Sex Without the Head or the Hips:

The Inferences Made on Bone and the Use of the Lower Body to Estimate Sex

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

When it comes to the sex estimation of a skeleton, the main factors contributing to which methods are used depend on which skeletal elements are present. When a skeleton is uncovered that is essentially complete, with little deterioration due to taphonomic processes, it can be easy to use morphological methods in identifying sex. These methods generally rely on the use of the skull and the pelvic gridle. However, when it comes to archaeological excavations and forensic cases, the remains that are uncovered are rarely in perfect condition and seldom complete. It has become essential within studies to identify methods revolving around the estimation of sex through a variety of skeletal remains, such as the bones of the lower body. Although the postcranial bones of the lower body can be sexed, the methods are less widely applicable since they are much more population specific than the sexually dimorphic traits of the skull and pelvis. However, more work must be done in the use of the lower body in order to standardize these methods and broaden their applicability. Through an examination of the literature and published studies, a database has been created that focuses on investigations that analyze sex methodologies from the bones of the lower body. It is through the analysis associated with this database in which themes have been uncovered that need to be addressed. These themes involve the correlation between elements, the use of univariate and multivariate analysis, the measurements taken on the bones and which show more dimorphism than others, discussions surrounding which side of the bones have been utilized and evidence of asymmetry. By utilizing metric methods and creating a database that addresses the standards and problems surrounding these methods, we have the ability to offer other options, as well as provide the opportunity to highlight the ability to identify the diversity of past peoples' social and biological identity through a much wider selection of skeletal elements.

Key Words: Bioarchaeology, sexing methodologies, metrics, discriminant function analysis, sex estimation

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Chapter 1: The Publics, Archaeology, and Forensic Anthropology

1.1 Introduction

The information gathered by archaeological investigations is of particular importance as it provides insights not only regarding a site itself, but also the lives of those that occupied the site. When it comes to skeletal remains, it must be noted that although they provide a wealth of knowledge and information, they are only a sample of any given population. Yet there are tools and methods that if properly utilized in the study of human remains, can help contribute to our understanding of the society as a whole. It must be kept in mind that although skeletal remains themselves are products of the past, their history and the analysis of the samples may influence and have implications within the modern world.

It is within this argument of modernity that we see exactly how public anthropology can become a useful tool with engaging the publics in open discussions about the past and present. It is important to consider not only how the discipline can impact the views on the world as we see it today, but also how it can play a part in helping to uncover facts and truths about something that has occurred in the past. It is through topics such as heritage studies and forensic archaeology/anthropology that we see how the research that has developed within bioarchaeology are important to the publics.

1.2 Changes Due to COVID-19

Before discussing publics archaeology and ethical considerations, it is important to understand that the research shown throughout this thesis has changed from where it began to what it has become. As a result of COVID-19 restrictions, the initial topic changed. My proposed research involved the study of the material from the Sanctuary of Ismenian Apollo at Thebes, excavated by Kevin Daly and Stephanie Larson of Bucknell University from 2011-2015. The site includes an Early Christian/Byzantine cemetery that had been located in the abandoned sanctuary; this cemetery appears to relate to an Early Christian monastery and hospice (Liston 2019). Graves at the site have been partially exhumed as part of the regular burial process, and due to this, elements of the skeleton that are most often used to evaluate and examine the sex of individuals are missing (Liston 2019). However, there are complete feet and leg bones that have been uncovered from most of the burials. I initially proposed to use the tarsal bones, specifically the talus and calcaneus, to determine the sex of the individuals and identify the impacts of any pathology present on this analysis.

Unfortunately, this topic became impossible to pursue with restrictions to travel. Although a lot of the background research previously completed could no longer be used, an interesting theme did start to develop within the remaining articles that focused on sexing methods revolving around elements beyond the pelvic girdle and cranium. It was through this idea of determining sex when those commonly used elements are missing that a new thesis was formed.

1.3 Publics Issues

An especially important aspect to the field of bioarchaeology and those disciplines involved is their relationship with the publics. Yet the definition of 'public' is not as straightforward as one would believe; thus, neither is the definition of public archaeology. In order to understand one, we must understand the other, as they are twofold, and are interconnected. The publics that are known within 'public archaeology' has been used to reference several different areas, including the general public, those who do not have any formal training and the public sector, those within heritage management that are involved in the preservation and administration of archaeological resources (Richardson and Almansa-Sanchez 2015, Grima 2016, Oldham 2017). However, even within this definition of the publics, there is a separation based on one's geographic location, culture, and society (Richardson and Almansa-Sanchez 2015). Due to this, it is important to understand that there is no single, standardized group that will fit into a basic definition of who is the public. This means that there cannot be one section within the discipline that has a sole focus on dealing with the public, nor is there one area that can answer all the questions relating to the public (Grima 2016). Therefore, it becomes multi-disciplinary and a key focus is the co-operation between a multitude of sectors, disciplines, and individuals, all of whom will be impacted by the work being conducted.

1.3.1 Heritage and Bioarchaeology

When we look at the relationship between bioarchaeology and the publics, an important consideration is how the information uncovered will impact the modern world. The most straightforward connection regarding this is how the interpretations created will affect the public's view on heritage. Cultural heritage is an important topic, and it is a topic that will have a direct impact not only on how people view themselves and their past, but also those around them. It is key to understand that although extremely important, public archaeology does not only involve working with communities and providing educational opportunities, but that it is also about the management of the knowledge uncovered and how it relates to this concept of heritage (Richardson and Almansa-Sanchez 2015). The discipline of bioarchaeology itself is one in which there are regular changes regarding the knowledge and understanding of what has been uncovered. It is this constant dialogue within the discipline that has led to a relationship between the past and the present, which has therefore led to an importance in understanding how archaeology affects the publics regarding heritage.

1.3.2 Forensic Anthropology

Bioarchaeology and forensic anthropology are related disciplines with differing objectives and goals. Both rely on a set of methods, practices, and terms to answer the questions their investigation has provided. It is within these areas of discussion in which we see an overlap in the work conducted and it is here we see an importance to the publics. The methods and terminology revolving around the estimation of sex in a bioarchaeological sample and a modern forensic sample are similar, yet different (Scheuer 2002, Ubelaker 2006). Both disciplines utilize non-metric and metric methods; the former applies the visual assessment of an element to determine sex, compared to the latter, which employs measurements, statistics, and functions to determine the probability of biological sex. It is within these differences throughout the disciplines that one notes distinctive terminology. Despite the differences between the disciplines, the crossover is great enough that words like ‘assessment’, ‘estimation’, ‘determination’, ‘accuracy’, and ‘reliability’ need to be standardized to assist in public understanding. For more on this, see the work conducted by Bruzek and Muraik (2006) and Moore (2013).

Skeletal collections of known sex have been studied, allowing for the development and reliability not only of the methods used, but the terminology as well. By creating multi-disciplinary conversations and acknowledging the differences that have created discrepancies or similarities, we offer the chance as researchers to engage not only with other disciplines, but also the publics in open discussions surrounding topics of the past and present. It is this collaboration between the disciplines and the creation of a multitude of methods that offer investigators the ability to identify the individual(s) within their sample when they are faced with incomplete or damaged remains.

1.4 Discipline Relevance

The discipline of bioarchaeology is vast, and there are a variety of reasons as to why the following research will be important within the field. Although long bones of the lower leg and the bones of the foot can be sexed, the methods are less widely applicable since they are much more population specific than the sexually dimorphic traits of the skull and pelvic girdle. However, these bones should not be so easily and immediately dismissed when it comes to sex investigations and more work must be done in this area to standardize these methods and broaden their applicability. Also, sex is a universal variable that will be present within all skeletal investigations regardless of the question being asked. This makes research surrounding sex and sex methodology important in the discipline.

In Chapter Two, I will examine the use of metric methods as a viable sexing practice, that can augment the more commonly used methods and provide reasonably accurate data when the skull and pelvic bones are not available. Through my discussions in Chapter Two, I will suggest areas where improvement is needed. An important aspect to this thesis is Appendix A (pages 45-59), in which I have assembled a database of investigations that analyze sex from the bones of the lower body. A database of this kind can be extremely useful to bioarchaeologists in the field and lab when skeletal remains are uncovered, especially if the bones are commingled, partial, or fragmentary, or when those elements that are more commonly used to estimate sex are too damaged to be used or are missing altogether. The database is organized by skeletal element and provides the population under investigation as well as the accuracy of the results and the methodology utilized. This can be used to quickly identify appropriate methods and references when only limited skeletal elements have preserved to the degree needed to be used to identify sex. The database produced makes investigations that have already been completed on different populations and different periods more accessible to researchers conducting similar work. Following the database, I have compiled several tables that can also be useful within the discipline (Appendices B to E, p. 60-76). These tables vary, as they focus on measurements used and summarize those variables that are the most or least accurate and dimorphic, which can be helpful to researchers using those specific elements.

1.5 Proposed Venue for Publication

My research would be appropriate for publication to the *International Journal of Osteoarchaeology*. This journal has been chosen due to the fact that it focuses on original research regarding both human and animal remains within a variety of archaeological perspectives (Wiley Online Library 2020). The papers submitted to this journal seek to identify and understand past ideologies based on the examination of skeletal remains (Wiley Online Library 2020). This journal is important regarding its focus and impact within the fields of anthropology, archaeology, forensics, and arts and humanities. The journal is easily accessible to both the academic and non-academic populations and will therefore be publicly available to anyone who has an interest in the research at hand. Although there is a paywall, members of the community will have access to my research through Wiley Online Library.

Chapter 2: The Lower Body Being Used to Estimate Sex

2.1 Introduction

As an interdisciplinary field, bioarchaeology is well placed to contribute to the understandings of a wide range of knowledge of past individuals and populations. Skeletal remains offer a direct and substantial link to understanding our past, and we have an obligation as researchers to serve not only past, but also present, and future generations with our knowledge. Bioarchaeologists rely on the use of qualitative and quantitative analyses to generate conclusions surrounding differences in behaviour based on functional adaptations, as well as environmental and genetic differences. It has become essential within studies to identify methods revolving around the estimation of sex beyond the use of the pelvic gridle and the cranium. Even though methods surrounding sex estimation of postcranial bones of the lower body are population specific, the accuracy rates are proven to be just as reliable (Kemkes-Grottenthaler 2005, Murphy 2002. Garcia 2012). Therefore, more work needs to be done in this area to standardize these methods and broaden their applicability.

2.1.1 Creating a Biological Profile

When skeletal remains are uncovered, either archaeologically or forensically, the first and most important question to ask is who do the bones represent. This leads to the estimation of the four main components of a biological profile: sex, age-at-death, ancestry, and stature. Creating a precise profile will revolve around understanding how they all affect one another. By having accurate estimates in each component, the identity of the individual’s skeletal remains becomes much more specific.

It is through standard works (e.g. . Phenice 1969, Trotter 1970, Meindl and Lovejoy 1985, Brooks and Suchey 1990, Buikstra et al. 1994, and White and Folkens 2005) that we have methods that enable researchers to properly and accurately identify the information needed to conduct their investigations. However, many of these resources focus on the cranium and pelvic girdle, two elements that best reflect biological differences in sex, but which may not always preserve well enough to be properly utilized, or which may have been lost due to post-mortem cultural practices. It has been widely accepted across the discipline that the use of the pelvic girdle provides the most reliable and accurate results when it comes to sex estimation of skeletal remains and this can be seen due to the differing reproductive roles of males and females (White and Folkens 2005). The skull is considered the next best element after the pelvis for sex estimation due to the visual, morphological traits that have been identified regarding sexual dimorphism of the cranium (White and Folkens 2005). However, the skull and pelvis do not always preserve, and other bones may be needed to evaluate sex, in particular, the postcranial bones of the lower body.

2.1.2 Intrinsic Factors and Extrinsic Factors

Factors contributing to sexual dimorphism in the human skeleton that arise from the biology of the individual are known as intrinsic factors (Moore 2013). Extrinsic factors are those that are introduced from outside of the body (Moore 2013). Examples of extrinsic factors include nutrition and adaptations based on environmental stressors. They may also reflect the physical workload and forces being applied to the muscles of the individual. These factors may be responsible for both rate acceleration and reduction of growth and development, depending on the specific situation (Moore 2013).

Postcranial bones, especially long bones such as the femur and tibia, may vary by sex due to differences in the timing of growth, which results in a difference in lengths of certain bones between biological males and females (Ruff and Hayes 1988, Lieberman et al. 2001). Despite this being partially due to genetics and therefore can be classified as an intrinsic factor, the growth seen in these bones can also be associated with extrinsic factors such as the environment and nutrition (Moore 2013). These examples blur the line between solely intrinsic versus extrinsic factors and we must look at how each influences the other in order to properly understand how postcranial bones, specifically those of the lower body, can be successfully used to estimate the sex of an individual.

