | X | X | N | N | N | N | N | N | N |
| N | 968-10-40/N9164 | M | MA | N | N | N | N | M | N | N | N | N | N | M | M | M | N | N | N | M | N | N | N |
| N | 968-10-40/N8939 | F | OA | M | P | MD | X | M | M | X | M | M | M | M | P | MD | M | M | M | P | M | MD | M |
| N | 968-10-40/N9186 | M | MA | M | MD | M | M | M | M | N | M | N | M | M | M | M | N | N | N | N | N | N | N |
| N | 968-10-40/N9179 | F | OA | MD | M | M | M | M | M | N | N | N | N | M | M | M | M | M | M | N | N | N | N |
| N | 968-10-40/N9183 | F | OA | MD | M | M | M | M | M | N | N | N | N | M | X | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9180 | F | YA | N | M | N | M | M | M | X | X | X | N | M | M | M | P | M | MD | N | N | N | M |
| N | 968-10-40/N9032 | F | MA | M | M | M | M | M | M | M | M | M | M | N | M | N | N | M | N | N | M | N | N |
| N | 968-10-40/N9043 | M | MA | MD | N | M | M | M | M | M | M | M | M | N | N | N | M | M | M | M | M | M | N |
| N | 968-10-40/N9190 | M | YA | M | N | N | M | M | M | M | M | M | N | N | N | N | M | M | M | M | M | M | N |
| N | 968-10-40/N9085 | M | OA | M | M | M | N | M | N | M | M | M | N | M | M | M | M | M | M | M | M | M | M |
| C | 968-10-40/N9253 | M | OA | P | N | M | P | P | P | X | MD | MD | MD | N | M | N | M | M | M | M | M | M | N |
| C | 968-10-40/N9252 | M | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| C | 968-10-40/N9269 | F | OA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| C | 968-10-40/N9254 | M | MA | M | M | M | M | M | M | X | M | M | M | M | M | M | M | M | M | M | M | M | M |
| C | 968-10-40/N9268 | F | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | X | M | M | M |
| C | 968-10-40/N9265 | M | OA | X | P | P | X | X | X | X | X | X | P | X | X | X | M | M | M | M | M | M | M |
| C | 968-10-40/N9273 | F | MA | M | N | N | M | M | M | X | X | X | N | M | M | M | N | N | N | N | N | N | N |
| C | 968-10-40/N9261 | M | OA | M | M | M | MD | M | M | MD | M | M | M | M | M | M | MD | M | M | X | M | M | M |
| N | 968-10-40/N9406 | F | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| C | 968-10-40/N9277,78 | F | OA | X | M | M | N | M | N | X | X | X | N | M | X | M | M | M | M | M | X | M | M |
| C | 968-10-40/N9255 | M | YA | M | M | M | MD | MD | MD | N | N | N | M | N | N | N | MD | MD | MD | X | M | M | M |
| N | 968-10-40/N9049 | F | OA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9123 | F | YA | M | M | M | M | M | M | N | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9065 | F | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |

| Site | Individual | Sex | Age | SL | SR | S | EL | ER | E | WL | WR | W | ULJ | HL | HR | H | KL | KR | K | AL | AR | A | LLJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 968-10-40/N9070 | M | MA | M | N | N | M | M | M | M | N | N | N | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9143 | M | OA | M | M | M | M | M | M | MD | M | M | M | M | M | M | P | M | MD | M | M | M | M |
| N | 968-10-40/N9153 | M | YA | N | N | N | M | M | M | M | M | M | N | N | M | N | M | M | M | M | M | M | N |
| N | 968-10-40/N9177 | M | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9176 | M | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9172 | F | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9188 | PF | MA | M | M | M | MD | MD | MD | X | N | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9226 | F | YA | M | N | N | M | M | M | X | X | X | N | N | M | N | N | N | N | N | N | N | N |
| N | 968-10-40/N8997 | F | YA | N | M | N | M | M | M | N | M | N | N | N | N | N | N | M | N | N | N | N | N |
| N | 968-10-40/N9012 | F | YA | N | N | N | N | N | N | M | M | M | N | M | N | N | N | N | N | M | M | M | N |
| N | 968-10-40/N9167 | F | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | N | M | N | N |
| N | 968-10-40/N9182 | F | OA | MD | M | M | M | M | M | X | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9040 | F | YA | M | M | M | MD | MD | MD | N | M | N | M | M | M | M | M | M | M | M | N | N | N |
| N | 968-10-40/N92340 | F | MA | M | M | M | M | M | M | M | X | M | M | M | M | M | M | M | M | M | N | N | N |
| N | 968-10-40/N9064 | F | YA | M | M | M | M | M | M | X | X | X | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9120 | F | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9016 | F | OA | M | M | M | MD | MD | MD | X | P | P | MD | X | X | X | M | M | M | M | M | M | M |
| N | 968-10-40/N9121 | F | OA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9106 | F | OA | M | M | M | M | M | M | M | M | M | M | MD | MD | MD | M | M | M | M | M | M | M |
| N | 968-10-40/N9148 | M | OA | M | M | M | M | M | M | M | P | MD | M | MD | MD | MD | M | M | M | X | M | M | M |
| N | 968-10-40/N9097 | M | OA | MD | MD | MD | M | M | M | MD | MD | MD | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9170 | M | YA | N | X | N | N | N | N | MD | P | MD | N | M | M | M | M | M | M | MD | MD | MD | M |
| N | 968-10-40/N9218 | M | YA | M | M | M | M | M | M | M | P | MD | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9222 | M | YA | M | X | M | M | M | M | M | M | M | M | M | M | M | N | N | N | N | N | N | N |
| N | 968-10-40/N2225 | M | YA | M | M | M | X | X | X | M | M | M | M | M | M | M | M | M | M | N | M | N | N |
| N | 968-10-40/N9005 | M | MA | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9159 | M | MA | MD | P | MD | M | M | M | M | M | M | M | M | M | M | MD | MD | MD | M | M | M | M |
| N | 968-10-40/N9160 | M | MA | M | M | M | M | M | M | M | X | M | M | M | M | M | N | M | N | P | MD | MD | M |
| N | 968-10-40/N9205 | M | OA | M | MD | M | M | M | M | M | M | M | M | MD | MD | MD | MD | MD | MD | M | M | M | M |

