UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Sex determination from the bones of the forearm in a modern South African sample

By

Isabelle Linda Odile Barrier

Submitted in Fulfillment of the Requirements for the Degree of Master of Science

In the Health Sciences Faculty

University of Pretoria

Pretoria

November 2007

Declaration:

I declare that this thesis is my own, unaided work, and is being submitted in fulfillment of the requirements for the degree of Master of Science (Anatomy) to the University of Pretoria. It has not been submitted for any other degree or examination at any other University.

Signed

____

___________ day of _____________________ 2007

ABSTRACT

With a large number of unidentified skeletal remains found in South Africa, the development of osteometric standards to determine sex from various bones is crucial. It is imperative that a forensic anthropologist have access to a variety of techniques both morphological and metric, which can be used to establish accurate demographic profiles from complete, fragmentary and/or commingled remains. Standards for South African populations are available for the cranium, humerus, pelvis, femur, tibia, calcaneus, and talus. No research has been done on bones of the forearm, even though they are known through international studies to exhibit sexual dimorphism. The purpose of this research was to develop discriminant function formulae to determine sex from the radius and ulna for a South African population. The sample consisted of 200 male and 200 female skeletons from the Pretoria Bone (University of Pretoria) and Raymond A. Dart (Witwatersrand University) collections. Sixteen standard anthropometric measurements were taken from the radius (9) and ulna (7) and subjected to stepwise and direct discriminant function analysis.

Distal breadth, minimum midshaft diameter and maximum head diameter were the best discriminators of sex in the radius, while minimum midshaft diameter and olecranon breadth were selected for the ulna. Classification accuracy for the forearm ranged from 76% to 86%. In summary, the radius and ulna can be considered moderate discriminators for determining sex in a South African group. However, it is advised that whenever possible these formulae are used in conjunction with visual methods to determine sex from skeletal remains.

ABSTRAK

Die groot aantal ongeïdentifiseerde skeletale oorblyfsels wat in Suid-Afrika gevind word noodsaak die ontwikkeling van osteometriese standaarde om geslag met behulp van verskillende bene te bepaal. Dit is belangrik dat 'n forensiese antropoloog toegang tot 'n verskeidenheid morfologiese en metriese tegnieke het wat gebruik kan word om akkurate demografiese profiele uit volledige, gefragmenteerde en/of gemengde reste op te stel. Standaarde vir Suid-Afrikaanse bevolkings is vir die skedel, humerus, pelvis, femur, tibia, kalkaneus en talus beskikbaar. Geen navorsing is nog op die bene van die voorarm gedoen nie ten spyte van internasionale studies wat toon dat hierdie bene wel seksuele dimorfisme vertoon. Die doel van hierdie studie was om diskriminante funksie formules te ontwikkel om geslag met behulp van die radius en ulna op Suid-Afrikaanse bevolking te bepaal. Die steekproef het uit 200 manlike en 200 vroulike skelette uit die Pretoria Bene Versameling (Universiteit van Pretoria) en die Raymond A. Dart Versameling (Universiteit van die Witwatersrand) bestaan. Sestien standaard antropometriese afmetings is op die radius (9) en ulna (7) gedoen en met behulp van trapsgewyse en direkte diskriminante funksie geanaliseer.

Distale breedte, minimum midskag deursnit en maksimum deursnit van die kop was die beste diskriminante van geslag vir die radius, terwyl minimum midskag deursnit en breedte van die olekranon vir die ulna geselekteer is. Akkurate klassifikasie vir die voorarm varieer tussen 76% en 86%.

Samevattend, kan die radius en ulna as middelmatige diskriminante vir die bepaling van geslag in 'n Suid-Afrikaanse groep beskou word. Omdat die voorbeelde in die steekproef vanuit onopgeëisde oorblysels afkomstig is, is dit moontlik dat wanvoeding en 'n lae sosio-ekonomiese status vir die middelmatige diskriminasie in die swart Suid-Afrikaanse populasie, wanneer dit met ander groepe vergelyk word, verantwoordelik is. Daar word aanbeveel dat die formules sover moontlik saam met visuele metodes gebruik word om geslag vanuit skeletale oorblyfsels te bepaal.

Acknowledgements

Firstly, I would like to thank my supervisor Dr E.N. L'Abbé for her patience, encouragement and relentless editing over the last year.

I would like to thank my external examiner for reading and evaluating this work, your time is much appreciated.

Several people have helped along the way, Professor P. Becker for his guidance and helping me with the statistical analyses; Marius Loots for supplying me with the appropriate computer software to conduct the statistical analyses; as well as the staff at the preclinical library must be thanked for handling all my requests, for sometimes-obscure articles.

Lastly I would like to thank my friends and family for their support and willingness to help with data collection, organization of research materials and editing. For all those who read copies of this dissertation in various stages of completion, thank you for your input. Sean, your patience with my mood swings has meant a great deal, thank you for your tireless support, letting me rant and always being there smiling and offering coffee.

Dedicated to my parents,

Without whose unwavering support I would not have come this far

TABLE OF CONTENTS

Page

CHAPTER

LIST OF TABLES

Page

LIST OF FIGURES

Page

When their bones are picked clean and the clean bones gone,

They shall have stars at elbow and foot.

- Dylan Thomas ‘ And Death Shall have no Dominion’

Chapter 1
Introduction

Violent crime is on the rise worldwide, and South Africa is no exception. Several hundred unidentified remains are retrieved each year in a condition of advanced or complete decomposition (e.g., skeleton). The most common source of discovery of badly decomposed remains is often by tipoffs from a member of the public who may come across the body in a vacant plot, shallow burial or the veldt, weeks, or months, after death. As is often the case, these remains are fragmentary in nature, not only because of carnivore activity or a natural veldt fire, but also due to the deliberate removal (or fragmentation) of the body by the perpetrator to either avoid identification or for ritualistic purposes. (1-4)

Further confounding the problem is that many of these victims are of low socio-economic status and never had medical or dental treatment, a fact that reduces the possibility of observing individualizing characteristics, such as dental or medical procedures, that might lead, via normal channels, to their identification. While DNA analysis has proven successful in identifying unknown victims and perpetrators of crime, it is of little value when there are no family members to positively identify or claim the deceased. (5-7) In South Africa, the SAPS and forensic pathologists frequently encounter situations in which standard avenues for identification, e.g., fingerprints, DNA and antemortem dental records, are of little or no value. In these situations, the expertise of a forensic anthropologist is often utilized; of which their responsibilities are to develop a profile (age, sex, ancestry and stature) of the deceased as well as to describe any visible trauma and/or taphonomic changes that may have occurred between death and discovery. (8-11)

Upon the discovery of skeletal material, many questions are asked, some of which include: is it animal or human, how many are there, to whom do they belong, and what caused their death? (10,12) While information on animal verses human remains are fairly straightforward and can be evaluated via macroscopic or microscopic techniques, commingled remains are a more complex issue. (10,13-15) The frequency of commingled cases has increased in modern society where a large percentage of the population commutes en mass to and between cities using busses, trains and even airplanes. These large concentrations of people of mixed age, origin and sex, suggest that in the event of a disaster there will be an increased number of victims, resulting in the need for these remains to be separated and identified. (1,13,16) Furthermore, it is not uncommon for forensic anthropologists to be involved in the excavation of mass graves, in which a dozen of more individuals were thrown together in a single burial pit, irrespective of familial relations. (17,18) In this context, the separating and counting of individuals is simplified when numerous techniques are available for distinguishing between bones based on sex, age and ancestry. (14,15,19) However, in circumstances were the death count is high and the remains are extremely fragmented (e.g. World Trade Center disaster), DNA and microscopic techniques rather than macroscopic analysis is preferred. (20-25) Once it has been ascertained whether the remains belong to one or many individuals, the next step is to address the questions as to whom does a particular skeleton belong, namely the possibly identifying features of that person, and how, if possible, did the person die. (17) While the anthropologist is not responsible, or qualified, to determine the manner and cause of death, their knowledge of bone biomechanics and fracture patterns on bone is often used, in conjunction with a forensic pathologist, to establish conclusions regarding the death of an unknown person.

In instances where a forensic pathologist cannot determine the biological characteristics of that person from visual means, the expertise of a forensic anthropologist is required. While a discussion on the advancements in methodology for the estimation of age and determination of ancestry is beyond the scope of this thesis, it can be said that much work has been done in this field both overseas and in South Africa. (26-31) Although age and ancestry are equally important aspects of a forensic case, the determination of sex from skeletal remains is generally the first step in the establishment of a demographic profile of the deceased, as knowledge of a person's sex, theoretically, cuts the possible number of victims in half. (32)

However, the determination of sex in the human skeleton is not always a simple task; in fact, such an endeavor can be quite problematic in the early childhood years with secondary sex characteristics appearing only after the onset of puberty. (10,14,32,33) Biologically and hormonally motivated sex traits have a clear logic for their presence, such as the need of pelvic enlargement in women to facilitate childbearing; whereas culturally motivated sex traits are linked to continuous activity and functional stress of one sex group in the population, an example would be that of ‘porter’s neck’ in rural African women. This condition results in micro-fractures of the vertebra and overdevelopment of neck and shoulder muscles, with subsequent muscle attachments on the bone, as a result of carrying heavy loads on their heads. (34,35) Other bony adaptations to repeated physical stress include shin splints observed in athletes and stress fractures of the femur and pelvis in female ballet dancers, to name but a few. (36, 37)

With this in mind, just how accurate is an anthropologist in determining sex from a complete, partially complete or fragmented adult skeleton? In practice, one can approach determining sex from human remains in two ways; which include firstly, the use of macroscopic features such as differences in brow ridge shape and pelvic inlet size, and secondly, measurement of the skeletal structures such as the humerus or femora. While morphological techniques are widely used among forensic anthropologists to determine sex, little research has been done to quantify the accuracy of these methods on different populations. Currently, anthropologists defend their conclusions, regarding the determination of sex and/or ancestry, on experience with studying skeletal remains on the population in question. While this is a plausible defense, and in most cases the increased number of years of experience does increase the chances of an accurate sex and/or ancestry determination, it cannot be quantified and thus is difficult to defend in a court of law. Another confounding problem is that incomplete or fragmentary remains can also dramatically reduce the likelihood of assigning the correct sex. (16,38,39) Morphological analysis is thus often used in conjunction with osteometry, which has provided a viable solution to reducing intra-observer error, with the use of standard anthropometric measurements to quantify size differences between the sexes of a particular population. (32)