As noted by Moore, "the plasticity of bones during growth and development enables our skeletal system to be designed specifically for our size/weight, activities, and behaviours" (Moore 2013, 94). It is these load-bearing bones that show a direct relationship between growth and development influenced by intrinsic and extrinsic factors, and the measurements and traits investigated when creating a statistical equation to estimate sex (Ruff and Hayes 1988, Lieberman et al. 2001, Moore 2013). By understanding both genetic and environmental factors that play a role in growth and development of the lower leg bones, bioarchaeologists are better able to develop informed estimations of sex. Although intrinsic factors are more common across all populations, their rate of development may differ given other extrinsic factors at play (Moore 2013). Being able to identify these traits may be key in understanding how one can use the research of a different population or group than their own. It is through the use of metrics within sex investigations that conclusions can be made on this topic.

2.2 Sex Assessment and Estimation of Bones of the Lower Limbs

2.2.1 Materials and Methods

This thesis is a meta-analysis of 79 investigations that I identified by using journals including the International Journal of Osteoarchaeology, the Journal of Forensic Science International, American Journal of Physical Anthropology, American Journal of Anthropology, World Archaeology Journal, Journal of Forensic and Legal Medicine, Journal of Public Archaeology, and more. These journals are used due to their interest in research related to bioarchaeology, forensic anthropology, the study of skeletal remains, and sex estimation. The 79 investigations chosen for the database (Appendix A, p.45-59) are those that focus on sex estimation utilizing the bones of the legs and feet.

Of these, 37 are studies of documented skeletal collections. Examples include: the Terry Skeletal Collection at the Smithsonian Institution, the Raymond A Dart Collection of Human Skeletons, the Luis Lopes Collection from the Natural History Museum of Lisbon, Hamann-Todd Collection at the Cleveland Museum of Natural History, the Coimbra Identified Skeletal Collection, the Frassetto Skeletal Collection, the Cretan Collection, and the Athens Collection.

Several investigations (30) are studies involving documented medical and forensic samples, body donation programs, and university skeletal collections. Examples include: the William M Bass Donated Skeletal Collection, the Yishui Medical School, the Chiang Mai University Hospital, Medico-Legal Institute at Bhopal, the Body Donation Program of the Department of Medical Biology at the University of Amsterdam, the Institute of Legal Medicine at the University, the Jikei Medical University, the Department of Radiology of the AMC, and the Clinic of Radiology of the University of Mainz.

Some investigations (12) utilize samples from archaeological sites and excavations. Examples include: the Prehistoric population remains from the Lowie Museum, the Libben Site Collection, Prehistoric Remains of the Canary Islands, Medieval Archaeological sites in Croatia, the Sao Martinho Medieval Collection, the Klunk, Koster, Schild and Yokem Mound Skeletal Series, and the Duff, Kirian, Treglia, Boose, Pearson Village, Sun Watch and Buffalo Sites. These investigations also included sex estimation methods using the pelvic girdle and cranium to support their accuracy results. These studies cannot verify the actual biological sex, meaning they are less valuable than the studies presented with known and documented material.

For inclusion within my database, the reported accuracy results of the identified investigations had to be above 60%. There are five (5) exceptions to this cut-off point, including: Dittrick and Suchey (1986) with their lowest range being at 53.8%, Robinson and Bidmos (2011) with their lowest range being at 54.7%, Bidmos and Dayal (2003) with their lowest range being at 57.5%, Abd-Elaleem et al. (2012) with their lowest range being at 51.8%, and Bidmos et al. (2020) with their lowest range being at 56.0%. These studies have still been included because the investigators looked into multiple samples within the same investigation and had results for other skeletal elements that did fit the inclusion diameters (Appendix A, p. 45-59).

2.2.2 The Use of Post Cranial Bones in Sex Estimation

Sex assessment and estimation through skeletal remains can be accomplished through either morphologic/non-metric methods, or metric analyses. Non-metric methods focus on the observation of morphological differences present on the element in question (Scheuer 2002, White and Folkens 2005). This method is highly dependent upon the experience of the observer

(Scheuer 2002, Garcia 2012). The investigator should be well acquainted with the population in question and must have enough experience within the field to successfully sex a skeletal element visually (Garcia 2012). In addition, the bones that investigations use morphological methods on may not be found complete enough to use this method of estimation, or they may not be found at all (Loth and Henneberg 1996). However, this statement is also true for metric methods.

Metric methods are those that utilize measurements and statistics to estimate sex (White and Folkens 2005). A key argument made for metric methods is that they allow for the reproducibility of the measurements across all investigations (Introna et al. 1998, Garcia 2012). They potentially allow investigators to produce similar results regardless of experience (Garcia 2012). However, simply taking measurements of the element is not enough, and these measurements may be used to develop equations and functions to allow for probability to be tested and ranges to be created. It is here where discriminant function analysis, a key tool used within almost all investigations cited in the database (Appendix A, p. 45-59), becomes a focus of this investigation. Research shows that applying metric methods to post-cranial bones can provide just as high an accuracy rate in the estimation of sex as the skull or the pelvis (Appendix A, p. 45-59) (Albanese et al. 2008, Garcia 2012).

2.2.3 Discriminant Function Analysis as a Method in Sex Estimation Investigations

Discriminant function analysis is a specific statistical tool that allows investigators to classify unknown individuals into a specific group, such as their biological sex (DiGangi and Moore 2013). It then allows for the probability to be tested in these unknown cases by combining several variabilities, or measurements, and creating a set function (Dibennardo and Taylor 1982). The function will then allow for the level of significance to be created. This breakdown of analysis and classification is what makes discriminant function analysis a key methodology for sex estimation (Dibennardo and Taylor 1982).

Using statistics within bioarchaeology, specifically in sexing methodologies, is key since "the statistical procedure and the manner in which the result[s] [are] stated, reflect[s] our belief that culture and environment affect the form [of what is being studied]" (Tugby 1970, 635). It is by utilizing discriminant function analysis that we can measure the impact of intrinsic and extrinsic factors that shape bone morphology and use it to categorize samples into either biological male or female categories.

Discriminant function analysis uses a variety of measurements on a specific element and develops an assortment of tests to determine error rates and asymmetry within the element. The measurements can be used in either univariate or multivariate analysis. Univariate analysis analyzes one specific variable, while multivariate analysis uses two or more variables (Tugby 1970, DiGangi and Moore 2013). Lastly, by utilizing discriminant function analysis, researchers indicate which variables are more highly weighted than others, allowing conclusions to be made about whether they are population specific and their impact on dimorphism (Dibennardo and Taylor 1982). All these factors lead to the popularity of metric methods regarding sex estimation investigations.

2.2.4 Other Forms of Data Analysis and Methods

Although metric analysis is the main methodology utilized, the measurements may be acquired in various ways. Bones may be measured directly, or from images such as CT scans and radiographs. CT scans utilize standard image reconstruction and create 2D planes in which CT-based measurements are then collected (Colman et al. 2018). CT images also provide the opportunity to create functions on current populations, which will assist in more modern forensic cases (Mahfouz et al. 2007, Colman et al. 2018). The use of radiographs and X-Rays is also employed, in which investigators applied standard sliding calipers and protractors to take measurements over the physical copy of the X-Ray (Riepert et al. 1996). This method was chosen due to the accessibility of scans and how the use of dry bone is not required (Riepert et al. 1996).

An additional form of data analysis is the use of machine learning by Navega et al. (2015). This involves developing algorithms that learn and map certain properties (Navega et al. 2015). This would allow for the prediction of data under a specific phenomenon to be completed (Navega et al. 2015). The difference between machine learning methods and the more commonly used statistical methods is the fact that machine learning methods do not need to fit more specific statistical assumptions (Navega et al. 2015). However, with this method comes the necessary rigorous training and the higher chances of error in under- and over-fitting (Navega et al. 2015).

Another form of data analysis is geometric 3D models and surface based and landmark methodology. Shape analyses, as shown by Brzobahata et al. 2014 and 2016, is useful as it offers more preservation of anatomical correlation across the bony surfaces. Logistic regression is another common method of data analysis (Albanese et al. 2008). The use of nonlinear classification is a method that involves the use of 3D imaging to extract specific measurements (Mahfouz et al. 2007, Albanese et al. 2008). The software created then separates the results into a variety of categories, such as specific geometric features, or principal axes, which are then associated with linear discriminant classifications (Mahfouz et al. 2007). Similar to using discriminant function analysis, this allows for more repeatable investigations and offers investigators the chance to assess sex through CT images, if the physical bone is no longer available (Mahfouz et al. 2007).

2.2.5 Limitations in Determining Sex

Something that must be noted across the investigations analyzed is that authors failed to identify the limitations within their choice of method. All methods will have limitations that should be identified within the investigation. There is no single trait or combination of traits that will be 100% accurate (Buikstra et al. 1994). Accuracy will vary from not only one trait to another, but also across each individual skeleton analyzed (Buikstra et al. 1994, White and Folkens 2005). Similarly, specific traits and characteristics that are used to evaluate sex are population specific, which will affect the accuracy rates across investigations (White and Folkens 2005). There will be differences in timings of puberty across populations that suggests the timing and appearance of certain traits used will vary (Moore 2013). Finally, there will always be skeletons that overlap between male and female traits: there will be more robust females and more gracile males (White and Folkens 2005, Agarwal and Glencross 2007, Agarwal 2012, Agarwal 2016). These are factors that must be taken into consideration in any investigation revolving around sex estimation.

Regarding metric methods, limitations will range from the measurements made to the data analysis and choices made by the models and programs. There is more within metric methods aside from making simple measurements as investigators generally use different instruments, different software, different calibration strategies, and different resolutions and corrections. Authors who utilize metric methods argue that visual methods are much more subjective and have higher error rates (Scheuer 2002, Garcia 2012, Curate et al. 2016).

However, the same argument can be made for metric methods based on which measurements the investigator is including, the way in which the measurements have been made, and the tools used for data analysis. Investigators are assuming that the trait they are focusing on is normally distributed across the sample in question (DiGangi and Moore 2013). The probability is also based on how likely the specific element will fit into the created category based on variability (DiGangi and Moore 2013). Not all skeletal elements will be equally effective and not all measurements made will be equally effective (Appendices D and E, p. 71-76). Subjective choices are also made regarding which measurements and variables will be the focus of the data analysis, and the program itself will also be established based on statistical merit (DiGangi and Moore 2013). The limitation here is that the program, or investigator, may choose predictors that have no practical significance or have less significance. Although these limitations may be avoided with experience and an understanding of which predictors may be more important, that also adds new limitation levels as investigators will make changes to the programs and models created (DiGangi and Moore 2013). These limitations must be addressed within all investigations relating to sex estimation.

2.2.6 Bones of the Legs and Feet

2.2.6a Femur

The femur is the most robust element and is often well preserved in either forensic or archaeological contexts (Black 1978, Albanese et al. 2008, Curate et al. 2016). The size and angle of the neck is directly and functionally related to the length of the pubic bone and therefore reflects sexual dimorphism in the pelvis (Albanese et al. 2008, Curate et al. 2016).

Starting with the proximal portion of the femur, dimensions of the head and neck width and length, show dimorphic characteristics (Curate et al. 2016). These measurements relate to how structural demands associated with locomotion and childbirth affect the angle and length of the femoral neck, allowing this aspect to be a good indicator of sex (Curate et al. 2016). On the diaphysis the width exhibits sexual dimorphism more than length, and therefore the shaft may be useful in sex estimation (Black 1978, Dibennardo and Taylor 1979). This is a result of bone remodelling in tubular bones during adolescence, and that "cortical bone is laid down at a greater rate in males than in females, and, in males, a larger proportion of the bony growth is at the subperiosteal surface" (Black 1978, 227). The distal portion has been studied much less than the proximal and the shaft. However, Asala et al. (2004) argue that it is less due to the distal end being studied or not studied, and more so due to it not being studied independently, or that the discriminating factors have not yet been adapted to the fragmentary distal portions. The distal end of the femur is more often used in conjecture with multivariate functions.

2.2.6b Patella

It has been shown that the patella, as a dense sesamoid bone, is often well preserved (Introna et al. 1998, Dayal and Bidmos 2005, Kemkes-Grottenhaler 2005). The size of the patella is highly dependent upon the dimensions of the femur and reflects functional stresses and associate muscle mass (Kemkes-Grottenhaler 2005, 130, Introna et al. 1998). There are several traits that can be measured to estimate the sex including the maximum width, breadth, and thickness, along with the maximum height of the interior and exterior facies articularis (Appendix B, Table 2, p. 62). Therefore, we can infer that a smaller bone would be associated with biological females, compared to biological males, who are generally associated with a larger percentage of muscle mass, and therefore a larger patella bone. This is also a pattern that is reflected within the general size dimorphism we see in humans.

2.2.6c Tibia

Like the femur, the tibia supports body weight and is involved in any movement of the lower body (Holland 1991, Lucena dos-Santos et al. 2018). In addition to this, the tibia is the second largest bone and is likely to be well preserved (Deepthi et al. 2019). The tibia has multiple sexually dimorphic traits including measurements surrounding the diaphysis circumference, the epiphyseal breadths, and the maximum diameter at the nutrient foramen (Appendix B, Table 3, p. 62-64). As in the other limb bones, during the adolescent period, the rate of cortical bone growth increases more in males than in females thereby affecting the diameters of the diaphysis (Iscan and Miller-Shaivitz 1984a). These differences persist through adulthood.