| Site | Individual | Sex | Age | SL | SR | S | EL | ER | E | WL | WR | W | ULJ | HL | HR | H | KL | KR | K | AL | AR | A | LLJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 968-10-40/N9105 | M | OA | M | M | M | M | M | M | M | M | M | M | M | MD | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9194 | M | OA | MD | MD | MD | M | M | M | M | M | M | M | M | M | M | P | P | P | P | P | P | MD |
| C | 968-10-40/N9272 | F | YA | X | X | X | X | M | M | X | X | X | M | X | M | M | N | N | N | N | M | N | N |
| C | 968-10-40/N9249 | F | MA | M | M | M | M | M | M | X | M | M | M | M | M | M | P | MD | MD | M | M | M | M |
| C | 968-10-40/N9291 | M | MA | P | P | P | M | M | M | M | M | M | M | M | M | M | MD | MD | MD | MD | MD | MD | M |
| C | 968-10-40/N92754 | PM | OA | P | P | P | X | M | M | X | X | X | MD | M | M | M | MD | MD | MD | M | MD | M | M |
| C | 968-10-40/N9250 | F | OA | M | M | M | X | M | M | X | M | M | M | MD | M | M | M | M | M | X | M | M | M |
| C | 968-10-40/N9246 | PM | OA | X | X | X | M | M | M | X | M | M | M | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N9096 | F | YA | N | N | N | N | N | N | N | N | N | N | N | N | N | M | M | M | M | M | M | N |
| N | 968-10-40/N9079 | M | YA | N | M | N | M | M | M | M | M | M | N | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N8959 | PM | MA | M | P | MD | M | M | M | M | M | M | M | MD | MD | MD | P | M | MD | M | M | M | M |
| N | 968-10-40/N9200 | M | OA | MD | P | MD | M | MD | M | X | M | M | M | M | MD | M | M | M | M | M | M | M | M |
| N | 968-10-40/N8988 | PM | MA | M | M | M | M | M | M | M | M | M | M | N | M | N | M | M | M | M | M | M | N |
| N | 968-10-40/N9054 | F | MA | M | M | M | MD | M | M | M | M | M | M | M | M | M | M | MD | M | M | M | M | M |
| N | 968-10-40/N8979 | F | YA | M | M | M | N | N | N | N | M | N | N | M | M | M | M | M | M | M | M | M | M |
| N | 968-10-40/N8983 | PM | YA | M | N | N | M | M | M | N | M | N | N | N | N | N | M | M | M | M | N | N | N |
| N | 968-10-40/N9048 | M | OA | M | MD | M | M | M | M | M | MD | M | M | MD | MD | MD | M | M | M | M | M | M | M |
| N | 968-10-40/N9139 | F | OA | M | M | M | M | M | M | M | M | M | M | M | MD | M | M | M | M | M | M | M | M |

# APPENDIX F: OVERALL OSTEOARTHRITIS PREVALENCE COMPARISONS BETWEEN LEFT AND RIGHT SIDES OF INDIVIDUAL JOINTS

| Side | Joints | n/N | % | OR | p-value |
|---|---|---|---|---|---|
| L | Shoulder | 61/72 | 84.7 | 1.33 L+ | 0.5101 |
| R | Shoulder | 58/72 | 80.5 | | |
| L | Elbow | 60/70 | 85.7 | 0.62 R+ | 0.3727 |
| R | Elbow | 67/74 | 90.5 | | |
| L | Wrist | 42/56 | 75 | 0.60 R+ | 0.2584 |
| R | Wrist | 55/66 | 83.3 | | |
| L | Hip | 57/72 | 79.1 | 0.62 R+ | 0.2906 |
| R | Hip | 61/71 | 85.9 | | |
| L | Knee | 61/76 | 80.2 | 0.76 R+ | 0.5251 |
| R | Knee | 64/76 | 84.2 | | |
| L | Ankle | 55/71 | 77.4 | 0.93 R+ | 0.8607 |
| R | Ankle | 59/75 | 78.6 | | |

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