While the debate among the efficacy of methods used to determine sex from skeletal remains continues, the forensic anthropologist, in practice, applies both morphological and metric techniques to determine sex of an unknown person. (31) Numerous local and international studies have been conducted to improve the accuracy in determining sex from complete and fragmentary remains using the scapula, clavicle, humerus, ulna, radius, the sternal ends of the ribs, sternum, femur, tibia, fibula and calcaneus. (12,32,33,40-53) For the most part, long bones, e.g., femur, humerus, tibia, are generally favored in osteometric studies, as they appear to yield the highest levels of classification accuracy. Furthermore, in most studies preference has been shown for circumference measurements, as these variables have been associated with differential bone development and robusticity, and proximal and distal measurements, which concern areas subject to greater functional or occupational stress. (54,55) However, none of these methods are perfect, and there are certain factors to consider when embarking on an osteometric study; such as sample representation and the variability of robusticity within and among populations both of which can affect the interpretation of the results. (31,38,56)

Concerns about sample representation are based on the manner in which the results of that sample can be applied to the living population. For instance, can an individual born in the late 18th century accurately represent someone born in the 20th century? In order to address this question, one must consider that the planet and indeed all life that it supports are in a constant state of flux: evolving, adapting, and changing, none more so than humans. Over time, Human beings change as they adapt to their environment, and in turn adapt the environment to suit themselves. As modern society seeks out more and more control over its destiny, health, life and the world in which we live, there has been a steady increase in hormones for the beautification of humankind: in the treating of acne, wrinkles, and morning sickness. Hormones are increasingly present in the life of young adults to boost growth, contraception, and improving sports performance. Farmers use them to enhance and augment crop production. (57,58) A variety of growth regulators serve as antibiotics, pesticides or herbicides; and soil and water chemistry have been greatly altered. In other words the sense of normality has changed and as a result the biology of human beings, as well as the demands on the body is changing, as form follows function. (58) These changes have been termed ‘secular trends’, derived from the Latin *saeculum*, meaning an age, and refers to a length of time roughly equal to the potential lifetime of a person, or the equivalent of the complete renewal of a human population. (59) Hence ‘secular’ refers to lasting for an age, a generation, a century, a very long period of time etcetera, as opposed to periodical, which refers to a short period of time. Secular change in its inception was understood as a slow but persistent change. Today, it refers to a long-term systematic and non-random changes in a wide variety of traits, through successive generations of a population living in the same territory. (60) Until recently secular trends were thought to be unidirectional, and that direction was upwards: for example, changes in stature and robusticity of a population were increasing. Simply put, people were getting taller and larger over time as a result of globalization trends, an increase in health and nutrition awareness, and access to better foodstuffs. (61) Although this is referred to as the ‘usual secular trend’, it is not a universal truth; and it has been demonstrated through various studies that secular trends could be expressed as either an increase or decrease of traits, often referred to as positive or negative secular trends, respectively. (62) In populations with favorable living circumstances positive trends have been observed in: increased mean birth weight, decrease in ‘premature’ babies, increased growth rate for stature and mass, earlier onset of puberty, increase in mean stature and mass, increase in various adult body proportions. (59) Secular trends, either positive, or negative, are bound to continue and even accelerate in response to changes in culture, diet and the environment, and as they appear to affect sexual dimorphism, research on the skeletal structure needs to follow suit to remain current and applicable. These changes will however, not continue unabated forever and eventually humankind should reach their genetic growth potential.

Expression of sexual dimorphism is another factor to consider when conducting osteometric studies. Variability is clearly evidenced as one glances around a room, street or even on a television screen. Although most modern populations are a melting pot of various cultural origins and we all have the same basic features (e.g. two eyes, two ears, and upright posture etcetera), men and women appear in different shapes, sizes and colours. At the turn of the century the human skeleton had already been investigated and certain morphological differences were noted with regard to both sex and ancestry. (63) Three major trends were considered to influence sexual dimorphism namely, reproductive function as expressed in the morphology of the pelvis, genetic differences that influenced body size and proportions, and lastly differences in musculature between the sexes. (39) Researchers realized that despite sharing the same basic structure; sexual dimorphism, stature and other visible characteristics appeared to differ between population groups.

Therefore, it was suggested that osteometric studies should be considered “population specific”, which implies that sexual dimorphism varies between populations to such an extent that osteometric standards developed from one group cannot be reliably used on another population. (31) For example, using foreign standards, such as those for African Americans and applying them a South African group, is not as reliable as developing standards from a modern South African skeletal collection. (32,40,53) This said, the notion of population specificity, although still valid in present-day South Africa is bound to change in the future as the population becomes more heterogeneous, due to cultural, dietary and environmental changes.

An attempt to address these problems is through the systematic study of modern skeletal collections available around the world. South Africa has a long tradition of academia in the field of physical anthropology aided in part by the establishment of two large skeletal collections at the University of the Witwatersrand and the University of Pretoria, the Raymond A. Dart and Pretoria Bone collections, respectively. (49,64) A significant amount of literature in the field of physical anthropology is the result of local research and contributions, based on these collections. (40,42,65-70) Forensic anthropologists in South Africa are particularly fortunate to have access to both the Pretoria Bone Collection and Dart Collection, as these are not only modern collections, but also two of the few skeletal collections worldwide, to still be growing. (64) These collections present researchers with the opportunity to collect modern and up-to-date data. A country such as South Africa, with its combination of high crime rates and large number of unidentified skeletal remains, calls for forensic anthropologists to develop South African based standards to determine sex from complete and incomplete skeletons, as well as improving methods for the estimation of age, ancestry and stature.

Osteometric studies focusing on the determination of sex, have recently been developed for the South African skull, humerus, pelvis, femur, tibia, talus and calcaneus. (40,42,43,53,65,70-73) This study adds to the existing knowledge on osteometric research in South Africa, and focuses on the relatively forgotten bones: the radius and ulna. The purpose of this study is to develop discriminant function formula from the bones of the forearm, so as to assist the anthropologist and/or pathologist in providing information for answering the question “to whom do these bones belong”.

Chapter 2
Literature review

2.1. Introduction

This chapter examines the development of the human skeleton with regard to males and females, provides a discussion on the bones of the forearm, and presents a comprehensive review of the various anthropological techniques, both morphologic and metric, that have been used to assess sexual dimorphism in the human skeleton. Particular focus has been placed on research conducted on South African samples.

2.2. Developmental osteology as the basis for sexual dimorphism

Two types of ossification are observed in the human skeleton, namely endochondral and intramembranous. (74,75) Endochondral ossification is of concern in this study, as this is the process through which long bones form and develop. During gestation a cartilaginous model, or replica of the future long bone is created, and acts as a type of scaffolding for the future bone. Prior to three lunar months, osteoblasts, or bone forming cells, begin to lay down bone within the centre of this structure, and continually move outward toward the proximal and distal ends of the bone. (76) By 12 weeks gestation, the initial diaphysis has been calcified. As bone is being laid down, the cartilage continues to grow both appositionally and interstitially (thus it grows in width and in length). Secondary ossification centres, responsible for promoting longitudinal growth of the bone throughout childhood and the adolescent years, develop at the proximal and distal ends of the bone; in a region of rapid bone growth, often referred to as the growth, or epiphyseal, plate. The cartilage is formed on the epiphyseal side of this growth plate, whilst on its diaphyseal side chondrocytes age, degenerate and dies; and at the same time, blood vessels and osteoblasts move in to ossify the cartilage matrix. (77,78) Growth is complete when the epiphyses and diaphysis are fused.

There is an indication that the cadence at which size and maturity increase, differs between the sexes before birth, with a tendency for ossification centers to appear earlier in females than males. Postnatally, however, skeletal maturation is more advanced in males than females, with ossification in the shaft occurring earlier in the former. (79-81) The order in which secondary epiphyseal centers ossify also differs between the sexes. For example, in males, the capitulum of the radius ossifies first, then the medial epicondyle; while, for females the order is reversed. (82)

As one can expect, differences in the width or circumference of bone between males and females is developmental in nature. During puberty, cortical bone is built at a faster pace in males than females as a means to compensate for rapid muscle expansion in males, as muscle mass requires an augmented skeleton to support the accompanying increase in weight. Differential hormonal secretions, which contribute to the appearance of sexual dimorphism in a population, influence an adolescent growth spurt that occurs at a later stage and is more intense in boys than girls. These hormones thus have a greater influence at a critical phase of growth. (83) This process leads to adolescent males increasing their bone circumference faster than females. The cross-sectional area of the bone continues to increase after puberty, but at a more reduced pace so that the bones of males, which became larger at puberty, continue to remain larger than females into adulthood. (32,84)

Growth in the human skeleton begins in various stages during puberty; similarly, individual bones reach skeletal maturity at different times: the proximal end of the radius fuses circa 15-16 years and 17 years for the male ulna, and a year or two earlier for females. (82) The distal end of the forearm fuses around 16 or 17 years of age for the radius, and 19 years for the ulna. (78) This is slightly earlier than in the lower limbs with the proximal femur, tibia and fibula fusing between 17 and 18 years, and distally 15 to 16 years. (78) This occurrence could be explained by both our bipedal gait and the need to support the increase in muscle and skeletal weight during puberty. (63,76)

2.3. Osteological review of the adult forearm

The forearm of the human skeleton consists of the radius and the ulna, two long bones which each present an elongated shaft and two extremities with articular facets. The ulna is the stable element of the medial aspect of the forearm while the radius, situated laterally, moves around it during pronation and supination. (82,85)

The proximal head of the radius is slightly concave and articulates with the capitulum of the humerus at the elbow joint. The head tilts laterally from the line of the shaft and is connected by a somewhat constricted neck, below which, on the medial side one finds the radial tuberosity which projects anteriorly. (76)