The proximal portion of the tibia expands relative to the shaft, providing an area to support body weight and transfers the forces placed upon the body through the femur (Lucena dos-Santos et al. 2018). Not only is the tibia a weight-bearing bone, but the proximal end is also subjected to a greater amount of stress compared to other joints of the body (Holland 1991). The diaphysis is also a good indicator of sex based on measurements surrounding shaft circumference and diameter at the nutrient foramen (Iscan and Miller-Shaivitz 1984a, b, Garcia 2012). It is these unique characteristics that are prime examples as to its importance in sex assessments.

2.2.6d Fibula

Out of all the bones of the lower body, the fibula is the least useful due to its lack of dimorphism and poor preservation (Sacragi and Ikeda 1995, Fasemore et al. 2018). The proximal portion is composed of an outer layer of thin, compact bone that covers spongy bone (Sacragi and Ikeda 1995). As a result, this portion is more likely to break apart do to taphonomic processes. Therefore, the diaphysis and the distal end are more useful for estimating sex by utilizing measurements of shaft circumference, antero-posterior diameter at nutrient foramen, mediolateral diameter at nutrient foramen, and bilateral diameter of the lateral malleolar fossa (Appendix B, Table 4, p. 64).

2.2.6e Foot Bones

Foot bones are used in sex estimation due to their compact size, and the fact that they have a smaller surface area compared to long bones, meaning they are less exposed to taphonomic processes (Mountrakis et al. 2012). If properly excavated, the bones of the feet can be excellent tools regarding sex estimation. In forensic contexts, the bones of the feet may preserve well since they are encased within some form of protection, such as socks and/or shoes (Bidmos and Asala 2003, Peckmann et al. 2005, DiMichele and Spradley 2012, Kim et al. 2013).

The talus has been shown useful for sex estimation due to measurements focusing on maximum length, height of head, and maximum trochlear length and breadth (Appendix B, Table 4, p.64-67). These are measurements that depict the bones role in locomotion and weight transmission.

The most robust bone in the foot is the calcaneus (DiMichele and Spradley 2012, Nathena et al. 2017). The calcaneus is important regarding its pivotal role in movement and weight transmission and is sexually dimorphic in measurements such as maximum length, load arm width and length, and maximum width (Appendix B, Table 5, p.64-67) (Nathena et al. 2017).

We can make similar statements regarding the metatarsals given how, when properly excavated, the shape of these bones allows for better preservation (Robling and Ubelaker 1997). Unfortunately, their size is also their detriment as they are not always uncovered during an excavation. The length and width have been utilized to identify dimorphism (Appendix B, Table 5, p.64-67).

Much less work has been conducted on the phalanges of the foot. These bones may preserve well enough to be utilized since their small size correlates to less surface exposure for taphonomic factors (Byers et al. 1989, Karakostis and Moraitis 2014). However, since investigations surrounding the use of small bones rely on preservation and their recovery within the field, it is not always possible to utilize these bones (Karakostis and Moraitis 2014).

2.3 Results, Analysis and Discussion

The bones of the human body do not develop in isolation but are affected by the growth and lifetime stresses of nearby or associated bones and the bones of the lower legs are of no exception. A pattern in the analysis and summary of each element within the database is that the various features that are measured are useful due to how all the elements relate to each other.

When analyzing data from investigations of the femur, there is a relationship between the angle of the femoral head, which can then be associated directly to sexual dimorphism in pelvic widths associated with childbirth and locomotion (Asala 2001and 2002, Albanese et al. 2008, Murphy 2005, Curate et al. 2016). The angle of the neck of the femur and the length of the neck will reflect the differences between males and females as seen through measurements of femoral neck width and femoral neck axis length (Appendix B, Table 1, p. 60-61).

Additionally, there are muscle attachments and tendons within the legs that can be affected by the sex and shape of bone. The patella-femoral joint articulations reflect specific shape changes within the bone (Introna et al. 1998, Kemkes-Grottenthaler 2005). As muscle mass of an individual increases, the muscle attachment site on the bone increases as well, and the bone adapts and strengthens. This increase in size is utilized in metric methods as males are generally larger and more robust than females (Kemkes-Grottenthaler 2005). Therefore, the physical forces on the femur will influence the size and shape of the patella. Continuing down the leg, the ligaments associated with the patella that then articulate with the tibia also show adaptations based on size. The tibia is connected to the patella through the patellar ligaments, which would then explain why the proximal portion of the tibia shows sexual dimorphism (Holland 1991). As forces increase, so too does muscle mass; thereby indicating that muscles throughout the lower body all adapt and change.

2.3.1 Univariate Versus Multivariate Analysis

A key theme that has become apparent throughout the research is the perception that, regardless of the element being used, single measurements will be much less useful regarding sex estimation (Steele 1976, Peckmann et al. 2015). Authors argue that single measurements create ranges that are larger, thereby creating an index that allows for more overlap between male and female estimates (Steele 1976, Peckmann et al. 2015). The implied argument here is that univariate analysis is not as accurate in determining the probability of sex compared to the use of multivariate analysis and there is a higher chance of error in the estimates made.

Univariate analysis is important since it is more likely to be applicable within fragmentary or pathological remains, as one dimension is more likely to be preserved compared to multiple. Although it is important for investigations to take and consider as many measurements as possible, this does not imply it is a more accurate tool. It is possible that more univariate functions would be useful as only 39% (22/57) of the methods examined use or include univariate statistics (this only includes investigations that fit the criteria of utilizing a single element with discriminant function analysis). Consequently, there is a need for a variety of univariate functions that can assist in a larger number of investigations when fragmentary and incomplete remains have been uncovered (Appendix A, p. 45-59).

2.3.2 Work Completed on the Elements

When I analyzed the investigations surrounding sex estimation of the bones of the lower legs, I found that certain elements are studied more often than others. Of the 79 investigations analyzed within this thesis, 17 were on the femur, 5 on the patella, 15 on the tibia, 4 on the fibula, 1 on the femur and tibia combined, and 37 on the bones of the foot. Breaking down the investigations on the foot bones, 28 focused on the tarsals, 22 of which were solely based on either the talus (11) or the calcaneus (11). What these numbers are showing is the bones that are studied more frequently are done so due to their relationship with locomotion and weight transmission. They are also elements that have a higher rate of preservation, even partially, and can therefore be useful within sex estimation (Bidmos and Asala 2003, Peckmann et al. 2005, Albanese et al. 2008, DiMichele and Spradley 2012, Kim et al. 2013).

My analysis shows that these patterns are seen throughout all the elements examined in this thesis. In order of investigated most to least, it is seen within the: femur, tibia, talus and calcaneus, patella, and fibula. It is this ranking that implies sexually dimorphic patterns that are a focus within metric investigations.

It is known that metric methods are population specific, and it is for this reason that more work needs to be done on all elements, regardless of how often they have been studied. If the patterns of dimorphism and asymmetry are population specific, then the standards created for one data set will not necessarily produce accurate results in a different population (Steyn and Iscan 1997). Due to population variation, additional studies of individual bones will continue to contribute to the development of sex estimation. By creating functions and equations for a variety of populations (such as Amerindian populations, North American White and Black populations, Northern Chinese populations, South African White and Black populations, etc.), researchers are creating a stronger and more defined collection set (Appendix A, p. 45-59).

Not only are metric methods population specific, but they are also temporally specific, which is a factor that must be considered within these investigations. Over time, populations change and grow, and by doing so, their nutrition and environment change as well. These intrinsic and extrinsic factors will impact bone morphology in a way that is evident among skeletal investigations (Moore 2013). As mentioned earlier, there are twelve (12) investigations that utilized skeletal remains from archaeological samples, and these investigations are examples of the care researchers must take in their methodology. These investigations would have to utilize sex evaluation of the pelvic bones and cranium to support any results they determined through estimation of the bones of the lower legs and feet. Due to this, we know that these studies cannot verify the biological sex of the remains present. This means that researchers must be careful in applying methods that have been based on modern populations to the remains of an archaeological collection that cannot be accurately verified.

2.3.3 Asymmetry of the Lower Limb Bones

An important consideration moving forward is asymmetry of human leg bones and how this will affect the measurements and formulas created, if at all. Will the ranges of male to female statistics differ depending on which side of the body the bone came from? Should statistics be created that focus solely on the left or the right side, or should the collection be mixed between the two? Kemkes-Grottenhaler states research completed on Southern African populations (Macho 1991) as well as from a skeletal sample from Sredisce (Cuk et al. 2001) has shown that the left limb is generally more developed than the right (Kemkes-Grottenhaler 2005, 130). This argument is supported by Gualdi-Russo (2007) who argues that there is a dominant pattern among the long bones of the lower limb to be more robust on the left side. However, based on the World Congress of Anthropology in 1882, it has been argued that investigations should utilize the left as standard within their measurements (Park 2018). This decision was made given more often than not, individuals are right dominant, meaning the bones of the left side will be smaller and slightly less robust (Park 2018). However, despite this the argument is not directly supported throughout the investigations analyzed, thereby creating a gap in the works conducted.

Of the 63 investigations analyzed for this discussion, 27% (17/63) specified the use of the left side throughout their research, 8% (5/63) specified in the use of the right side, 8% (5/63) specified in the use of the left, however the right was used in certain scenarios (such as when the left bones were not present within the collection or they were too damaged to use), 23% (18/63) used both the left and the right, and 29% (18/63) did not specify which side they utilized. For a more specific breakdown on the investigations analyzed, see Tables 6-11 (Appendix C, p. 68-70). This should be enclosed within the materials and methods section of these investigations, especially regarding reproducibility of results. However, as the above percentages show, this has not been the case. This is not only an issue that relates to the information disseminated throughout reports, but it is one that questions asymmetry within the bones and how this will have an affect on sex estimation and the ranges created.

Although asymmetry has been brought up as a factor that may affect sex estimation and is still worth examining, it may not affect the bones enough that it will affect the estimates made. Certain authors have argued that it is the bones of the lower left side that are longer and heavier on average, yet they do not provide the necessary data to support this claim within their own investigation (Black 1978, Dibennardo and Taylor 1979, Cuk et al. 2001, Case and Ross 2007, Kujanova 2008). Understanding how asymmetry affects the bones of the lower legs, if at all, is a topic that can be investigated further in future investigations.

2.3.4 Width Versus Length

Regarding the different types of measurements that are made throughout all the elements investigated, a pattern can be seen among which form of measurement is more accurate in sex estimation. Through an analysis of all investigations within the database, it seems there is a stronger correlation between width, breadth, diameter and circumference, and sex accuracy versus length and sex accuracy, mostly in long bones. Tables 12-21 (Appendices D and E, p. 71-76) shows that there are more measurements based on variables involving width than length. For the femur, 35% of investigations cite the diameter as being the most accurate or dimorphic measurement taken, and 43% of investigations cite the length as being the least accurate or dimorphic. The tibia shows a similar pattern in which 44% of investigations cite the circumference as being the most useful measurement, and 40% cite the length as being the least useful. Although the preservation of the element will also dictate which measurements are used, as well as whether it is a fragmentary remain or an entire bone, this is an important pattern within these investigations.

Case and Ross (2007) argue that activity-related changes within limb bones appear within the midshaft, making the measurements of circumference and diameter integral to the function of that bone. Compare this to investigations that utilize or focus upon length, and we learn that although the length of an element will be affected based on the individual's biological sex, the change is relatively slight beyond that. "The main impact on length measurements will be genetic and nutritional" whereas width and breadth can be impacted by environmental and societal stresses in the form of workload (Case and Ross 2007, 268).

Although the investigations vary on which measurements they used and focused on (Appendix B, Tables 1-5, p. 60-67), analysis shows width as being more accurate than length. This may be due to the fact that long bones are important in supporting an individuals' weight. Diaphyseal circumference is key in supporting the muscles associated with mass, and the conclusions here are supported in Tables 12-16 (Appendix D, p. 71-74). Understanding the functional demands on long bones may be important in determining which measurements to utilize and which ones to place a more significant weight upon. The research analysed indicates that these functional demands greatly impact the bone that can then be calculated as shown through sexual dimorphism.

This argument is supported through the analysis of the fibula as well. Although it has been determined that the fibula is one of the least dimorphic bones of the lower limb, it does still show evidence that can assist in sex estimation (as evident through the circumference and diameter of the shaft as well as the bilateral diameter of the lateral malleolar fossa). The fibula is not a key element in the support of body mass, and for this reason, it would most likely show less dimorphism than the femur or tibia. This can be seen through the few investigations analysed (Appendix A, p. 45-59). The authors who focus on the fibula focus either on the distal end, or the shaft (Appendix B, Table 4, p.64). The shaft is crucial to the arguments surrounding width versus length as the shaft is a primary area for muscle attachment.

These results vary however when we look to the bones of the foot, proving that one specific variable cannot be classified as most dimorphic across all elements. Regarding the tarsals, it is length that is more dimorphic than width (Steele 1976, Riepert et al. 1996, Bidmos and Asala 2003, Harris and Case 2012). Specifically looking at the talus and calcaneus, the measurements associated with breadth and length generally contribute more accurately to sex estimation than those of height (Bidmos and Asala 2003). The reasoning behind why the tarsal bones are well suited for sex estimation is based on the fact that they are associated with weight-bearing characteristics (Harris and Case 2012).

Within Tables 12-16 showing which measurements were most accurate/dimorphic (Appendix D, p. 71-74) the variances we see among the foot bones comes from whether or not the author argued the use of the measurement as most accurate on its own, or overall, in all functions created. Therefore, there seems to be less of a pattern among the foot bones compared to what can be seen among the long bones. However, a careful evaluation of all these measurements and all conclusions made show that a combination of length and breadth variables will provide the most accurate results regarding the sexing of tarsal bones.

Populations generally show some form of sexual dimorphism based on size and weight (Barrett et al. 2001). This is especially true of bones involved in weight bearing characteristics, such as the femur, tibia, talus, and calcaneus. Regarding long bones, the research shows a pattern in which variables involved in width are more useful than variables involved in length

(Appendix D, p. 71-74). Yet this argument cannot be made across all elements, as shown through the talus and calcaneus. Identifying one key measurement as being more dimorphic or accurate in metric methods is difficult due to population variances and element variabilities.

However, it must be noted that during puberty, there is appositional bone growth and remodelling throughout almost all elements in the human body (Moore 2013). We can infer that if the age-at-death of the individual is not considered during the investigation, then researchers may increase their error rates associated to their sexing methods and functions (Case and Ross 2007). This factor will also be prevalent in cases that focus on bone length differences. If a set of elements is measured to be quite long compared to the female average within the collection, then there is a chance that the individual could be misclassified as male, despite being female, or vice versa if the bone length is smaller than the male average (Agarwal 2012, Agarwal 2016). Despite this argument, it is important to remember that these measurements are affected temporally, and by population group (Iscan and Shihai 1995). It is also important to note that although there may be more functions in which the authors cited width as being the most useful, it is those functions that combine several different variables, mixing length and width together, that create the highest accuracy and provide the best opportunity for correct estimations (such as Steyn and Iscan 1997, Holland 1991, Colman et al. 2018).

2.3.5 Descriptions of Measurements Taken

Another issue that can be found within the investigations analysed are shown within Tables 1-5 (Appendix B, p. 60-67). As can be seen within these tables, several measurements have been taken for each element, focusing on investigations that utilize discriminant function analysis, each with varying degrees of labelling and explanation. However, for the purposes of this argument, I have not combined any of the measurements if they are the same but written or worded differently. This is because I want to show how it can become confusing within the field to reference several different investigations on one element that all have different ways of labelling or explaining their measurements. For example, when we focus on the patella (Appendix B, Table 2, p. 62) we have five separate investigations, many of which use the same or similar measurements. Yet, some authors, such as Kemkes-Grottenthaler (2005), simply state they are using the measurements seen within the investigation conducted by Introna et al. (1998). The investigation done by Introna et al. (1998) simply lists the measurements with no specific explanation on how they were measured or exactly where on the patella the features can be found. Moving forward to Bidmos et al. (2005) and Dayal and Bidmos 2005, we see a slightly different list of measurements taken, one less than those used by the previous two authors, and a more specific description of not only the measurement taken, but exactly how the measurement was taken.

What I argue is that these descriptions can cause confusion when new investigations are conducted as there are a variety of measurements taken and a variety of descriptions provided, some leaving little room for error (such as Bidmos et al. 2005 , Dayal and Bidmos 2005), others leaving room for unknowns when it comes to how to specifically measure that feature or where it is located (such as Introna et al. 1998, Kemkes-Grottenthaler 2005). Table 2 (Appendix B, p. 62) shows ten (10) measurements taken with different wording, even though six of these measurements are essentially the same feature. It is also a case in which we cannot assume the knowledge and the experience of the individual taking these measurements. Within metric investigations, authors need to be as descriptive as possible when it comes to listing and describing the measurements utilized. This is a key aspect to their methodology, and if they wish their work to be reproducible, they need to be much more specific. Although only the patella was used as a specific example for this argument, the same can be said for each element listed within the database (Appendix B, p. 60-67). It is a consistent problem throughout all metric investigations, and it is one that must be addressed.

When we look to the long bones, they are generally elements that have distinctive breaks: the proximal portion, the shaft, and the distal portion. The argument made above can still be seen within these sections, and Tables 1-5 (Appendix B, p. 60-67) break down the measurement based on which section of the bone is examined. Certain authors specifically investigate the proximal end, shaft, or distal end of bones, making their work easier to categorize (such as Black 1978, Asala 2001, Fasemore et al. 2018). However, certain authors utilize the entire bone, yet create functions from this selection that may be useful for fragmentary remains (such as Asala et al. 2004). Yet even between these different types of investigations, the measurements taken need to be specified in a more descriptive manner. Too many authors simply state which measurements they wish to follow, without explaining exactly how they took those measurements. This can lead to error when these investigations are reproduced by others. However, the authors that tend to use the entire bone and create functions and equations regarding fragmentary remains may be particularly useful when it comes to long bones that have not broken into the three distinct sections yet are not perfectly preserved. The femur may have a broken head, and therefore proximal head measurements can no longer be used on it, however some of the other functions may allow for this landmark to be missing.

The fibula is one bone in which there is a consistency within the measurements listed within the investigations. Both Sacragi and Ikeda (1995) and Tabencki (2015) use the distal end of the fibula in their investigations while using the same measurement descriptions and images.

Although the fibula seems to contradict the above argument, this may be due to this element not being as widely used as the other elements. This means that not as many measurements have been taken, and the authors use the few publications already produced without making changes to their methodology. This implies that the fibula has not been investigated to the same depth as the other long bones, most likely because it is less well preserved and shows the least amount of dimorphic differences (Sacragi and Ikeda 1995, Fasemore et al. 2018).

2.3.6 Bias

Visual methods using defined sexual characteristics of the skull and pelvis have been predominant within the discipline. *Standards for Data Collection from Human Skeletal Remains* (Buikstra et al. 1994) denotes chapter three to sex estimation, solely using methods for the pelvic girdle and the cranium. *The Human Bone Manual* (White and Folkens 2005) has a section in chapter nineteen (19.4) for the estimation of sex in which we see more than two elements discussed with the mention of dimorphic limb bones. However, the authors state that "because these functions are often not tested beyond (or independent of) the skeletal population on which they were based, claims of accuracy are sometimes questionable" (White and Folkens 2005). Although the overall argument is accurate, many authors who focus solely on metric methods include cross validation results within their research. Therefore, although metric methods may be population specific, dismissing them (even partially) as a useful method may be detrimental to the discipline.

Although inclusion bias may occur, it is difficult to avoid due to the skeletal representation within the archaeological record and, at times, in forensic cases. Bias is expected within all scientific disciplines and in order to address it "we need to ask old questions in new ways so that we can think systematically about the intertwining of bodies and culture" (Fausta-Sterling 2005, 1516-1517). Acknowledging differences and bias allows bioarchaeologists to move beyond the past of obscuring information within their research. As shown throughout this thesis, the elements of the lower leg can be just as accurate in identifying the biological sex of an individual as the cranium and pelvic girdle (Appendix A, p. 45-59). Further work can be conducted regarding the issues surrounding a sex dichotomy and sex versus gender within bioarchaeology (Agarwal 2012, Agarwal 2016).

2.4 Conclusion

Throughout this thesis a variety of topics have been discussed, ranging from the biological profile and preservation of skeletal elements to themes within metric sexing methodologies. However, throughout all of these topics, the same argument has been brought up time and time again, and that is that the use of metric methods as a useful and practical method within the field needs to be addressed and acknowledged. By creating a database that includes methodologies focused on postcranial bones – specifically elements of the lower body – I have created an open method of communication regarding population-specific methods. It provides not only a way to quickly reference work that has been done in this area, but also offers a set of references on specific populations from specific time periods that the publics can access. These references address the geographic and temporal issues within metric methods; however, they also attempt to move past them by utilizing a variety of collections, both archaeological and forensic. It is also research that impacts the publics interest due to how the conversation surrounding sex is apparent across a variety of discussions. By creating a database and allowing it to be accessible to the public, I have provided a wide range of research that explains how sex can be determined through a range of methods and forms of analysis, but also the inherent limitations that sex estimation also has.

However, my research has also shown that the information that has been disseminated throughout these reports is an issue that needs to be addressed. A number of areas are discussed that authors left out of their investigation, such as the limitations to the methods chosen, the side the bone is from, and the descriptions of measurements made. These are important aspects to the investigation being analyzed and too much information is missing that can be easily addressed within the research. Also, despite the usefulness that has been show among the bones of the lower legs and feet to be utilized for accurate sex estimation (Appendix A, p. 44-58), it should be noted that those measurements viewed as key within these investigations are perhaps those measurements that are affected by a lifetime of activity and are greatly affected by body mass (Case and Ross 2007). This is a factor that may influence researcher's decision as to avoiding these bones if other remains are present. Further work can be done not only regarding the information necessary to reproduce the investigations, but also regarding topics such as asymmetry and the impact, if any, it would have on sex estimation.

Postcranial bones can be used to help identify the sex of the remains; however, they are somewhat less accurate than the pelvic gridle and the cranium. There are common themes that have been presented and analyzed throughout this thesis, as well as areas of improvement that need to be addressed. By acknowledging the different methods available and understanding the bias that is entwined, bioarchaeologists have the ability to move beyond the past of obscuring information with their research or leaving questions unanswered that may be vital to understanding the knowledge that is uncovered. By using metric methods and creating a database that addresses the standards and problems surrounding these methods, we have the ability to offer other options, as well as provide the opportunity to highlight the ability to identify the diversity of past peoples' social and biological identity through a much wider selection of skeletal elements.

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Appendix A: Database of Case Studies Using the Bones of the Legs and Feet to Estimate Sex

DFA = Discriminant Function Analysis
(U) = Univariate Analysis
(M) = Multivariate Analysis
Unless otherwise specified, the ranges for the accuracy are multivariate, for DFA methods only

Femur	Author (Date)	Method	Collection	Population	Accuracy	DOI Reference
Shaft	Black (1978)	Metric - DFA	Libben Site Collection, Ontario County, Ohio, USA	Amerindian	85.0 - 89.4 (U) 85.8 (M)	https://doi.org/10.1002/ajpa.1330480217
	Dibennardo and Taylor (1979)	Metric - DFA	The American Museum of Natural History, New York City, USA	North American Whites	79.0 - 86.0	https://doi.org/10.1002/ajpa.1330500415
	Dibennardo and Taylor (1982)	Metric - DFA	Terry Skeletal Collection at the Smithsonian Institution in Washington DC, USA	North American Blacks	70.8 - 81.5	https://doi.org/10.1002/ajpa.1330580206
	Dittrick and Suchey (1986)	Metric - DFA	Lowie Museum - University of California Berkeley, USA	Central California Prehistoric	62.1 - 85.0 (U - Early) 53.8 - 90.6 (U - Middle and Late) 55.1 - 88.7 (U - Combined)	https://doi.org/10.1002/ajpa.1330700103
	Iscan and Shihai (1995)	Metric - DFA	Yishui Medical School (Shandong), China	Northern Chinese	81.7 - 94.9	https://doi.org/10.1016/0379-0738(95)01691-B

	Steyn and Iscan (1997)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa; University of Pretario, South Africa	South African Whites	85.9 - 91.4	https://doi.org/10.1016/S0379-0738(97)00156-4
	King et al. (1998)	Metric – DFA	Chiang Mai University Hospital, Thailand	Thai	85.6 - 94.2 (M) 85.6 - 93.3 (U)	https://doi.org/10.1520/JFS14340J
	Mall et al. (2000)	Metric - DFA	Institute of Anatomy at the University of Colonge and the Institute of Legal Medicine at the University of Tubingen, Germany	Contemporary German	67.7 - 91.7 (U)	https://doi.org/10.1016/S0379-0738(00)00240-1
Head	Asala (2001)	Metric - Demarking Points	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Whites and Blacks	N/A	https://doi.org/10.1016/S0379-0738(00)00444-8
Head	Asala (2002)	Metric - Demarking Points	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Whites and Blacks	N/A	https://doi.org/10.1016/S0379-0738(02)00114-7