The shaft of the radius follows a gentle curve in a lateral and anterior direction, widening considerably at the distal end. Close examination of the radial shaft reveals three borders: the inter-osseous border runs straight down the medial side of the bone, from the tuberosity to the posterior border of the ulnar notch of the radius; the posterior border presents itself as a faint ridge running from the lower tip of the tuberosity to the dorsal tubercle at the distal extremity; and the anterior border passes down as a sharp oblique line that stretches from the tuberosity to the front of the styloid process. (76)

Examination of the ulna reveals a long bone with an expanded proximal end, a shaft and a head at the distal end. Proximally the ulna and the trochlea of the humerus form the elbow joint; laterally, the ulna articulates with the radius both proximally and distally at the superior and inferior radio-ulnar joints respectively. (76) The proximal end of the ulna is rather bulky and beak-like; it consists of a superior surface called the olecranon with the inferior surface delimited by the coronoid process, which encircle the anteriorly facing trochlear notch. The radial notch is located laterally to the coronoid process and serves as the platform for articulation with the circumference of the radial head. The tuberosity of the ulna is the roughened triangular area placed in front. (76,82)

The upper three quarters of the shaft is triangular while the lower quarter is rounded. Three borders and three surfaces appear along the length of the shaft, namely, the inter-osseous, anterior and posterior borders. The inter-osseous is found on the lateral aspect of the bone, it begins proximally at the junction of two lines that extend from the supinator crest and the antero-lateral margin of the coronoid process; it continues as the sharp attachment for the inter-osseous membrane connecting it to the radius, and fades towards the distal end of the bone. The anterior border is rounded and begins proximally on the medial aspect of the ulnar tuberosity and curves medially to terminate at the base of the styloid process. The posterior border is also rounded and runs from the apex of the coronoid process, curving sinuously to reach the posterior aspect of the styloid process. (76,86)

The distal end of the ulna presents a rounded head separated by a roughened area from the postero-medial location of the styloid process. A convex articular surface is present on the lateral side of the distal ulna and articulates with the ulnar notch of the radius at the inferior radio-ulnar joint. Distally an intra-articular disc attaches to the roughened area and separates the smooth surface of the head of the ulna from the carpal bones, the lunate and triquetrial bones. The ulna and radius are therefore not part of the wrist. (76)

The radius and ulna in a similar manner to the other long bones of the human skeleton are comprised of three parts: a diaphysis, epiphyses and a growth plate, which serves to separate the growing part of the bone from its shaft. (87,88) The diaphysis or shaft of the long bone has a hard and very dense collar of outer bone, also known as cortical bone, and an inner structure of spongy or cancellous bone. A thin layer of cancellous bone surrounds the lined medullar cavity in the shaft. The internal structure of the epiphyses is comprised mostly of this spongy cancellous bone and protected by a thin layer of compact bone. (87,88) The outer layer of the bone is covered in a strong fibrous membrane consisting of two layers of connective tissue: an outer fibrous layer contains fibroblasts; and the inner cambium layer contains osteoprogenitor cells which develop into osteoblasts (bone-forming cells). This membrane, known as the periosteum, plays a vital role in repairing damaged bone, by laying down additional bone, when necessary. If this protective layer is damaged or becomes infected the bone cannot heal itself. At the articular surfaces, the periosteum is replaced with hyaline cartilage, which acts as a shock absorber and supplies a smooth surface for joint movement and articulation. (78,87)

2.4. Methodology used to evaluate sexual dimorphism

The initial approach to understanding sexual dimorphism in human groups was to describe gross morphological features, such as the shape of the forehead, brow ridge and pelvic brim. The differences of these visual features were juxtaposed to explain how males and females differed from one another. These early studies elucidated on the characteristics that opposed the sexes regarding the skull and pelvis, with males being more ‘robust’, while females were more gracile, or infantile in their features. (89-93) When discussing skeletal morphology, it is generally accepted that males are larger than females with marked sites of muscle attachments, a more sloping forehead, larger supra-orbital torii, smoother and thicker supra-orbital margins, larger mastoid processes and a more pronounced external occipital protuberance. (63) In the mandible, the menton presents a square shape in males versus the rounder equivalent in females. Males often present with ramus flexure angulation in the posterior border of the mandibular ramus at the occlusal surface of the molars, as a result of post-adolescent growth. (33) This trait is absent in females who are suggested to retain the straight shape of juveniles. In the cases where ramus flexure is noted in females, it is found either near the neck of the condyle or associated with gonial eversion. (32) Visually, the clearest difference between the sexes appears in the bony structure of the pelvic girdle. Because the female pelvis is designed for both parturition and locomotion, several distinct architectural features oppose it to that of males, namely a rounder pelvic brim, wider sciatic notch and sub-pubic angle. Again, these bones are most often more gracile in appearance than those of males. (32) Many researchers have suggested that the pelvis, when preserved, is the best bone from which to determine sex from the skeleton. (26,32,40,41,65)

The shortcomings of using a purely morphological approach to classifying unidentified skeletal remains into the category of either male or female concerns the observer’s experience (and or bias) to identify and describe these features, the degree of sexual dimorphism present in a population, and the condition of the remains. (32)

Biases of the observer are problematic, and certain professional researchers have been known to initiate a ‘best-fit principle’, where the known sex of a specimen had to be ‘corrected’ to fit the pre-conceived ideas of "male" and "female" features. Although the renowned anthropologist Hrdlička was recognised as having one of the highest percentages of accuracy in determining the sex of an individual, his heavy dependency on size characteristics, and in particular observance of Eskimo skulls separate from the skeleton as a whole, led him to bear the brunt of much criticism on the part of his peers. (94) This in particular as, “he thought nothing of changing an earlier opinion when the skull measurements seemed out of line”. (94) Changing the designation of sex within a known skeletal sample is a problem as it reduces the range of variation, compromises the accuracy of the results, and biases the sample by affecting its demographic profile. (95) Morphological features may also be more or less visible from population to population, as is the case in Eskimo skulls, where most of the skulls appeared to lack robustiticy, or general "male" characteristics. (94) This problem is not a factor to be encountered in the Raymond A. Dart or Pretoria Bone collections. The expression of robusticity within a population is not solely the consequence of genetics, as was originally believed. The environment, lifestyle and cultural norms, can affect skeletal robusticity, and, in turn, one's interpretation of sex from the skeleton. Studying robusticity and changes in the human skeleton are highly relevant in the modern context. With the onset of secular trends, one may see changes in skeletal robusticity and the morphology of females, such as more robust crania, and more pronounced muscle attachments in professional female athletes. (96-98) However, regardless of selective processes, the features that define women as females, such as a wider pelvic is to be maintained, as it is function related.

When a skeleton is incomplete or fragmentary, the value of morphological indicators is also reduced. Morphological analysis is based on the presence and or absence of specific bony landmarks. If these landmarks are not visible because the necessary portion of the bone on which they are found has been damaged or is missing, the analyst is unable to use that bony characteristic to classify the individual as male or female. For this reason, more than one landmark is observed on the skeletal remains of an unknown person, so as to insure a higher degree of certainty as to correctly classifying sex. There are, however, instances, where little skeletal material is available for analysis that morphology is difficult, if not impossible. In such instances, the use of osteometry is often preferred. (32)

Standard osteometric measurements have been objectively used to evaluate sexual dimorphism in numerous skeletal samples. (28,31,40-44,47,48,50-55,63,65-67,69,71,73,99-125) Since the first attempts to quantify size differences between the sexes, osteometric studies have been carried out on virtually all bones of the skeleton, with varying degrees of success.

The use of osteometry began in the late 1940's, with a seminal study from Washburn. (126) In this paper, two standard anthropometric measurements, of the length of the pubis and the length of the ischium, were taken and used to calculate an ischio-pubic index, which was later shown to accurately classify sex 90% of the time. While many researchers agreed that using standard measurements and mathematical formulae was more simple and accurate than describing morphological changes; Washburn's method proved to be just as time consuming as morphological techniques, and the results were dramatically reduced when the bone was incomplete or fragmented. (126)

Pons (127) was the first to assess sexual dimorphism in the long bones. Visually, he noted that males tended to be larger than females in most dimensions for the femur and sternum. He established the hypothesis that a large femoral head could not belong to a female, the same way that a small femoral head would not belong to a male. He also noted that the sternum was consistently larger in males than females. In order to test his theory, Pons measured 272 sterna and femora from the 'Ferraz de Macedo' Collection in Lisbon. His measurements included the length of the femur, femoral head diameter, and minimum transverse diameter of the diaphysis and width of the lower articulation of the femur. Measurements of the sternum included total curvilinear and rectilinear length, length of the corpus, maximum width of the manubrium, as well as minimum width of the corpus. From these measurements, he developed discriminant function formulae which could classify the sexes with accuracies between 89 % and 95%. (127)

Two years later, Thieme and Schull (39) explored the sexing potential of several metric long bone variables, which included the femoral length, femoral head diameter, humeral length, and epicondylar width of the humerus, sternum width, clavicle length, ischium length and pubis length. The measurements were taken on 90 males and 101 females of African American origin from the Terry collection (in the United States). Results of the study revealed that the head of the femur was the most sexually dimorphic of all the variables, and appeared to be consistently larger in males than females. They also showed that the maximum length and bicondylar breadth of the humerus could be useful in assigning sex, and when using all the variables of the different bones combined, sex was correctly classified 98% of the time. (39)

A methodological concern regarding these earlier studies, and one which concerns us today, was that the morphological (and hence metric) appearance of 'maleness' and 'femaleness' varied considerably between populations as a result of genetic, environmental and cultural differences. (14) While males, worldwide, appear to be taller and more robust than their female counterparts, this degree of robustness has been shown to vary considerably between populations. (44) This concern led to the development of the theory, or paradigm, of "population specificity", which states that the discriminant function formula, developed from any standard osteometric study, should only be applied to individuals known, or suspected, to be from the population that was studied. (12) By the 1980's, this type of osteometric analysis of skeletal remains was done routinely and most of the skeleton has been analyzed in this manner, including the skull, humerus, femur, tibia, clavicle, scapula, ribs, vertebra and the pelvis. (15,26,39,45,49,52,70,94,108,127-131) From the aforementioned analyses, results indicated a general tendency for tubular bones to be more useful in distinguishing between the sexes, than the absolute length of the long bones. The reason being that bone length is closely linked to stature and associated with both genetics and sex, whereas the breadth or width of a bone is more directly related to robusticity. (106)

When looking at the sexing potential of the different parts of the appendicular skeleton, the femur and tibia have been used extensively with accuracy levels ranging from 76 to 95% in international studies, (44,45,47,48,51,103,104,113,114,117,132) while South African studies on these same bones have obtained classification accuracies between 86 to 91%. (40,65,73)

The foot is an interesting alternative to using the long bones of the leg, as the talus and calcaneus are compact bones, and less prone to damage. As a result there have been a few osteometric studies of the foot, resulting in 69 - 89% accuracy in distinguishing between the sexes in international studies (101,120) and a slightly higher percentage of accuracy of 73 - 92% in South African groups when using the calcaneus. (42) Likewise, the maximum length, head and epicondylar measurements of the humerus yielded an accuracy of 96% (53) in differentiating between males and females, which is comparable to that which has been observed internationally. (48,50,55,116,133)

Although these studies may appear repetitive in purpose and technique, the ability to determine the sexing potential of each of these bones equips the forensic anthropologist with options in the case of fragmented remains where not all the bones of the skeleton, or in fact not even a complete bone, have been recovered. The researcher then works with a checklist of the available bones and their obtainable measurements, which can be used in combination to optimize the determination of sex from the available skeletal material, with a known measure of accuracy. The radius and ulna may be smaller and more fragile bones than the large and heavy femur; however, estimating their power to differentiate between the sexes will nonetheless add to the data and provide alternative markers of sex, if more accurate bones (skull, pelvis) are absent or damaged.

2.5. Osteometric studies of the radius and ulna

Standard osteometric dimensions of the radius and ulna have been used to successfully distinguish between the sexes in several population groups, which include Europeans, Asians, and North Americans. (41,50,99,102,110,121,123)

Allen et al. (99) and Mall et al. (50) examined the sexing potential of the radius and ulna in separate studies of European samples. Allen and colleagues investigated the potential of sex determination from the radius in a modern Dutch collection. Midshaft sub-periosteal diameter, maximum length and maximum distal width were measured from roentgenograms. Distal width showed the highest consistency (85%) between estimated and documented sex. This method was of much significance, as it required only the presence of the distal fragment of the radius. (99) These researchers also suggested that tubular dimensions of the radius are equally useful in sorting between the sexes as that of the lower limbs (e.g.: femur).

In a sample of 143 individuals from Munich and Cologne, Mall and researchers assessed the sexing potential of the humerus, radius and ulna. The maximum length, head diameter and distal width were measured from the radius along with length, proximal width and distal width of the ulna. Percentages of accurate sex determination were the highest (95%) when all three bones were used together. When assessing the bones individually, radial measurements were the most sexually dimorphic (95%), followed by those of the humerus (93%), and then the ulna (90%). The maximum length of the radius and ulna were selected as having the highest classification accuracy for determining sex, with 89% accuracy for the radius, and 86% accuracy for the ulna. (50)

Several Asian studies have been undertaken in India, Turkey and Japan, using a variety of standard measurements and techniques of statistical analyses for both the radius and ulna.

From an Indian sample of 92 males and 39 females, Singh et al. (123) showed that total radial length, distal width and the weight of the bone were good discriminators of sex, or highly sexually dimorphic; other variables such as the circumferences of the radial head, radial tuberosity and the midshaft were less dimorphic and thus less useful indicators for determining sex. (123)

When assessing the ulna, Singh et al. (52) measured a sample of 245 individuals and found that length, and midshaft circumferences were the most accurate variables to discriminate sex. Although the weight of the bone was included in the study, it was later rejected, as it was not found to be statistically significant. (52) Similar results that suggested or indicated that these bones were moderate discriminators of sex were observed in a Turkish study that focused on the maximum length of each of the bones of the forearm. Results indicated a classification accuracy of 88 to 90% for each bone individually and then combined. (102)

The forearms are fragile bones, with the ulna being more fragile than the radius. Time and environmental degradation often mean that certain measurements cannot be obtained easily from this bone, as opposed to the femur and humerus. For this reason Purkait's study of 100 male and 60 female ulnae of the Bhopal Medicolegal Institute in Madhya Pradesh, India attempted to create new measurements specifically designed to determine sex from fragmentary ulnae, with a particular focus on the olecranon. The results yielded 85 to 91% accuracy when using the olecranon-coronoid angle and measurements of the inferior trochlear notch, respectively. (119)

The Far East is represented by Sakaue's study of the Japanese radius. In a similar fashion to the European and Indian studies, this research focused on radial length, sagittal head diameter, transverse head diameter, distal breadth, notch breadth and midshaft diameters. These variables were combined into a stepwise and direct discriminant function analysis. The highest percentages of correct classification (92%) were obtained when using sagittal head diameter and distal breadth, individually. (121) For the ulna, midshaft area had the highest percentage of correctly classifying the sexes (92%) when used on its own. The less dimorphic variables included radial length and trochlear notch height and depth.

The Northern American population standards were established by Berrizbeitia in her 1989 study of over 500 black and white North Americans, housed in the Terry collection at the Smithsonian Institute, Washington D.C. Measuring the minimum and maximum head diameters only, she suggested that the radius could be up to 96 % accurate in determining sex especially when both the left and right radius of the same person were used; although she did not observe significant asymmetry between the two sides. (41)

Holman and Bennett's 1991 study of 302 black and white skeletons from the Terry collection focused on maximum lengths of the humerus, radius and ulna, along with wrist breadth, referred to as semi-bistyloid breadth or SBB. (110) The best combination of measurements included that of radius SBB and radial length (89% was obtained for females and 92% for males) as well as ulna SBB and ulna length (72% for females and 84% for males). Females appeared to have higher percentages of classification accuracy than males. Once again the length measurements seemed to be crucial for the classification of males, especially for the ulna.

In summary, the radial length, distal breadth, circumference of the radial head of the radius as well as the maximum ulnar midshaft width and mid-shaft circumference of the ulna, have been shown to be good indicators of sexual dimorphism in various populations. The success of the radius and ulna in the determination of sex in other groups warrants an exploration into the sexing potential of these bones in a South African sample

Chapter 3
Materials and Methods

3.1. Origin of the skeletal material

The skeletal material used in this study was obtained from the Pretoria Bone Collection and the Raymond A. Dart Collection, which are housed at the University of Pretoria and the University of the Witwatersrand, respectively. These collections are similar in their demographic composition, such that the majority of the skeletons are of middle-aged males of African (black) ancestry. The term "black South Africans", as it used in this study, refers to the local descendants of native Africans, who colonized the southern parts of the continent a few thousand years ago. (134)

The large number of black South African males in these collections can be explained by the influx of migrant workers into the large cities, such as Johannesburg, during the last 80 years; many of who died in the city. While most of these migrant laborers had identification documents and were known persons, it was seldom that their families would either be aware of their death or had the funds to claim the remains. For this reason they are referred to as unclaimed, rather than unidentified. Families of the deceased may obtain the remains at any time, even after they have been accessioned into the skeletal collection. (64)

In these collections, the skeletal material was obtained in one of two ways: either from willed donations or unclaimed bodies from the hospitals in the area. In terms of the Human Tissues Act, no. 65 of 1983, anyone may donate his/her body to science for the purpose of tissue transplants, medical training and research. (64) This act also covers destitute people who die in public hospitals, if not claimed within the period of twenty-four hours, the body is transferred to the nearest medical school, embalmed and stored for up to one year. After such time if they remain unclaimed, the body is sent to the dissection hall, and eventually the skeletal collection. (64)

The Raymond A. Dart collection, which was established by Professor Dart in the 1920's, contains 2,642 complete skeletons; whilst the Pretoria Bone Collection has approximately 800 individuals, and an average of 50 additional skeletons are added each year. (64) Both collections represent the 19th and 20th centuries, with individuals having been born between 1863 and 1996.

3.2. The skeletal sample

The sample consisted of 400 forearms (200 male and 200 female). The age distribution of these individuals is presented in Table 1. All 200 males were obtained from the Pretoria Bone Collection along with 95 females, while the remaining 105 females were sourced from the Dart Collection. As can be seen, the majority of individuals fall within the middle to older age categories (40 to 70 years) with few individuals less than 30 years of age and even fewer greater than 80 years. The mean age for males was 53 (sd: 14.58) years and 47 (sd: 14.92) years for females.

For the purpose of this study black South Africans were chosen, as ages were more widely distributed in these groups and an adequately large sample size could be obtained.

Table 1: Age distribution groups of the sample by decade (n =400)

	Pretoria Bone Collection		Raymond Dart Collection	
Age intervals	Male	Female	Male	Female
	N = 200	n = 95	n = 0	N = 105
18 – 29	16	9	0	12
30 – 39	19	20	0	27
40 – 49	35	25	0	27
50 – 59	45	15	0	18
60 – 69	54	17	0	10
70 – 79	24	8	0	7
80 – 99	7	1	0	4
Mean age	53.6	47.6	0	46.1
Range	20 – 96	19 - 82	0 - 0	20 – 87

Since secular trends have been suggested to have an effect on the results of osteometric studies, the sample was originally selected to include only those born in the 20th century. However, sampling difficulties were encountered, and it thus became necessary to include a few specimens from the late 19th century.

Studies examining secular trends in black South Africans have focused on skeletal samples with birth dates from the early 1800's and mid 1900's, and although changes in cranial dimensions were observed in a black South African sample, (136) most research mentions either a very slight change, (134) or none at all. (62,137,138)

Although the Raymond A. Dart collection was established earlier than its modern counterpart at the University of Pretoria, the specimens chosen for this study are not significantly older than the Pretoria skeletons and both samples can be grouped without too much dispersion in the birth dates. In Table 2, the date of birth was sorted into ten-year cohorts. As can be seen, the majority of males and females had been born between 1910 and 1970, with less than ten born in the late 19th century.