	Asala et al. (2004)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Blacks	67.9 - 82.6 (U) 82.7 - 85.1 (M)	https://doi.org/10.1016/j.forsciint.2004.03.010
Head	Murphy (2005)	Metric - DFA	Department of Anatomy and Structural Biology, Otago School of Medical Sciences, Dunedin, New Zealand	Prehistoric New Zealand Polynesians	80.9 - 82.4	https://doi.org/10.1016/j.forsciint.2004.10.011
Proximal	Purkait (2005)	Metric - DFA	Medico-legal Institute at Bhopal, Central India	Indian	62.5 - 84.3 (U) 85.4 - 87.5 (M)	https://doi.org/10.1016/j.forsciint.2004.08.005
Proximal	Albanese et al. (2008)	Metric - Logistic Regression	Terry Skeletal Collection at the Smithsonian Institution, Washington DC; and the Grant Collection at the University of Toronto, Canada	Not Specified	89.4 - 95.0	https://doi.org/10.1111/j.1556-4029.2008.00855.x
	Robinson and Bidmos (2011)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa; Pretoria Bone Collection, Cape Town Skeletal Collection; Osteology Archive Student Collection, South Africa	South Africans of European Descent	85.9 - 90.5 (OC) 76.0 - 82.0 (Dart) 80.0 - 88.0 (Pretoria) 89.8 - 93.5 (Cape)	https://doi.org/10.1016/j.forsciint.2010.12.009

Proximal	Curate et al. (2016)	Metric - DFA	Luis Lopes Collection from the Natural History Museum of Lisbon, Portugal; Coimbra Identified Skeletal Collection of the University of Coimbra, Portugal	Portugese	80.1 - 86.2	https://doi.org/10.1016/j.forsciint.2016.06.011
Proximal	Colman et al. (2018)	Metric - Clinical CT Scans and Logistic Regression	Body Donation Program of the Department of Medical Biology of the Academic Medical Cneter, University of Amsterdam, the Netherlands and the use of a database of the Department of Radiology of the AMC	Dutch	86.0 - 92.0 (U)	https://doi.org/10.1016/j.forsciint.2017.12.029

Patella	Author (Date)	Method	Collection	Population	Accuracy %	DOI Reference
	Introna et al. (1998)	Metric - DFA	Institute of Legal Medicine at the University of Bari, Italy	Southern Italian	76.3 - 83.8 (M) 62.7 - 78.8 (U)	https://doi.org/10.1016/S0379-0738(98)00080-2
	Bidmos et al. (2005)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Whites	75.0 - 85.0 (M) 67.5 - 85.0 (U)	https://doi.org/10.1016/j.forsciint.2007.02.024

	Dayal and Bidmos (2005)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Blacks	78.3 - 85.0 (M) 65.5 - 78.75 (U)	https://doi.org/10.1520/JFS2004306
	Kemkes-Grottenthaler (2005)	Metric - DFA	N/A	Prehistoric Medieval Period	74.0 - 84.6 (M) 71.2 - 84.6 (U)	https://doi.org/10.1016/j.forsciint.2004.09.075
	Mahfouz et al. (2007)	Metric - CT Imaging and Nonlinear Classification	William M Bass Donated Skeletal Collection Housed at the University of Tennessee, Knoxville, USA	Modern North Americans	83.77 - 93.51	https://doi.org/10.1016/j.forsciint.2007.02.024

Tibia	**Author (Date)**	**Method**	**Collection**	**Population**	**Accuracy %**	**DOI Reference**
Shaft and Whole Bone	Iscan and Miller-Shaivitz (1984a)	Metric - DFA	Terry Skeletal Collection at the Smithsonian Institution, Washington DC, USA	American Whites and Blacks	65.8 - 78.5 (whites) 80.0 - 83.8 (blacks)	https://doi.org/10.1002/ajpa.1330640104
Shaft and Whole Bone	Iscan and Miller-Shaivitz (1984b)	Metric DFA	Terry Skeletal Collection at the Smithsonian Institution, Washington DC, USA	American Whites and Blacks	77.2 - 87.3 (whites) 80.0 - 91.3 (blacks)	https://doi.org/10.1520/JFS11775J
Proximal	Holland (1991)	Metric - Regression	Hamann-Todd Collection at the Cleveland Museum of Natural History, Cleveland, USA	Whites and Blacks	85 - 100	https://doi.org/10.1002/ajpa.1330850210

Proximal	Kieser et al. (1992)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	Caucasoid and South African Negroes	84.62 - 94.0 (U)	https://doi.org/10.1016/0379-0738(92)90143-K
	Iscan et al. (1994)	Metric - DFA	Jikei Medical University, Tokyo, Japan	Japanese	80.0 - 88.6	https://doi.org/10.1520/JFS13656J
	Steyn and Iscan (1997)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Whites	86.8 - 90.6	https://doi.org/10.1016/S0379-0738(97)00156-4
	Gonzalez-Reimers et al. (2000)	Metric- DFA	N/A	Prehistoric Remains of the Canary Islands	94.9 - 98.3	https://doi.org/10.1016/S0379-0738(99)00205-4
Fragmentary and Whole Bones	Slaus and Tomicic (2004)	Metric - DFA	Medieval Archaeological Sites in Croatia	Medieval Croatians	87.8 - 92.2 (M) 81.7 - 85.6 (U)	https://doi.org/10.1016/j.forsciint.2004.09.073
	Robinson and Bidmos (2011)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa; Pretoria Bone Collection, Cape Town Skeletal Collection;	South Africans of European Descent	86.8 - 90.6 (OC) 86.0 - 88.0 (Dart) 54.7 - 83.7 (Pretoria) 58.7 - 92.2 (Cape)	https://doi.org/10.1016/j.forsciint.2010.12.009

			and Osteology Archive Student Collection, South Africa			
Shaft Circumference	Garcia (2012)	Metric – Sectioning Points	Lisbon Collection and the Sao Martinho Medieval Collection, both Housed in the National Museum of Natural History, Lisbon, Portugal	Modern Portuguese and Medieval Portuguese	78 (Lisbon) 90 (Sao Martinho)	https://doi.org/10.1002/oa.1202
Epiphyses	Brzobahata et al. (2014)	Geometric Morphometric - DFA and 3D Models	N/A	Early Medieval Population of the Great Morvian Empire (Central Europe)	83.07 - 93.84	https://doi.org/10.1127/0003-5548/2014/0336
	Brzobahata et al. (2016)	Geometric Morphometric - Linear Regression and 3D Models (Surface Bassed and Landmark Methodology)	Department of Anthropology of the National Museum, Prague; Pachner Collection at the Institute of Anatomy, First Faculty of Medicine, Charles University, Prague	Medieval to Present Day Population of Central Europe (Czech Republic)	76.79 - 85.25 (Shape Size) 60.66 - 71.58 (Shape) 87.5 - 91.8 (landmark)	https://doi.org/10.1371/journal.pone.0166461

	Fasemore et al. (2018)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Africans (SAA) and South African Whites (SAW)	79.0 - 82.0 (SAA) 84.0 - 88.0 (SAW)	https://doi.org/10.1016/j.forsciint.2018.03.015
Tibial Plateau	Lucena dos-Santos et al. (2018)	Metric - Morphometry	Anatomy Sector of the Department of Animal Morphology and Physiology, the Rural Federal University of Pernambuco, Brazil	Modern Brazilians	Not Specified	http://doi.org10.4067/S0717-95022018000100104
	Deepthi et al. (2019)	Metric - DFA	Not Provided	Contemporary Sri Lankans	61.9 - 80.2	https://doi.org/10.4103/jfsm.jfsm_56_18

Fibula	**Author (Date)**	**Method**	**Collection**	**Population**	**Accuracy %**	**DOI Reference**
Distal	Sacragi and Ikeda (1995)	Metric - DFA	University Museum of the University of Tokyo, Japan	Japanese	90.6	https://doi.org/10.1002/oa.1390050205
	Aparna and Rajasree (2013)	Demarking Point - DFA - CT Scans	Osmania Medical College, Hyderabad, from Osteology Departments of Anatomy from Various Medical Colleges in Hyderbad; Living Patients	Not Specified	Not Provided	https://pdfs.semanticscholar.org/e17c/840c31c1b4d9671e3c6cde8a40bedccb4d26.pdf?_ga=2.265050127.1496699566.1590094781-124979299.1587346842
Distal	Tabencki (2015)	Metric - DFA and Linear Regression	William M Bass Donated Skeletal Collection; the University of Tennessee, Knoxville, USA	American Caucasian	85.2 (females) 89.0 (males)	https://www.researchgate.net/publication/277718013_Sex_Determination_Using_the_Distal_Articular_Surface_of_the_Fibula

Shaft - Nutrient Foramen	Fasemore et al. (2018)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Africans (SAA) and South African Whites (SAW)	69.0 - 74.0 (SAA) 70.0 - 77.0 (SAW)	https://doi.org/10.1016/j.forsciint.2018.03.015

Tarsals	**Author (Date)**	**Method**	**Collection**	**Population**	**Accuracy %**	**DOI Reference**
	Navega et al. (2015)	Metric - Machine Learning	Coimbra Identified Skeletal Collection, Portugal	Portuguese	88.0 - 90.0	https://doi.org/10.1007/s00414-014-1070-5
						-

Tarsals (Minus The Calcaneus and Talus)	**Author (Date)**	**Method**	**Collection**	**Population**	**Accuracy %**	**DOI Reference**
Cuboid	Harris and Case (2012)	Metric - DFA	William M Bass Donated Skeletal Collection; the University of Tennessee, Knoxville, USA	European-American	84.7 - 91.8	https://doi.org/10.1111/j.1556-4029.2011.02004.x
Navicular	Harris and Case (2012)	Metric - DFA	William M Bass Donated Skeletal Collection, the University of Tennessee, Knoxville, USA	European-American	84.1 - 84.5	https://doi.org/10.1111/j.1556-4029.2011.02004.x
Cuneiform I	Harris and Case (2012)	Metric - DFA	William M Bass Donated Skeletal Collection; the University of Tennessee, Knoxville, USA	European-American	83.0 - 90.9	https://doi.org/10.1111/j.1556-4029.2011.02004.x
Cuneiform II	Harris and Case (2012)	Metric - DFA	William M Bass Donated Skeletal Collection; the University of Tennessee, Knoxville, USA	European-American	82.4 - 83.6	https://doi.org/10.1111/j.1556-4029.2011.02004.x

Cuneiform III	Harris and Case (2012)	Metric - DFA	William M Bass Donated Skeletal Collection; the University of Tennessee, Knoxville, USA	European-American	82.3 - 85.5	https://doi.org/10.1111/j.1556-4029.2011.02004.x

Calcaneus	**Author (Date)**	**Method**	**Collection**	**Population**	**Accuracy %**	**DOI Reference**
	Riepert et al. (1996)	Radiographs and X-Rays	Clinic for Radiology of the University of Mainz, Germany	Central European	84.4	https://doi.org/10.1016/0379-0738(95)01832-8
	Introna et al. (1997)	Metric - DFA	Institute of Legal Medicine of the University of Bari, Italy	Southern Italian	66.25 - 83.75 (U) 76.25 - 85.00 (M)	https://doi.org/10.1520/JFS14192J
	Wilbur (1998)	Metric - DFA	Klunk, Koster, Schild, and Yokem Mound Skeletal Series, the Department of Anthropology, Indiana University, USA	Native Americans	87.8	https://doi.org/10.1002/(SICI)1099-1212(199805/06)8:3<180::AID-OA421>3.0.CO;2-D
	Murphy (2002)	Metric - DFA	Department of Anatomy and Structural Biology, Otago School of Medical Sciences, Dunedin, New Zealand	Prehistoric New Zealand Polynesians	88.4 - 93.5	https://doi.org/10.1016/S0379-0738(02)00301-8
	Bidmos and Asala (2003)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa; Pretoria Bone Collection, South Africa	South African Whites	72.9 - 85.8 (U) 81.7 - 92.1 (M)	https://doi.org/10.1520/JFS2003104

	Bidmos and Asala (2004)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa; Pretoria Bone Collection, South Africa	South African Blacks	63.8 - 79.3 (U) 79.3 - 86.2 (M)	https://doi.org/10.1520/JFS2003254
	Gualdi-Russo (2007)	Metric - DFA	Frassetto Skeletal Collection Housed in the Museum of Evolution, Department of Experimental Evolutionary Biology, University of Bologna, Italy	Northern Italians	87.9 - 90.7	https://doi.org/10.1016/j.forsciint.2006.10.014
	DiMichele and Spradley (2012)	Metric - DFA	William M Bass Donated Skeletal Collection; the University of Tennessee, Knoxville, USA	American Whites, Blacks, and Hispanics	80.08 - 88.10 (U) 86.69 (M)	https://doi.org/10.1016/j.forsciint.2012.03.026
	Harris and Case (2012)	Metric - DFA	William M Bass Donated Skeletal Collection, the University of Tennessee, Knoxville, USA	European Americans	78.9 - 81.8	https://doi.org/10.1111/j.1556-4029.2011.02004.x
	Kim et al. (2013)	Metric - DFA	Not Specified	Korean	81.7 - 89.4	https://doi.org/10.1016/j.forsciint.2013.03.012
	Nathena et al. (2017)	Metric - DFA	Cretan Collection, Greece	Contemporary Cretans	82.3 - 85.3	https://doi.org/10.1016/j.forsciint.2017.04.005