Osteometric studies require large study samples; these samples are most often taken from dissection room cadavers, which have been suggested to be from the lower socio-economic segment of a population. (33,139) This is a fact that cannot be controlled by the researcher; however, factors such as lower socio-economic status and/or poor nutrition need to be considered when interpreting the results.

Cause of death was thus investigated to determine if poor health could have played a role in this sample. Cause of death was not available for the Dart Collection specimens at time of sampling so only that from the Pretoria Bone Collection's specimens were recorded, and can be found in Table 3. Studying causes of death revealed a wide range of diseases that lead to morbidity, including chronic illnesses, congenital and degenerative ailments. Heart failure, cardio-vascular and cardio-respiratory arrests, Tuberculosis and bronchopneumonia were frequent, as were cases of general organ failure and a variety of cancers. The frequency of deaths related to Tuberculosis, and malnutrition may be indicative of a lower socio-economic group. However this *does not imply* that individuals who succumbed to diseases other than malnutrition were well-nourished, but the majority of diseases from which people died (e.g.,TB and respiratory illnesses) *does imply* the possibility of poor living conditions and/or inadequate access to health care.

Observations on communities of lower socio-economic background, have repeatedly suggested that these groups have lower levels of sexual dimorphism, which could lead to misclassification in a skeletal sample. A lower level of sexual dimorphism in a population translates to males appearing less muscular and more gracile, and closer in resemblance to their female counterparts, with major distinguishing features between males and females such as stature being diminished. (138,140)

Table 2: Distribution of dates of birth of the samples by decade

	Pretoria Bone Collection		Raymond A. Dart Collection	Sample distribution of both collections	
	Males n= 200	Female n=95	Female n=105	% Males	% Females
1870-1879	None	None	1	None	1
1880-1889	2	1	3	1	2
1890-1899	1	None	3	1	2
1900-1909	8	5	13	4	9
1910-1919	22	8	18	11	13
1920-1929	59	13	17	30	15
1930-1939	43	19	17	22	18
1940-1949	30	26	16	15	21
1950-1959	20	10	15	10	13
1960-1969	12	9	1	6	5
1970-1979	3	5	1	2	3

Table 3: Cause of death of the specimens in the Pretoria Bone Collection (n=295)

Cause of death	Male n=200	%	Female n=95	%
Unknown	26	13	17	18
Natural causes	3	2	None	0
Cancer - Generalised	7	4	1	1
Lung	6	3	1	1
Liver	4	2	1	1
Other	9	5	2	1
Cancer of the Cervix, uterus, breast	none	0	8	8
Organ Failure - General	2	1	2	1
Heart	28	14	8	8
Liver	7	4	1	1
Kidney	5	3	3	3
Cardio-vascular incident	6	3	1	1
Cerebro-vascular incident	13	7	2	1
Cardio-respiratory incident/respiratory failure or arrest	13	6	11	12
Infections	5	3	1	1
Lung infections, abcesses, bleeding	4	2	1	1
Tuberculosis	15	8	8	8
Broncho/pneumonia	18	9	14	15
HIV/AIDS	2	1	1	1
Dehydration	7	4	1	1
Malnutrition	4	2	3	3
Liver Cirosis/Alcohol poisoning	7	4	3	3
Metabolic diseases	5	3	4	4

3.3. Measurements

Skeletal material was examined before measurements were taken. Specimens that presented obvious bone pathology, such as disease (Figure 1) and trauma (Figures 2 and 3), were discarded, and only individuals over the age of 18 years were included to insure skeletal maturity.

Figure 1: Osteoarthritis (severe eburnation) of the elbow joint

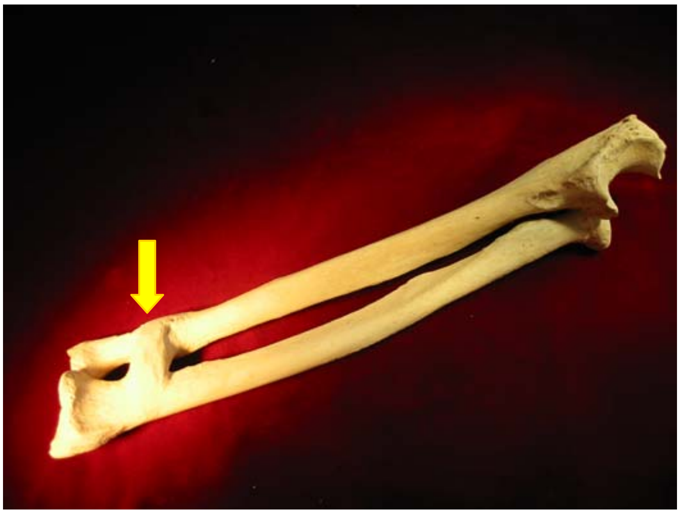

Figure 2: Fusion of the interosseous membrane, most likely trauma related

Figure 3: Healed fracture of the distal radius

Sixteen standard anthropometric measurements compiled from both Knussman (129) and Buikstra & Ubelaker (141), were used. All measurements were taken with a digital sliding caliper calibrated to 0.1mm, an osteometric board and a steel measuring tape. Whenever possible, the left side was used.

3.3.1. Radius

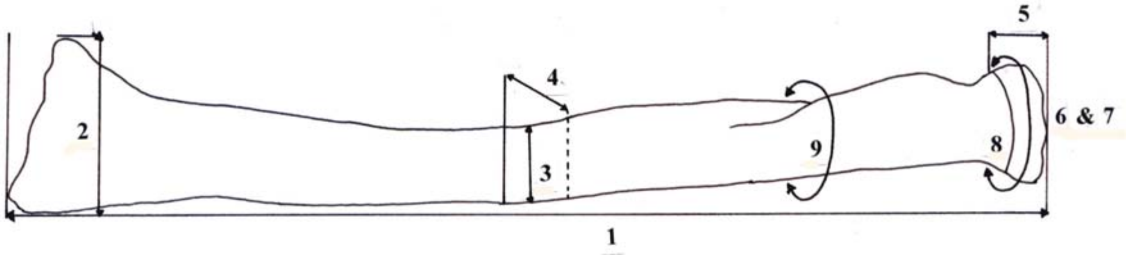

Figure 4: Measurements of the radius

Nine radial measurements were taken. The measurements are annotated in Figure 1, and described below:

1. Maximum length of the radius is measured from the most proximal end on the radial head to the tip of the styloid process. (141)

2. Distal breadth is recorded from the most medial point of the ulnar notch to the most lateral point of the styloid process. (129)

3. Sagittal diameter at midshaft, or minimum midshaft diameter, is the distance between the anterior and posterior surfaces of the midshaft. (141)

4. Transverse diameter at midshaft, or maximum midshaft diameter, is the distance from the medial to the lateral surfaces at the midshaft. (141)

5. Vertical radial head height, is the height of the radial head measured directly above the radial tuberosity. (141)

6 & 7 Minimum and maximum head diameter, is taken while rotating the digital caliper around the radial head, the smallest and largest diameters are recorded. (141)

8. Circumference of the radial head is taken by placing the tape measure around the radial head. (141)

9. Circumference at the tuberosity is taken by placing the tape measure around the contour of the tuberosity. (141)

3.3.2. Ulna

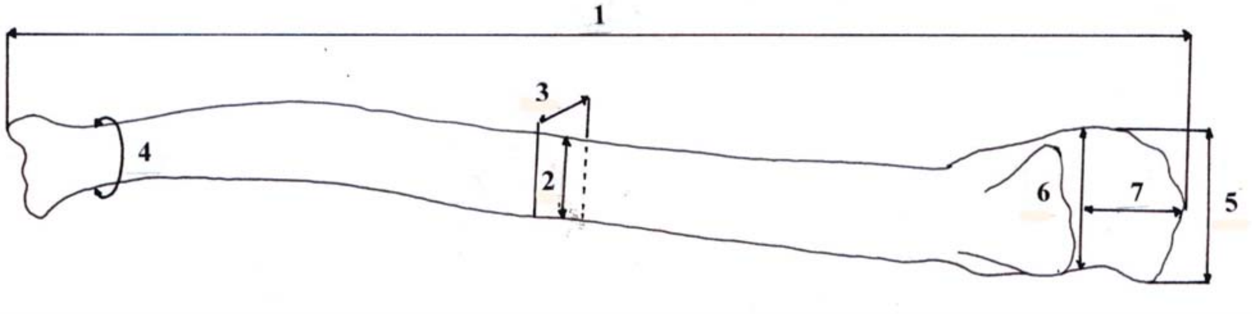

Figure 5: Ulna measurements

Seven ulnar measurements were taken. These measurements are illustrated in Figure 2, and the description of each measurement is as follows:

1. Maximum length of the ulna is measured from the most superior point of the olecranon to the most inferior point on the styloid process. (141)

2. Anterior-posterior diameter, or dorso-volar diameter, is the maximum diameter of the diaphysis where the crest exhibits the greatest development in antero-posterior plane. (141)

3. Medial-lateral diameter, or transverse diameter, is the distance between medial and lateral surfaces of the ulna at the level of greatest crest development. The measurement is taken perpendicular to the anterior-posterior diameter. (141)

4. Minimum circumference of the ulna is the least circumference of the ulna, measured at the distal end of the bone. (141)

5. Olecranon breadth is the greatest breadth of the olecranon measured perpendicularly to the crest of the *incisura trochlearis.* (129)

6. Minimum Olecranon breadth is the smallest breadth of the proximal end of the ulna, measured in the region of the *incisura trochlearis.* (129)

7. Height of the Olecranon is the distance measured from the intersection in the crest of the *incisura trochlearis* to the diagonal line coming from the highest point of the olecranon cap. (129)

3.4. Statistical analyses of metric variables

Data were analyzed using SPPS version 11.5$^{©}$. A stepwise discriminant function was run on the radius and ulna variables separately, and was used to select the optimal combination of dimensions to develop formulae for classifying sex. The first step of the analysis was to determine if there were any noticeable differences between the sexes based on the available measurements, and to assess the statistical significance of these differences, if they did exist. An analysis of variance test (ANOVA) was used and provided descriptive statistics including the minimum and maximum measurements, as well as the range and means for all variables.

Discriminant function analysis has become the gold standard in anthropology to sort binominal characteristics between two groups, such as the level of sexual dimorphism between and within populations. This statistical method identifies variables that are the most competent at separating the dichotomous sample, identifying which groups of variables perform with equal success, and at selecting groups with systematic similarities or differences. Discriminant analysis builds a predictive model for group membership (in this case males or females), based on the observed characteristics (measurements) of each case. The procedure generates a discriminant function (or, for more than two groups, a set of discriminant functions) based on linear combinations of the predictor variables that provide the best discrimination between the groups. The functions are generated from a sample of cases for which group membership is known; and then applied to new cases with the available measurements but of which group membership is unknown.

The accuracy of the discriminant function is expressed by the *P*-value, *F*-ratio and Wilk's Lambda. The *P*-value indicates the level at which values are statistically significant, generally P=0.001. The *F*-ratio is used to assess whether the differences between the groups are statistically significant, with higher *F*-ratio scores, indicating a stronger significance. Wilk's Lambda identifies the contribution each variable had in distinguishing between the sexes and defines the order in which the dimension will appear in the discriminant function formula. Wilk's Lambda also indicates how much variability exists between the groups. If a score of 1 is obtained for the Wilk's Lambda, it implies that the group means are equal. Likewise, smaller lambda values suggest increased variability between the groups (such that there is a larger overlap between males and females), and decreased variability within the group (such that there is less of a gap between the biggest and smallest specimen of a same group, such as the male group). (142,143)

After the stepwise discriminant functions are calculated, those variables that appear to best distinguish between the sexes were selected and subjected, alone, to direct discriminant analysis so as to develop formulae for determining sex from fragmented remains.

Classification accuracies were tested using the following procedure: instead of dividing the total sample into a study and a control group, which would have considerably reduced sample size, a 'leave one out classification' procedure was employed to measure the effectiveness of the discriminant function. This method of analysis classified each individual specimen by the functions derived from all the other cases, except the one tested. The procedure was then repeated for all the specimens in the sample. (142,143) The results were then cross- validated to determine whether or not specimens were correctly assigned to either the male or female group.

Posterior probabilities, or analysis of correct classification, were also assessed to determine the extent at which each individual skeleton fits in his/her sex group. This analysis was calculated by evaluating the number of correctly classified specimens versus the total number of specimens in the sample. The higher posterior probabilities obtained, the more certainty one has of the level of accuracy of an individual belonging to the correct group.

Chapter 4
Discriminant Function Analysis of the Forearm

4.1. Descriptive statistics of the forearm

An analysis of variance test (ANOVA) provided descriptive statistics including the means, standard deviations and *F*-ratios of all the variables in both sex groups (see Table 3). The greatest differences in mean values appeared to be in radial length (males: 255mm, females: 230mm. sd: 14.82), distal breadth (males 34.63mm, females: 31.16mm. sd: 34.63), and maximum head diameter (23mm, females: 20mm. sd: 23.17). The greatest differences in mean values for the ulna was found in maximum length (males: 274mm, females: 249mm. sd: 14.97).

A statistically significant difference ($p > 0.001$) was found between males and females for the osteometric variables of both the radius and the ulna. As can be seen in Table 4, the univariate F-ratio scores were the highest in the length, breadth and circumference diameters, and lowest in measurements associated with the height of the proximal portion of the forearm, such as the vertical head diameter and the olecranon height. The reason for this may be associated with differences in robusticity between the sexes, with males having larger, thicker bones and more pronounced muscle attachments than females. From the descriptive statistics, it is possible to suggest that the metric variables with the highest F-ratios mentioned above, could be useful in distinguishing between the sexes of black South Africans; similarly, variables with low univariate F-ratios may not be as useful in distinguishing between these groups.

Table 4: Means, Standard deviations, Univariate *F*-ratio and demarking points for the radius and ulna

Variable descriptions	Males (n=200)			Females (n=200)				
	Mean	SD	SE	Mean	SD	SE	*F*-ratio *	t-test
Radius								
Radial length	255.70	14.82	1.04	230.95	13.59	0.95	302.20	17.38
Distal breadth	34.63	2.28	0.16	31.16	1.88	0.13	275.5	16.59
Minimum mid-shaft diameter	11.85	0.93	0.06	10.26	1.09	0.07	245.11	15.65
Maximum midshaft diameter	15.58	1.54	0.10	13.87	1.50	0.10	125.58	11.20
Vertical head diameter	10.46	1.20	0.08	9.49	1.26	0.08	61.56	7.84
Minimum head diameter	22.13	1.72	0.12	19.79	1.32	0.09	231.05	15.20
Maximum head diameter	23.17	1.49	0.10	20.63	1.62	0.11	264.88	16.27
Head circumference	72.16	4.71	0.33	65.09	4.30	0.30	245.50	15.66
Circumference at tuberosity	51.60	4.34	0.30	46.26	4.40	0.31	149.12	12.21
Ulna								
Ulna length	273.76	14.97	1.05	249.24	13.76	0.97	293.53	17.04
Minimum midshaft diameter	13.28	1.17	0.08	11.31	0.95	0.06	326.86	18.07
Maximum midshaft diameter	16.90	1.55	0.10	14.67	1.39	0.09	226.72	15.05
Minimum circumference	36.77	3.44	0.24	33.24	2.96	0.22	120.49	10.97
Maximum olecranon breadth	25.79	2.20	0.15	22.74	1.66	0.11	244.43	15.63
Minimum olecranon breadth	18.91	2.01	0.14	17.07	1.70	0.12	97.41	9.87
Olecranon height	23.26	1.95	0.13	21.75	1.89	0.13	61.23	7.82

4.2. Stepwise and direct discriminant analysis of the forearm

Stepwise analysis was run on nine measurements from the radius and seven measurements from the ulna. The stepwise discriminant function procedure was performed using Wilk's Lambda with F = 3.84 to enter and F = 2.71 to remove. Wilk's Lambda determined the order in which the variables were selected to enter into the function; that selection order is shown in Table 5.

When all nine variables were entered for the radius (Function 1), selected variables included: radial length, distal breadth, minimum midshaft diameter and maximum head diameter. Consequently, these variables also had the largest univariate F-ratios, and hence were expected to show the largest metric discrimination between the sexes. However, if the bone is fragmented, the maximum radial length is not a useful predictor variable. Therefore, an additional stepwise analysis was performed with total length removed (Function 2). As expected, the three variables that were most successful (or most discriminatory) included: distal breadth, minimum midshaft diameter and maximum head diameter. A direct analysis was then carried out on these above-mentioned variables, as they appeared to be the most constructive in statistically discriminating between the sexes (see Table 5, direct Functions 3, 4, 5).

For the ulna measurements (Table 5), only three of the seven variables were selected as best discriminators of sex, namely: ulna length, maximum olecranon breadth and minimum midshaft diameter. When ulna length was removed from these variables in Function 2, the choice of the best variables remained the same. Similarly, a direct analysis was conducted on the best predictor variables, which included minimum and maximum midshaft diameters (Function 3) and maximum olecranon breadth (Function 4).

Table 5: Stepwise and direct discriminant function analysis for the forearm

Step variable entered	Wilks' Lambda	Equivalent F – Ratio
Radius		
Function 1: All variables		
1. Radial length	0.56	302.20
2. Distal breadth	0.49	201.59
3. Minimum midshaft diameter	0.46	153.33
4. Maximum head diameter	0.46	117.95
Function 2: Length removed		
1. Distal breadth	0.59	275.50
2. Minimum midshaft diameter	0.52	180.64
3. Maximum head diameter	0.49	134.62
Function 3: Distal breadth	0.59	275.50
Function 4: Maximum head diameter	0.60	264.88
Function 5: Minimum midshaft diameter	0.61	245.11
Ulna		
Function 1: All variables		
1. Minimum midshaft diameter	0.54	326.86
2. Ulna length	0.46	233.14
3. Maximum olecranon breadth	0.44	166.01
0		
Function 2: Length removed		
1. Minimum midshaft diameter	0.54	326.86
2. Maximum olecranon breadth	0.48	207.98
3. Maximum midshaft diameter	0.48	142.70
Function 3: Midshaft variables		
1. Minimum midshaft diameter	0.53	341.69
2. Maximum midshaft diameter	0.63	230.71
Function 4:Maximum olecranon breadth	0.62	244.43

* - degrees of freedom 398

Canonical discriminant coefficients produced by the stepwise and direct analyses are displayed in Table 6. Four columns can be seen and include the unstandardized coefficient, the standard coefficient, the structure coefficient and the group centroids. The unstandardized coefficient, or raw coefficient, is used to calculate the discriminant function formulae. The standard coefficient provides information on the contribution of that variable to the overall classification, while the structure coefficient assesses the product-moment correlation between the variables and the discriminant function, respectively. The sectioning point is calibrated to zero as the samples are of equal proportion. If the calculated value falls below zero, the bone, is more likely to classify as female, and above zero, as male.

The following example is presented as a means to explain how to calculate these formulae.

Radius Function 1 (stepwise)

0.03 x maximum radial length
+ 0.10 x distal breadth
+ 0.35 x minimum midshaft diameter
+ 0.18 x maximum head diameter
– 19.13 x the constant
= discriminant score.

The first coefficient is multiplied by its associated variable and then added to the second coefficient with its associated variable etcetera. If the coefficient is negative, it is subtracted from the coefficient that precedes it. The constant is always added to the end of the formula. For example, if a radius has a distal breadth of 33 mm, a midshaft circumference of 5 mm and a sagittal midshaft diameter of 12 mm, the calculation would be as follows:

Radius Function 1 (stepwise)

0.03 x 251.00
+ 0.10 x 37.70
+ 0.35 x 11.63
+ 0.18 x 25.71
– 19.13 = discriminant score

7.53
+ 3.77
+ 4.07
+ 25.89
+ 19.13
= + 22.13

The result, +22.13, is then compared to the sectioning point, which is the average of the two male and female centroids. Since the value is situated above the sectioning point (0), the individual would be classified as female. It should be noted that the further away the discriminant score is from the sectioning point, the more confident the estimation.