Talus	**Author (Date)**	**Method**	**Collection**	**Population**	**Accuracy %**	**DOI Reference**
	Steele (1976)	Metric - DFA	Terry Skeletal Collection, Smithsonian Institution in Washington DC, USA	Whites and Blacks	83.0 - 88.0	https://doi.org/10.1002/ajpa.1330450323

	Barrett et al. (2001)	Metric - DFA	Duff, Kirian Treglia, Boose, Pearson Village, Sun Watch and Buffalo Sites	Ohio Valley Native Americans	93.3 (Prehistoric Sample) 84.6 - 85.7 (Late Prehistoric Sample) 66.7 - 85.0 (Protohistoric Sample) 82.4 - 86.5 (Combined Sample)	https://www.researchgate.net/publication/11570037_Estimation_of_sex_from_the_Talus_in_prehistoric_native_Americans
	Murphy (2002)	Metric - DFA	Department of Anatomy and Structural Biology, Otago School of Medical Sciences, Dunedin, New Zealand	Prehistoric New Zealand Polynesians	85.1 - 93.3	https://doi.org/10.1016/S0379-0738(02)00189-5
	Wilbur (2002)	Metric - DFA	Klunk, Koster, Schild, and Yokem Mound Skeletal Series, the Department of Anthropology, Indiana University, USA	Native Americans	88.7	https://doi.org/10.1002/(SICI)1099-1212(199805/06)8:3<180::AID-OA421>3.0.CO;2-D
	Bidmos and Dayal (2003)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Whites	57.5 - 81.7 (U) 77.5 - 87.5 (M)	https://doi.org/10.1097/01.paf.0000098507.78553.4a
	Bidmos and Dayal (2004)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Blacks	80.0 - 85.8 (U) 84.2 - 89.2 (M)	https://doi.org/10.1520/JFS2003431

	Gualdi-Russo (2007)	Metric - DFA	Frassetto Skeletal Collection housed in the Museum of Evolution, Department of Experimental Evolutionary Biology, University of Bologna, Italy	Northern Italian	90.7 - 95.7	https://doi.org/10.1016/j.forsciint.2006.10.014
	Abd-Elaleem et al. (2012)	Metric - DFA	Departments of Anatomy of Minia and Cairo Universities; Forensic Medicine Department of Justice Office in Minia Governates, Egypt	Egyptian	51.8 - 90.9 (U) 83.6 - 85.5 (M)	https://doi.org/10.1016/j.jflm.2011.12.003
	Harris and Case (2012)	Metric - DFA	William M Bass Donated Skeletal Collection, the University of Tennessee, Knoxville, USA	European-American	90.9 - 92.4	https://doi.org/10.1111/j.1556-4029.2011.02004.x
	Mahakkanukrauh et al. (2014)	Metric - DFA	Chiang Mai University Skeletal Collection, the Faculty of Medicine's Forensic Osteology Research Center, Thailand	Thai	79.1 - 89.8 (U) 88.0 - 91.4 (M)	https://doi.org/10.1016/j.forsciint.2014.04.001
	Peckmann et al. (2015)	Metric - DFA	The Athens Collection, the Department of Animal and Human University Physiology, National and Kapodistrian University of Athens, Greece	Greek	69.3 - 87.3 (U) 86.7 - 96.5 (M)	https://doi.org/10.1016/j.jflm.2015.03.011
Metatarsals	**Author (Date)**	**Method**	**Collection**	**Population**	**Accuracy %**	**DOI Reference**
	Robling and Ubelaker (1997)	Metric - DFA	Terry Skeletal Collection, Smithsonian Institution in Washington DC, USA	Whites and Blacks	85.5 - 93.3 (Blacks) 87.5 - 96.9 (Whites)	https://doi.org/10.1520/JFS14261J

	Mountrakis et al. (2010)	Metric - DFA	The Athens Collection, the Department of Animal and Human University Physiology, National and Kapodistrian University of Athens, Greece	Greek	80.5 - 90.1 (U)	https://doi.org/10.1016/j.forsciint.2010.03.041
	Bidmos et al. (2020)	Metric - DFA and Logistic Regression	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa	South African Blacks	56.0 - 71.0 (U) 79.0 - 84.0 (M)	https://doi.org/10.1080/00450618.2019.1711180

Phalanges	Author (Date)	Method	Collection	Population	Accuracy %	DOI Reference
Proximal	Karakostis and Moraitis (2014)	Metric - DFA	Athens Collection, Greece	Greek	84.8 (M) 72.2 – 90.9 (U)	https://doi.org/10.1127/0003-5548/2014/0423

Element (Combination)	Author (Date)	Method	Collection	Population	Accuracy %	DOI Reference
Talus and Calcaneus	Steele (1976)	Metric - DFA	Terry Skeletal Collection, Smithsonian Institution in Washington DC, USA	Whites and Blacks	79.0 - 89.0	https://doi.org/10.1002/ajpa.1330450323
Metatarsal 2, Talus, and Calcaneus	Wilbur (2002)	Metric - DFA	Klunk, Koster, Schild, and Yokem Mound Skeletal Series, the Department of Anthropology, Indiana University, USA	Native Americans	78.46 - 87.54 (U)	https://doi.org/10.1002/(SICI)1099-1212(199805/06)8:3<180::AID-OA421>3.0.CO;2-D

Talus and Calcaneus Articular Surface	Murphy (2004)	Metric - DFA	Department of Anatomy and Structural Biology, Otago School of Medical Sciences, Dunedin, New Zealand	Prehistoric New Zealand Polynesians	92.3	https://doi.org/10.1016/j.forsciint.2004.06.040
Talus and Calcaneus	Gualdi-Russo (2007)	Metric - DFA	Frassetto Skeletal Collection, the Museum of Evolution, Department of Experimental Evolutionary Biology, University of Bologna, Italy	Northern Italians	87.9 - 95.7	https://doi.org/10.1016/j.forsciint.2006.10.014
Metatarsals, Proximal Phalanges, and First Distal Phalanx	Case and Ross (2007)	Metric - DFA	Terry Skeletal Collection, Smithsonian Institution in Washington DC, USA	White Americans of European Descent	82.2 - 83.4 (M) 74.1 - 79.6 (U)	https://doi.org/10.1111/j.1556-4029.2006.00365.x

Element	**Author (Date)**	**Method**	**Collection**	**Population**	**Accuracy %**	**DOI Reference**
Tibia and Femur	Steyn and Iscan (1997)	Metric - DFA	Raymond A Dart Collection of Human Skeletons, School of Anatomical Sciences, University of Witwatersrand, Johannesburg, South Africa; University of Pretoria, South Africa	South African Whites	85.9 - 91.4	https://doi.org/10.1016/S0379-0738(97)00156-4

Appendix B: Measurements Taken on Each Element

The following is several tables that list all measurements used within the investigations analysed within the database.

*Note: For each of the following tables, several measurements have been listed that may appear to be the same measurement, only worded slightly different. This is purposefully done and is explained within the analysis section of the thesis.

**Note: As noted within the thesis, due to the fact the discriminant function analysis has more universal relevance across all elements, only those investigations that used discriminant function analysis and metrics are listed in the tables below. This is due to the fact that this is a specific methodology within the broader topic of sexing methods, and as a supporting argument to the use of discriminant function analysis as a core method, it is easier to list relevant investigations that use the exact same method versus those that utilize a different method. Logistic regression was also included since a key aspect is the use of specific measurements.

Table 1: Measurements Taken on the Femur

Authors Who Used the Measurement (Date)	Measurements Taken for the Proximal Portion
Curate et al. (2016)	Neck Axis Length
Asala et al. (2004), Murphy (2008), Curate et al. (2016), Colman et al. (2018)	Superoinferior Neck Diameter
Asala et al. (2004), Albanese et al. (2008), Colman et al. (2018)	Head Diameter
Albanese et al. (2008)	Greater Trochanter to Fovea Capitis
Purkait (2005), Albanese et al. (2008)	Greater Trochanter to Lesser Trochanter
Albanese et al. (2008)	Lesser Trochanter to Fovea Capitis
Purkait (2005)	Articular Margin of the Head to the Greater Trochanter
Purkait (2005)	Articular Margin of the Head to the Lesser Trochanter
Asala et al. (2004)	Upper Epicondylar Length
Asala et al. (2004)	Anteroposterior Subtrochanteric Diameter
Asala et al. (2004)	Transverse Subtrochanteric Diameter
Colman et al. (2018)	Vertical Head Diameter
Murphy (2008), Colman et al. (2018)	Transverse Head Diameter
Murphy (2008), Colman et al. (2018)	Head Circumference
Colman et al. (2018)	Head-neck Length
Colman et al. (2018)	Transverse Neck Diameter
Colman et al. (2018)	Neck Circumference
Colman et al. (2018)	Upper Epiphyseal Length
Colman et al. (2018)	Frontal Head Length
Colman et al. (2018)	Neck Length
Authors Who Used the Measurement (Date)	**Measurements Taken for the Shaft**
Black (1978), Dibennardo and Taylor (1979), King et al. (1998)	Circumference

Authors Who Used the Measurement (Date)	**Measurements Taken for the Distal Portion**
Asala et al.(2004)	Bicondylar Breadth
Asala et al.(2004)	Medial Condylar Length
Asala et al.(2004)	Lateral Condylar Length
Authors Who Used the Measurement (Date)	**Measurements Taken for the Entire Bone as well as Fragmentary Bone**
Dittrick and Suchey (1986), Iscan and Shihai (1995), Steyn and Iscan (1997), Asala et al. (2004), Robinson and Bidmos (2011)	Head Diameter
Iscan and Shihai (1995), Steyn and Iscan (1997), Robinson and Bidmos (2011)	Distal Breadth
Steyn and Iscan (1997), Dibennardo and Taylor (1979, 1982), Iscan and Shihai (1995), King et al. (1998), Asala et al. (2004), Robinson and Bidmos (2011)	Transverse Diameter
Steyn and Iscan (1997), Dibennardo and Taylor (1982), Dittrick and Suchey (1986), Iscan and Shihai (1995), King et al. (1998), Mall et al. (2000)	Maximum Length
Steyn and Iscan (1997), Dibennardo and Taylor (1979, 1982), Dittrick and Suchey (1986), Iscan and Shihai (1995), King et al. (1998)	Midshaft Circumference
Steyn and Iscan (1997), Dibennardo and Taylor (1982), Dittrick and Suchey (1986), Iscan and Shihai (1995), King et al. (1998), Asala et al. (2004)	Anteroposterior Diameter
Mall et al. (2000)	Maximum Midshaft Diameter
Mall et al. (2000)	Condylar Width
King et al. (1998), Mall et al. (2000), Asala et al. (2004)	Vertical Head Diameter
Mall et al. (2000)	Transverse Head Diameter
Mall et al. (2000)	Head Circumference
Asala et al. (2004)	Minimum Vertical Neck Diameter
Asala et al.(2004)	Upper Epicondylar Length
Dittrick and Suchey (1986), King et al. (1998), Asala et al.(2004)	Bicondylar Breadth
Asala et al. (2004)	Medial Condylar Length
Asala et al. (2004)	Lateral Condylar Length
Dittrick and Suchey (1986)	Physiological Length
Dittrick and Suchey (1986)	Subtrochanteric Anterior-posterior Diameter
Dittrick and Suchey (1986)	Subtrochanteric Medio-lateral Diameter
Dittrick and Suchey (1986)	Midshaft Medio-lateral Diameter

Table 2: Measurements Taken on the Patella

Authors Who Used the Measurement (Date)	Measurements Taken
Introna et al. (1998), Bidmos et al. (2005), Dayal and Bidmos (2005), Kemkes-Grottenthaler (2005)	Maximum Height
Introna et al. (1998), Kemkes-Grottenthaler (2005)	Maximum Width
Bidmos et al. (2005), Dayal and Bidmos (2005),	Maximum Breadth
Introna et al. (1998), Bidmos et al. (2005), Dayal and Bidmos (2005), Kemkes-Grottenthaler (2005)	Maximum Thickness
Introna et al. (1998), Kemkes-Grottenthaler (2005)	Height of Facies Articularis Exterior
Introna et al. (1998), Kemkes-Grottenthaler (2005)	Width of Facies Articularis Exterior
Introna et al. (1998), Kemkes-Grottenthaler (2005)	Width of Facies Articularis Interior
Introna et al. 1998, Kemkes-Grottenthaler (2005)	Height of Facies Articularis Interior
Bidmos et al. (2005), Dayal and Bidmos (2005)	Maximum Height of Articulating Facet
Bidmos et al. (2005), Dayal and Bidmos (2005)	Maximum Width of Medial Articulating Facet
Bidmos et al. (2005), Dayal and Bidmos (2005)	Maximum Width of Lateral Articulating Facet