A direct discriminant analysis was applied to evaluate the diagnostic ability of individual variables that were previously selected as best discriminators of sex during the stepwise analysis. The results of the direct analyses appear in Table 6, as Function 3, Function 4 and Function 5 and refer to analyses of the distal breadth, maximum head diameter and minimum midshaft diameter, respectively.

To calculate the discriminant score for a single variable is the same as calculating the discriminant formula using multiple variables: the dimension is first multiplied by its unstandardized coefficient and then added to the constant. Another approach is to use demarking points. A demarking point is calculated for each variable, used in the direct discriminant functions, and referred to the average of the group's means (see Table 6). This permits one to compare the value without having to calculate a discriminant function formula. A value above would automatically be male, and anything below would be female.

Table 6: Canonical discriminant function coefficients and demarking points for the radius

Functions	Variables	Unstandardized coefficient	Standard coefficient	Structure coefficient	Group centroids
Function 1 – All variables	Radius total length	0.03	0.44	0.79	M = 1.09
	Distal breadth	0.1	0.22	0.76	F = -1.09
	Minimum midshaft diameter	0.35	0.35	0.71	
	Maximum head diameter	0.18	0.29	0.74	
	(Constant)	-19.13			
Function 2 - radial length removed	Distal breadth	0.17	0.35	0.82	M = 1.00
	Minimum midshaft diameter	0.46	0.47	0.77	F = -1.00
	Maximum head diameter	0.26	0.42	0.8	
	(Constant)	-16.63			
Function 3 – Distal breadth	Distal breadth	0.48	1	1	M = .83 F = -.83
	(Constant)	-15.71			
* Demarking point: M>33mm<F					
Function 4 – Maximum head diameter	Maximum head diameter	0.64	1	1	M = .81
	(Constant)	-14.02			F = -.81
* Demarking point: M>22mm<F					
Function 5 – Minimum midshaft diameter	Minimum midshaft diameter	0.98	1	1	M = .783
	(Constant)	-10.88			F = -.783
* Demarking point: M>11mm<F					

Table 7: Canonical discriminant function coefficients and demarking points for the ulna

Functions	Variables	Unstandardized coefficient	Standard coefficient	Structure coefficient	Group centroids
Function 1 – All variables	Ulna total length	0.03	0.46	0.75	M = 1.12
	Minimum midshaft diameter	0.49	0.53	0.8	F = -1.12
	Maximum olecranon breadth	0.16	0.31	0.69	
	(Constant)	-18.49			
Function 2 – ulnar length removed	Minimum midshaft diameter	0.54	0.58	0.87	M = 1.03
	Maximum midshaft diameter	0.14	0.21	0.72	F = -1.03
	Maximum olecranon breadth	0.22	0.43	0.75	
	(Constant)	-14.5			
Function 3 – ulna midshaft variables	Minimum midshaft diameter	0.68	0.73	0.94	M = .95
	Maximum midshaft diameter	0.26	0.38	0.78	F = -.95
	(Constant)	-12.54			
* Demarking point: M>12mm<F					
Function 4 - Maximum olecranon breadth	Maximum olecranon breadth	0.51	1	1	M = .78
	(Constant)	-12.43			F = -.78
* Demarking point: M>24mm<F					

The classification accuracy of the radius and ulna for the discriminant function formulae are presented in Table 8, as Functions 1 and 2 in the stepwise analysis as well as Functions 3 to 5 in the direct analyses. In general, the analyses with multiple variables exhibited better classification accuracy than those of single variables. This was to be expected as it has been repeatedly demonstrated that using a combination of various measurements leads to a higher rate of accuracy than when only a single variable is employed. (50,52,53) In much the same way, using several skeletal elements yields higher rates of accuracy than using a single bone. (63)

As can be seen in Table 8, the row marked ‘original’ refers to the percentage of individuals predicted to belong to either the male or female group; whereas the cross validation classification test determined the accuracy of assignment of specimens to either a male or female category. This was achieved by reclassifying each case to see whether that individual case was attributed to the same group membership as during the first classification. Subsequently, the test allows an observation of the number of specimens classified versus the number of specimens in the sample.

For the radius, Function 1 (see Table 8) showed that 176 females out of a possible 200 cases were correctly classified with 24 individuals misclassified as males, thus resulting in 88% accuracy. Cross validation showed that only one extra case was misclassified, therefore not greatly affecting the overall percentage. When the length measurement was removed in Function 2, females once again scored higher than males (Table 8) with 88 versus 86% accuracy, respectively. The mean accuracies for single variables in Functions 3 to 5, spanned 80 to 82% and 79 to 86% (Table 8) for males and females. The single best discriminating variable was the minimum midshaft diameter, with 86% for females and 82% for males, whereas the worst single variable was that of maximum head diameter with 80% for males and 82% for females.

In the ulna, the percent of correct group membership recorded higher accuracies in females as compared to males (Table 8) for all Functions. When using all the variables combined in Function 1, female accuracy levels reached as high as 89% and males 87%. When length measurements were removed in Function 2, the percentage of accuracy obtained for the females in Function 1 did not change. With the male sample, however, the percentages of accurate classification fell from 87 to

83%, an explanation could be that stature, and therefore the length of the bones, rather than their circumference could be the most sexually dimorphic feature of the ulna.

Although it would appear that females are better classified than males, this phenomenon may imply a lack of pronounced robusticity in the male group, which increased their chances of them being misclassified as females. Or, the variability between males and females may be less than the variability found within a same-sex group. Males vary from robust to small, whereas females may just cluster in the small category.

In summary, the measurements of the radius and ulna appear to be moderate discriminators of sex in a black South African sample. In the radius, the most discriminating variables included the radial length, distal breadth, and maximum head diameter, whereas maximum ulnar length, minimum and maximum midshaft diameters and maximum olecranon breadth were the best variables for the ulna. In direct analysis, the single most useful variable for both the radius and the ulna was the minimum midshaft diameter. Overall accuracies ranged between 80 and 89%, with males having a greater chance of being misclassified than females.

Table 8: Percentage of predicted group membership and cross validation for the forearm

			Males			Females	
Functions	Variables	Total n	Correct n	%	Total n	Correct n	%
Radius							
Function1 - All variables	Original	200	172	86	200	176	88
	Cross validated	200	169	85	200	176	88
Function 2 – Length removed	Original	200	168	84	200	175	88
	Cross validated	200	168	84	200	175	88
Function 3 - Distal breadth	Original	200	159	80	200	165	83
	Cross validated	200	159	80	200	165	83
Function 4 – Maximum head diameter	Original	200	159	80	200	164	82
	Cross validated	200	159	80	200	164	82
Function 5 – Minimum midshaft diameter	Original	200	164	82	200	171	86
	Cross validated	200	163	82	200	171	86
Ulna							
Function1- All variables	Original	200	173	87	200	177	89
	Cross validated	200	173	87	200	176	88
Function 2 – Length removed	Original	200	166	83	200	176	88
	Cross validated	200	166	83	200	176	88
Function 3 – Midshaft variables	Original	200	167	84	200	173	86
	Cross validated	200	167	84	200	173	86
Function 4 – Maximum olecranon breadth	Original	200	151	76	200	165	83
	Cross validated	200	151	76	200	165	83

4.4. Posterior probabilities

Although multivariate classification, such as discriminant function analysis, provides an understanding of the assignment of every case within the sample, the actual connection of a particular individual to its group, is best assessed by its likelihood of being reassigned to its original group. This is achieved by a posterior probability analysis of correct classification. Posterior probabilities were calculated by looking at the number of correctly classified specimens versus the total number of specimens classified. Higher posterior probabilities confirmed the levels of accuracy of an individual's affinity with the sample population.

The posterior probabilities are calculated in cohorts of 20 percent intervals. Typically, when the majority of the data classifies above 80% certainty, the analysis can be considered successful in discriminating between the groups. Data classifying between 40 to 60% indicates a lot of uncertainty as to whether the analysis can be used to successfully distinguish the sexes. Classification results under 40% indicate that the variables cannot discriminate between the sexes, or that the statistical analysis may have been performed incorrectly.

In this study, the majority of the sample (145 males and 136 females) classified with above 80% certainty for Functions 1 and 2 of the radius (see shaded areas in Table 9). This was somewhat reduced in the direct discriminant functions (Function 3,4,5), however over half of the sample (n=159-164 for males; n= 164-171 for females) were distinguishing at 80 to 100% certainty.

A similar pattern was observed for the ulna (see Table 10), in which the stepwise analyses scored higher posterior probabilities than the direct analyses. One hundred and forty-two males and 140 females classified above 80% certainty when using all the measurements in Function 1. When length was removed in Function 2, 130 males and 140 females classified above 80% certainty. With the direct analyses of Function 3 and 4 showed just over half of the male sample (103-108 individuals out of 200), along with 121 females in Function 3 classified above 80% certainty, however, only 80 females (under half of the sample), classified within this range in Function 4. These results are to be expected and demonstrate that a greater percentage of accuracy can be achieved with a combination of variables.

As can be seen, none of the Functions for either the radius or the ulna classified below 40% certainty, and thus these equations can be considered useful in determining sex of an unidentified person.