Table 3: Measurements Taken on the Tibia

Measurements Taken for the Proximal Portion	Authors Who Used the Measurement (Date)
Anteroposterior Diameter of the Joint Surface of the Medial Condyle	Lucena dos-Santos et al. (2018)
Transverse Diameter of the Joint Surface of the Medial Condyle	Lucena dos-Santos et al. (2018)
Anteroposterior Diameter of the Joint Surface of the Lateral Condyle	Lucena dos-Santos et al. (2018)
Transverse Diameter of the Joint Surface of the Lateral Condyle	Lucena dos-Santos et al. (2018)
Anterior Transverse Measure of the Inter-Condyle Area	Lucena dos-Santos et al. (2018)
Posterior Transverse Measure of the Inter-Condyle Area	Lucena dos-Santos et al. (2018)
Middle Transverse Measure of the Inter-Condyle Area	Lucena dos-Santos et al. (2018)

Anteroposterior Measure of the Inter-Condyle Area	Lucena dos-Santos et al. (2018)
Anterior Measure of the Inter-Condyle Area	Lucena dos-Santos et al. (2018)
Posterior Measure of the Inter-Condyle Area	Lucena dos-Santos et al. (2018)
Biarticular Breadth	Holland (1991), Kieser et al. (1992)
Medial Condyle Articular Width	Holland (1991), Kieser et al. (1992)
Medial Condyle Articular Length	Holland (1991), Kieser et al. (1992)
Lateral Condyle Articular Width	Holland (1991), Kieser et al. (1992)
Lateral Condyle Articular Length	Holland (1991), Kieser et al. (1992)
Measurements Taken for the Shaft	**Authors Who Used the Measurement (Date)**
Circumference at Nutrient Foramen	Iscan and Miller-Shaivitz (1984b), Fasemore et al. (2011), Garcia (2012)
Transverse Breadth	Iscan and Miller-Shaivitz (1984a, b)
Anteroposterior Diameter	Iscan and Miller-Shaivitz (1984a, b), Fasemore et al. (2011)
Minimum Shaft Circumference	Iscan and Miller-Shaivitz (1984a, b)
Proximal End of Tibia to Nutrient Foramen	Fasemore et al. (2011)
Mediolateral Diameter	Fasemore et al. (2011)
Measurements Taken for the Entire Bone as well as Fragmentary Bone	**Authors Who Used the Measurements (Date)**
Maximum Length	Iscan and Miller-Shaivitz (1984a, b), Iscan et al. (1994), Gonzalez-Reimers et al. (2000), Slaus and Tomicic (2004), Deepthi et al. (2019)
Transverse Breadth	Iscan and Miller-Shaivitz (1984a, b), Iscan et al. (1994), Steyn and Iscan (1997), Gonzalez-Reimers et al. (2000), Slaus and Tomicic 2004, Deepthi et al. (2019)
Anteroposterior Diameter	Iscan and Miller-Shaivitz (1984a, b), Iscan et al. (1994), Steyn and Iscan (1997), Gonzalez-Reimers et al. (2000), Deepthi et al. (2019)
Minimum Shaft Circumference	Iscan and Miller-Shaivitz (1984a, b). Iscan et al. (1994), Steyn and Iscan (1997), Gonzalez-Reimers et al. (2000), Deepthi et al. (2019)
Proximal Epiphyseal Breadth	Iscan and Miller-Shaivitz (1984b), Iscan et al. (1994), Steyn and Iscan (1997), Gonzalez-Reimers et al. (2000), Slaus and Tomicic (2004), Robinson and Bidmos (2011), Deepthi et al. (2019)
Distal Epiphyseal Breadth	Iscan and Miller-Shaivitz (1984b), Iscan et al. (1994), Steyn and Iscan (1997), Gonzalez-Reimers et al. (2000), Slaus and Tomicic (2004), Robinson and Bidmos (2011), Deepthi et al. (2019)
Maximum Diameter at the Nutrient Foramen	Slaus and Tomicic (2004)

Circumference at the Nutrient Foramen	Iscan et al. (1994), Gonzalez-Reimers et al. (2000), Slaus and Tomicic (2004), Deepthi et al. (2019)
Physiological Length	Steyn and Iscan (1997)
Circumference	Steyn and Iscan (1997)

Table 4: Measurements Taken on the Fibula

Measurements Taken for Distal Portion	**Authors Who Used the Measurement (Date)**
Perpendicular A	Sacragi and Ikeda (1995) and Tabencki (2015)
Perpendicular B	Sacragi and Ikeda (1995) and Tabencki (2015)
Perpendicular C	Sacragi and Ikeda (1995) and Tabencki (2015)
Bilateral Diameter of the Lateral Malleolar Fossa	Sacragi and Ikeda (1995) and Tabencki (2015)
Length of Lateral Malleolus	Sacragi and Ikeda (1995) and Tabencki (2015)
Measurements Taken for Nutrient Foramen	**Authors Who Used the Measurement (Date)**
Proximal End of Fibula to Nutrient Foramen	Fasemore et al. (2018)
Circumference at Nutrient Foramen	Fasemore et al. (2018)
Antero-Posterior Diameter at Nutrient Foramen	Fasemore et al. (2018)
Mediolateral Diameter at Nutrient Foramen	Fasemore et al. (2018)

Table 5: Measurements Taken on the Foot Bones

Authors Who Used the Measurement (Date)	**Measurements Taken for the Tarsals (Except Talus and Calcaneus)**
Harris and Case (2012)	Maximum Length
Harris and Case (2012)	Maximum Breadth
Harris and Case (2012)	Maximum Height
Authors Who Used the Measurement (Date)	**Measurements Taken for the Talus**
Steele (1976), Wilbur (1998), Barrett et al, (2001), Murphy (2002), Bidmos and Dayal (2003, 2004), Gualdi-Russo (2007), Abd-Elaleem et al. (2012), Harris and Case (2012), Mahakkanukrouh et al. 2014, Peckmann et al. (2015)	Length
Steele (1976), Wilbur (1998), Barrett et al. (2001), Murphy (2002), Bidmos and Dayal (2003, 2004), Gualdi-Russo (2007), Abd-Elaleem et al. (2012), Harris and Case (2012),	Width

Mahakkanukrouh et al. (2014), Peckmann et al. (2015)	
Steele (1976), Wilbur (1998), Barrett et al. (2001), Murphy (2002), Bidmos and Dayal (2003, 2004), Gualdi-Russo (2007), Abd-Elaleem et al. (2012), Harris and Case (2012), Mahakkanukrouh et al. (2014), Peckmann et al. (2015)	Body Height
Bidmos and Dayal (2003, 2004), Abd-Elaleem et al. (2012), Peckmann et al. (2015)	Head-Neck Length
Steele (1976), Wilbur (1998), Murphy (2002, 2004), Bidmos and Dayal (2003, 2004), Abd-Elaleem et al. (2012), Mahakkanukrouh et al. (2014), Peckmann et al. (2015)	Trochlear Length
Bidmos and Dayal (2003, 2004), Peckmann et al. (2015)	Length of Posterior Articular Surface
Steele (1976), Wilbur (1998), Murphy (2002, 2004), Bidmos and Dayal (2003, 2004), Abd-Elaleem et al. (2012), Mahakkanukrouh et al. (2014), Peckmann et al. (2015)	Trochlear Breadth
Bidmos and Dayal (2003, 2004), Peckmann et al. (2015)	Breadth of Posterior Articular Facet
Bidmos and Dayal (2003, 2004), Peckmann et al. (2015)	Head Height
Mahakkanukrouh et al. (2014)	Length of Inferior Articular Surface
Mahakkanukrouh et al. (2014)	Breadth of Inferior Articular Surface
Mahakkanukrouh et al. (2014)	Minimum Inferior Interarticular Distance
Mahakkanukrouh et al. (2014)	Maximum Lateral Malleolar Surface Height
Mahakkanukrouh et al. (2014)	Minimum Interarticular Distance Across the Neck
Abd-Elaleem et al. (2012)	Neck Width
Abd-Elaleem et al. (2012)	Neck Height
Abd-Elaleem et al. (2012)	Calcaneal Articular Surface Length
Abd-Elaleem et al. (2012)	Navicular Articular Surface Height
Authors Who Used the Measurement (Date)	**Measurements Taken for the Calcaneus**
Steele (1976), Introna et al. (1996), Wilbur (1998), Murphy (2002), Bidmos and Asala (2003, 2004), Gualdi-Russo (2007), DiMichele and Spradley (2012), Harris and Case (2012), Kim et al. (2013)	Maximum Length
Steele (1976), Murphy (2002), Bidmos and Asala (2003, 2004), DiMichele and Spradley (2012), Kim et al. (2013)	Load Arm Length

Steele (1976), Introna et al. (1996), Wilbur (1998), Murphy (2002), DiMichele and Spradley (2012)	Load Arm Width
Nathena et al. (2017)	Load Arm Height
Bidmos and Asala (2003), Kim et al. (2013)	Dorsal Articular Facet Length
Steele (1976), Introna et al. (1996), Wilbur (1998), Murphy (2002), Bidmos and Asala (2003, 2004), Gualdi-Russo (2007), Kim et al. (2013), Nathena et al. (2017)	Body Height
Kim et al. (2013)	Minimum Body Height
Introna et al. (1996), Bidmos and Asala (2003, 2004), Harris and Case (2012), Kim et al. (2013), Nathena et al. (2017)	Maximum Height
Bidmos and Asala (2003, 2004), Kim et al. (2013), Nathena et al. (2017)	Cuboidal Facet Height
Bidmos and Asala (2003, 2004), Gualdi-Russo (2007), Harris and Case (2012), Kim et al. (2013)	Medial Breadth
Bidmos and Asala (2003, 2004), Kim et al. (2013), Natheran et al. (2017)	Dorsal Articular Facet Breadth
Bidmos and Asala (2004), Nathena et al. (2017)	Dorsal Articular Facet Length
Steele (1976), Introna et al. (1996), Murphy (2002), Bidmos and Asala (2003), Kim et al. (2013)	Minimum Breadth
Intron et al. (1996)	Breadth of the Facies Articularis Talaris Posterior
Introna et al. (1996)	Breadth of the Facies Articularis Cuboidea
Introna et al. (1996)	Height of the Facies Articularis Cuboidea
DiMichele and Spradley (2012)	Posterior Circumference
Nathena et al. (2017)	Maximum Anterioposterion Length
Nathena et al. (2017)	Minimum Transverse Width
Nathena et al. (2017)	Maximum Transverse Width
Nathena et al. (2017)	Width of Sulcus Calcanei

Authors Who Used the Measurement (Date)	**Measurements Taken for the Metatarsals**
Wilbur (1998), Bidmos et al. (2020)	Length M1 – M4
Wilbur (1998), Bidmos et al. (2020)	Functional Length of M5
Wilbur (1998), Bidmos et al. (2020)	Morphological Length of M5
Case and Ross (2007)	Maximum Axial Length
Robling and Ubelaker (1997), Mountrakis et al. (2010)	Maximum Length
Robling and Ubelaker (1997), Mountrakis et al. (2010)	Medio-lateral Width of Head
Mountrakis et al. (2010)	Dorso-plantar Width of Head

Mountrakis et al. (2010)	Medio-lateral Width at Midshaft
Mountrakis et al. (2010)	Dorso-plantar Width at Midshaft
Robling and Ubelaker (1997), Mountrakis et al. (2010)	Medio-lateral Width of Base
Mountrakis et al. (2010)	Dorso-plantar Width of Base
Robling and Ubelaker (1997)	Superoinferior Head Height
Robling and Ubelaker (1997)	Superoinferior Base Height
Robling and Ubelaker (1997)	Midshaft Diameter
Authors Who Used the Measurement (Date)	**Measurements Taken for the Phalanges**
Karakastis and Moraitis (2014)	Maximum Length
Karakastis and Moraitis (2014)	Maximum Antero-posterior Width
Karakastis and Moraitis (2014)	Maximum Medio-lateral Width
Karakastis and Moraitis (2014)	Head
Karakastis and Moraitis (2014)	Midshaft
Case and Ross (2007)	Maximum Axial Length

Appendix C: Side of Element Investigated

The following is a table that dictates which side of the bone was used for each investigation within the database, which should be stated within the materials and methods section, or within the results if a difference between the two sides was discovered. This chart was created due to the interesting theme that the authors did not always present which side of the bone they worked with during their investigation.

*Note: For the foot bones, only the talus and calcaneus have been analysed due to the number of investigations that focus on these tarsal bones.

Table 6: Side of the Femur Used

Author (Date)	Side of Element Used
Black (1979)	Not Specified
Dibennardo and Taylor (1979)	Not Specified
Dibennardo and Taylor (1982)	Not Specified
Dittrick and Suchey (1986)	Not Specified
Iscan and Shihai (1995)	Not Specified
Steyn and Iscan (1997)	Not Specified
King et al. (1998)	Left (whenever possible)
Mall et al. (2000)	Not Specified
Asala (2001)	Left and Right
Asala (2002)	Left and Right
Asala et al. (2004)	Left
Murphy (2005)	Not Specified
Purkait (2005)	Left and Right
Albanese et al. (2008)	Left (unless there was damage or missing bone, then the right was used)
Robinson and Bidmos (2011)	Left
Curate et al. (2016)	Left
Colman et al. (2018)	Left (with the exception of eleven cases in which the right was used)

Table 7: Side of the Patella Used

Author (Date)	Side of Element Used
Introna et al. (1998)	Right
Bidmos et al. (2005)	Left
Dayal and Bidmos (2005)	Left
Kemkes-Grottenthaler (2005)	Left and Right
Mahfouz et al. (2007)	Left and Right

Table 8: Side of the Tibia Used

Author (Date)	Side of Element Used
Iscan and Miller-Shaivitz (1984)	Not Specified
Iscan and Miller-Shaivitz (1984)	Left
Holland (1991)	Left
Kieser et al. (1992)	Not Specified
Iscan et al. (1994)	Not Specified
Steyn and Iscan (1997)	Not Specified
Gonzalez-Reimers et al. (2000)	Right
Slaus and Tomicic (2004)	Left
Robinson and Bidmos (2011)	Left
Garcia (2012)	Left
Brzobahata et al. (2014)	Left
Brzobahata et al. (2016)	Left
Fasemore et al. (2018)	Not Specified
Lucena dos-Santos et al. (2018)	Left and Right
Deepthi et al. (2019)	Not Specified

Table 9: Side of the Fibula Used

Author (Date)	Side of Element Used
Sacragi and Ikeda (1995)	Right
Aparna and Rajasree (2013)	Left and Right
Tabencki (2015)	Not Specified
Fasemore et al. (2018)	Not Specified

Table 10: Side of the Talus Used

Author (Date)	Side of Element Used
Steele (1976)	Left
Wilbur (1998)	Left and Right
Barrett et al. (2001)	Left and Right
Murphy (2002)	Not Specified
Bidmos and Dayal (2003)	Left
Bidmos and Dayal (2004)	Left
Gualdi-Russo (2007)	Left and Right
Abd-Elaleem et al. (2012)	Right
Harris and Case (2012)	Left and Right
Mahakkanukrauh et al. (2014)	Left and Right
Peckmann et al. (2015)	Left

Table 11: Side of the Calcaneus Used

Author (Date)	Side of Element Used
Riepert et al. (1996)	Left and Right
Introna et al. (1997)	Right
Wilbur (1998)	Left and Right
Murphy (2002)	Not Specified
Bidmos and Asala (2003)	Left (unless the left was not available, then the right was used)
Bidmos and Asala (2004)	Left
Gualdi-Russo (2007)	Left and Right
DiMichele and Spradley (2012)	Left (unless the left was unavailable or did not meet certain criteria)
Harris and Case (2012)	Left and Right
Kim et al. (2013)	Left and Right
Nathena et al. (2017)	Left and Right

Appendix D: Most and Least Accurate/Dimorphic Measurements Used

*Note: The following tables all summarize the most accurate and the least accurate measurements used among each element of the lower limbs for each investigation within the database. As stated within the thesis, these measurements and landmarks need to be used in combination with other measurements in order to provide the highest level of accuracy.

**Note: As noted within the thesis, due to the fact the discriminant function analysis has more universal relevance across all elements, only those investigations that used discriminant function analysis and metrics are listed in the tables below. This is due to the fact that this is a specific methodology within the broader topic of sexing methods, and as a supporting argument to the use of discriminant function analysis as a core method, it is easier to list relevant investigations that use the exact same method versus those that utilize a different method. Logistic regression was also included since a key aspect is the use of specific measurements.

**Note: Even those measurements listed as the least accurate may have a high accuracy percentage and should not be disregarded in future investigations. It is within the author's specific investigation that they showed the least accuracy of the measurements investigated. The weight of the accuracy will also depend on which aspect of the element the measurements were being taken from. For this list, please see the above section entitled *Measurements Taken for Each Element*.

Table 12: Most and Least Accurate Measurements Used on the Femur

Author (Date)	Most Accurate/Most Dimorphic	Least Accurate/Least Dimorphic
Black (1978)	Shaft Circumference	Maximum Length
Dibennardo and Taylor (1979)	Circumference	Maximum Length
Dibennardo and Taylor (1982)	Circumference	Transverse Diameter
Dittrick and Suchey (1986)	Diameter of the Head	Subtrochanteric Medio-Lateral Diameter
Iscan and Shihai (1995)	Distal Breadth	Maximum Length
Steyn and Iscan (1997)	Distal Breadth	Head Diameter
King et al. (1998)	Maximum Head Diameter Bicondylar Breadth	Maximum Length
Mall et al. (2000)	Transverse Head Diameter	Maximum Length
Asala et al. (2004)	Vertical Head Diameter	Antero-Posterior Subtrochanteric Diameter
Murphy (2005)	Head Circumference	Not Specified
Purkait (2005)	Greater Trochanter to Lesser Trochanter	Articular Margin of Head to Greater Trochanter
Robinson and Bidmos (2011)	Distal Breadth	Transverse Diameter
Curate et al. (2016)	Femoral Neck Axis Length	Neck Diameter
Colman et al. (2018)	Transverse Head Diameter Vertical Head Diameter Head Circumference	Maximum Head Circumference

Table 13: Most and Least Accurate Measurements Used on the Patella

Author (Date)	Most Accurate/Most Dimorphic	Least Accurate/Least Dimorphic
Introna et al. (1998)	Maximum Height	Height of Facies Articularis Interior
Bidmos et al. (2005)	Maximum Height Maximum Breadth	Maximum Width of Lateral Articulating Facet
Dayal and Bidmos (2005)	Maximum Height Maximum Breadth	Lateral Articular Facet Breadth
Kemkes-Grottenthaler (2005)	Maximum Height	Width of the Facies Articularis Exterior

Table 14: Most and Least Used Accurate Measurements Used on the Tibia

Author (Date)	Most Accurate/Most Dimorphic	Least Accurate/Least Dimorphic
Iscan and Miller-Shaivitz (1984a)	Circumference	Maximum Length
Iscan and Miller-Shaivitz (1984b)	Circumference	Maximum Length
Holland (1991)	Biarticular Breadth	Medial Condyle Articular Width Lateral Condyle Articular Width
Kieser et al. (1992)	Biarticular Breadth	Medial Condyle Articular Width Lateral Condyle Articular Width
Iscan et al. (1994)	Circumference Epiphyseal Breadths	Maximum Length
Steyn and Iscan (1997)	Distal Epiphyseal Breadth	Proximal Epiphyseal Breadth
Gonzalez-Reimers et al. (2000)	Minimum Shaft Circumference Epiphyseal Breadth	Maximum Length
Slaus and Tomicic (2004)	Maximum Diameter at the Nutrient Foramen	Maximum Length
Robinson and Bidmos (2011)	Proximal Epiphyseal Breadth	Distal Epiphyseal Breadth
Garcia (2012)	Shaft Circumference	Not Applicable
Fasemore et al. (2018)	Circumference at the Nutrient Foramen	Not Specified
Lucena dos-Santos et al. (2018)	Anterior Transverse Measure of the Inter-Condyle Area	Middle Transverse Measure of Inter-Condyle Area
Deepthi et al. (2019)	Transverse Diameter at the Nutrient Foramen Minimum Circumference at the Shaft	Not Specified

Table 15: Most and Least Accurate Measurements Used on the Fibula

Author (Date)	Most Accurate/Most Dimorphic	Least Accurate/Least Dimorphic
Sacragi and Ikeda (1995)	No Individual Measurements Alone are Useful – All Measurements Combined Provide a High Accuracy	Any Measurement on its Own
Tabencki (2015)	Not Specified	Not Specified
Fasemore et al. (2018)	Circumference at Nutrient Foramen	Not Specified

Table 16: Most and Least Accurate Measurements Used on the Foot Bones

Author (Date) Tarsals Minus the Calcaneus and Talus	**Most Accurate/Most Dimorphic**	**Least Accurate/Least Dimorphic**
Harris and Case (2012)	Breadth Variables	Length Variables
Author (Date) Calcaneus	**Most Accurate/Most Dimorphic**	**Least Accurate/Least Dimorphic**
Introna et al. (1997)	Maximum Length Height of Calcaneus	Height of Facies Articularis Cuboidea Breadth of Facies Articularis Cuboidea
Wilbur (1998)	Combined Measurements	Individual Measurements
Murphy (2002)	Maximum Length	Not Specified
Bidmos and Asala (2003)	Dorsal Articular Facet Breadth	Load Arm Length
Bidmos and Asala (2004)	Length Measurements	Not Specified
Gualdi-Russo (2007)	Maximum Length	Body Height
DiMichele and Spradley (2012)	Load Arm Width Load Arm Length	Maximum Length
Harris and Case (2012)	Breadth Variables	Length Variables
Kim et al. (2013)	Minimum Breadth	Dorsal Articular Facet Length
Nathena et al. (2017)	Maximum Width	Maximum Length
Author (Date) Talus	**Most Accurate/Most Dimorphic**	**Least Accurate/Least Dimorphic**
Steele (1976)	Maximum Length	Not Specified
Barrett et al. (2001)	Combined Height, Width and Length Measurements	Not Specified
Murphy (2002)	Maximum Length	Not Specified
Wilbur (1998)	Combined Measurements	Individual Measurements
Bidmos and Dayal (2003)	Maximum Length	Head Height
Bidmos and Dayal (2004)	Height of Head	Width Head Neck Length
Gualdi-Russo (2007)	Maximum Length	Not Specified
Abd-Elaleem et al. (2012)	Maximum Length	Neck Length

Harris and Case (2012)	Breadth Variables	Length Variables
Mahakkanukrauh et al. (2014)	Maximum Trochlear Length Maximum Trochlear Breadth	Maximum Breadth of the Inferior Articular Surface
Peckmann et al. (2015)	Length Variables	Height Variables
Author (Date) Metatarsals	**Most Accurate/Most Dimorphic**	**Least Accurate/Least Dimorphic**
Robling and Ubelaker (1997)	Not Specified	Not Specified
Mountrakis et al. (2010)	Combined Length Measurements	Not Specified
Bidmos et al. (2020)	Combined Length Measurements	Individual Length Measurements
Author (Date) Phalanges	**Most Accurate/Most Dimorphic**	**Least Accurate/Least Dimorphic**
Karakostis and Moraitis (2014)	Medio-Lateral Width at the Head	Medio-Lateral Width at the Base

Appendix E: Total Percentages for Combined Measurement Types

The following is a summary of Tables 12 - 16: Most and Least Accurate/Dimorphic Measurement Used. The following tables provide the total number of times a broad measurement was used out of the total measurements listed, as well as their percentage.
*Note: The fibula has been excluded from this section due to a lack of data.
**Note: Regarding the foot bones, only the talus and calcaneus have been summarized below due to the frequency of investigation concerning these tarsal bones. There is not enough data to summarize each tarsal, metatarsal, and phalanx.

Table 17: Total Percentages for Most/Least Applicable Measurements of the Femur

Measurement Type	Total for Most Accurate/Dimorphic		Total for Least Accurate/Dimorphic	
Circumference	5/17	29%	1/14	29%
Diameter	6/17	35%	6/14	43%
Breadth	4/17	24%	0/14	0%
Length	2/17	12%	6/14	43%
Not Specified	N/A	N/A	1/14	7%

Table 18: Total Percentages for Most/Least Applicable Measurements of the Patella

Measurement Type	Total for Most Accurate/Dimorphic		Total for Least Accurate/Dimorphic	
Height	4/6	67%	1/4	25%
Breadth	2/6	34%	1/4	25%
Width	0/6	0%	2/4	50%

Table 19: Total Percentages for Most/Least Applicable Measurements of the Tibia

Measurement Type	Total for Most Accurate/Dimorphic		Total for Least Accurate/Dimorphic	
Circumference	7/16	44%	0/15	0%
Diameter	2/16	13%	0/15	0%
Breadth	6/16	34%	2/15	13%
Length	1/16	6%	6/15	40%
Width	0/16	0%	4/15	27%
Not Specified	0/16	0%	2/15	13%
Not Applicable	0/16	0%	1/15	7%

Table 20: Total Percentages for Most/Least Applicable Measurements of the Talus

Measurement Type	Total for Most Accurate/Dimorphic		Total for Least Accurate/Dimorphic	
Length	7/12	58%	3/11	27%
Height	1/12	8%	2/11	18%
Width	0/12	0%	1/11	9%
Breadth	2/12	17%	1/11	9%
Combined	2/12	17%	0/11	0%
Individual	0/12	0%	1/11	9%
Not Specified	0/12	0%	3/11	27%

Table 21: Total Percentages for Most/Least Applicable Measurements of the Calcaneus

Measurement Type	Total for Most Accurate/Dimorphic		Total for Least Accurate/Dimorphic	
Length	5/12	42%	5/11	45%
Height	1/12	8%	2/1	18%
Width	2/12	17%	0/11	0%
Breadth	3/12	25%	1/11	9%
Combined	1/12	8%	0/11	0%
Individual	0/12	0%	1/11	9%
Not Specified	0/12	0%	2/11	18%