Table 9: Percentage of posterior probability intervals of correct classification of sex for the radius

	Males		Females	
Posterior probability intervals	N	%	N	%
Function 1 – All variables				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	9	5	9	5
0.60 – 0.79	19	11	30	17
0.80 – 1.00	145	83	137	78
Function 2 - Length removed				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	7	4	10	6
0.60 – 0.79	26	15	40	23
0.80 – 1.00	136	80	126	72
Function 3 - Distal breadth				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	14	9	19	12
0.60 – 0.79	50	31	45	27
0.80 – 1.00	94	59	101	61
Function 4 - Maximum head diameter				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	16	10	12	8
0.60 – 0.79	51	31	51	32
0.80 – 1.00	98	59	96	60
Function 5 - Minimum midshaft diameter				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	25	15	16	9
0.60 – 0.79	60	36	56	33
0.80 – 1.00	79	48	99	58

Table 10:Percentage of posterior probability intervals of correct classification of sex for the ulna

Posterior probability intervals	Males		Females	
	N	%	n	%
Function 1 – All variables				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	6	3	6	3
0.60 – 0.79	24	14	31	18
0.80 – 1.00	142	82	140	79
Function 2 - Length removed				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	9	5	9	5
0.60 – 0.79	26	16	27	15
0.80 – 1.00	130	78	140	80
Function 3 - Midshaft variables				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	16	10	11	7
0.60 – 0.79	42	25	31	19
0.80 – 1.00	108	65	121	74
Function 4 - Maximum olecranon breadth				
0.00 – 0.19	-	-	-	-
0.20 – 0.39	-	-	-	-
0.40 – 0.59	10	6	19	12
0.60 – 0.79	48	30	56	34
0.80 – 1.00	103	64	90	55

Chapter 5

Discussion

5.1. Sexual dimorphism in the forearm

An accurate determination of sex is crucial when compiling a demographic profile of an unknown individual, as it theoretically cuts the total number of possible victims by half. (32) In South Africa, several hundred bodies are found each year in badly decomposed or skeletonized conditions, of which no evidence can be obtained from the remains through normal channels of investigation (e.g., forensic pathologists or the SAPS). In such situations, the investigative officer, in the hopes of obtaining a sample of DNA, often removes the teeth and proximal femur from the skeleton. Although DNA extraction is highly successful in determining the sex of the remains using sex-specific genes, a positive identification from the sample, if recovered from the bone, is only useful when family members and/or close relatives tentatively identify the deceased. DNA analysis also faces other challenges such as contamination and/or molecular degradation.

Thus, the initial onus in identifying an unknown person rests with the expertise of a forensic anthropologist, who is often asked by either a pathologist or investigating officer to provide a biological profile (age, sex, ancestry and stature) of the deceased as well as to assist in determining a cause and or manner of death from visible trauma (11,15,17,21,58) The validity of their conclusions is based on two factors; the first is their experience in working with skeletal material, and the second is acknowledging their limitations regarding what they can deduct from these remains. As one can expect, one's abilities to form a logical conclusion about an unknown person, whether they are in complete or fragmentary condition, is based largely on their knowledge of past and current research. Thus, the aim of this study was to contribute to current osteometric standards used in the determination of sex, by metrically examining the bones of the forearm, namely the ulna and radius.

As seen from numerous studies, (31,38,56) one's accuracy in classifying sex from skeletal remains is based largely on the degree of sexual dimorphism in the population, which can be defined as the observable physical traits within a group, that can be used to distinguish males and females. (12,32,33,40-53,64,58) For the most part, males tend to be taller, larger and more robust than their female counterparts. (32,144) However, the intensity, or degree of separation, between males and females in a group is often affected by genetics, environment, nutrition, lifestyle, and social status. This is a result of the human skeleton being affected by and responding to mechanical loading as well as changes in mechanical loading and activity patterns, which may affect the shape and strength of the bone over time. (40,145)

In a seminal study, Hall (146) noted that the degree of sexual dimorphism in a population was subject to decrease under environmental pressure, and that the "variation in sexual dimorphism appeared to be controlled to a much larger extent by variation in average male size, than by variation in average female size." (146) This is still a familiar hypothesis, which implies that the expression of male size and robusticity is more sensitive than that of females, with males needing a longer growth period to reach their full potential size. (147,148) Several studies have described that 'adverse living conditions' can reduce the degree of sexual dimorphism between males and females. (146,147,149-151)

Conversely, in favorable conditions, however, Rensch's rule may be applied in which he stated that, in a species where the males are larger than their female counterparts, the degree of sexual dimorphism increases relative to an increase in body size. (152) This appears to have been the case in some studies, where it was noted that in times of uncertainty, the level of sexual dimorphism increases dramatically with males being disproportionably taller than their female counterparts (138) Rensch's rule and the notion of an allometric relationship between male and female stature has however been contested in recent research by Gustaffson and colleagues. (153)

Studying Swedish stature data from the 10th to the 20th centuries, the authors state that their research shows no significant evidence pointing to a relationship between an increase in stature and an increase in sexual dimorphism, even though an increase in mean stature in both males and females was noted throughout this period of time. (144,153) The Swedes are not alone in growing taller, as several studies on European populations have shown an average increase in mean height of roughly 1cm per decade from 1880-1980. (140,154-157)

While the expression of sexual dimorphism in a population may not differ between generations, such that the visible separation between females and males will remain the same, the degree of this separation would be expected to differ between males and males, or females and females, of different generations. In this way, 18th century males and females would not only be shorter than their 20th century counterparts, but when comparing the 18th century females with 20th century females, differences in size and shape would be noticeable.

Studying growth and stature in South African populations, Tobias remarked that the absolute increase in San mean stature was almost doubled in males as in the females and coincided with a change in socio-economic patterns, including better nutrition. (138) Tobias goes on to state that changes in sexual dimorphism, particularly with regard to stature could be based largely on environmental stresses, rather than genetic inheritance. As mentioned above it has been well demonstrated, that in enhanced environmental and dietary conditions the degree of sexual dimorphism will increase especially with regard to stature; and consequently decrease in adverse conditions, including malnutrition. (138,158,158) Consequently, because genetics, environment and social conditions can vary dramatically between population groups, researchers have opted for the ‘population specific’ theory when approaching osteometric studies. (46,47,53,72,101,106,159) This theory simply states that osteometric standards should be developed for each population group, alone, irrespective of whether differences between and among the groups are known, or merely implied. Working within this paradigm, the development of osteometric standards, for the determination of sex has flourished worldwide, and continues to dominate much of today’s modern research regarding the classification of sex from skeletal remains. (1,66,67,69,71,102,121,160)

Research in South Africa has not been exempted from this line of inquiry, and local studies have produced discriminant function formulae for determining sex from the femur, humerus, tibia, patella, talus, and calcaneus. (12,32,33,40-53,66,68,69,71,64,58) Within all these studies, the proximal and distal areas of the long bones, such as the humeral or femoral head, have been shown to be the most dimorphic, such that they can be used to distinguish the sexes with an accuracy equivalent to or greater than 86%. (47,48,50,116) Other areas of the skeleton, such as the breadth and height of the patella, talus and calcaneus, are less accurate (69 to 92%) in separating the sexes, but have been considered valuable in situations in which the skeleton is grossly incomplete, or fragmented. (42,66,120,161) The classification results obtained from this study for the radius and ulna (82 to 88%) can be considered to fall in the middle of this spectrum (i.e. between the highly accurate bones: humerus, femur and tibia; and less accurate bones such as the talus, calcaneus and patella), and thus should be considered moderate discriminators of sex.

Direct comparisons between the results of this study and prior research were hindered, to some extent, as the combinations of measurements and techniques of analysis were not always the same. However, discussions can arise regarding the particular variables that were chosen, or not chosen, as best discriminators of sex between this study on the forearm and the various international studies. The variables that were selected from the forearm in a South African group were the maximum radial length, distal breath, maximum head diameter and minimum midshaft diameter of the radius, along with maximum ulna length, minimum midshaft diameter and maximum olecranon breadth.

The maximum (and physiological) length of a long bone has been directly correlated with stature (63), and stature has been shown to have a positive relationship with sexual dimorphism in that taller individuals are most often male, and shorter female. (54,95) With this in mind, it would be expected that the maximum length of a bone is to differ, perhaps considerably, between males and females within a particular group. In the South African study, maximum radial length was selected in the stepwise analysis (with classification accuracies of males: 86%, and females: 88%). Interesting to note, classification accuracy decreased almost 4% for males when maximum length was removed from the initial stepwise discriminant function. This directly suggests that bone length is moderately important in distinguishing the forearms of male and females in this group. This has been shown not only in this study, but in the various studies on the forearm conducted by both Singh et al. (1974, 1975) and a Turkish sample, (102) in which the maximum length of the forearm bones distinguished the sexes with a 90% accuracy or greater. (52,102,123) This is an unusual result, albeit one which has been noted before for black South Africans. (53) Although length measurements to distinguish sex are consistently used in osteometric studies, it is relatively uncommon that the maximum length of the bone is selected as the best discriminating variable. (39,46-48,50,51,66,73) The sidelining of length measurements may be attributed to either this particular variable not being a useful discriminator of sex in comparison to breadth and circumference measurements (55); or, because it fluctuates as it is strongly linked with stature and in turn other external factors such as nutrition. (138,151) Another possibility for the exclusion of maximum length variables from discriminant function equations is that the condition of a bone recovered from the field is not always pristine and often, in the case of forensic material, may have been affected by perimortem trauma or postmortem damage; in such instances a classification formula that included a variable for maximum length would be of less practical value than one that did not. For this reason, two additional stepwise analyses were performed without the maximum length for both the radius and ulna (see Function 2, pg. 36, 37 and pg 40). The results, while slightly less accurate for males as mentioned above, are to be useful when the maximum length of the bone cannot be measured. When this variable was removed, the dimensions that best discriminated between the sexes remained the same, namely the distal breadth, maximum head diameter of the radius, the olecranon fossa of the ulna, and midshaft diameters of both bones.

Throughout various studies of the forearm, distal breadth has been shown to be a good indicator of sex, with classification accuracies that ranged from 72 to 92%. (41,50,99,110,121,123) In Japanese groups, Sakuae (121) obtained a classification accuracy of 92%, when only using the distal breadth of the radius, whereas Dutch (99) and German researchers (50) obtained correct classification only 85% and 78% of the time, respectively, for the same variable. The discrepancy in classification accuracies between these populations lends credence to the theory of population specificity, such that equations developed for the forearm of Japanese groups would be less useful on German samples, and vice versa. This theory can also hold true for black South Africans, whose percentage of correct classification ranged between 80 and 83%, with males being less likely to be assigned to their own group. Just as the distal end of the radius was a moderate discriminator of sex for the South African group, so was the proximal end (or maximum head diameter) of this bone, which demonstrated a classification accuracy of 80% for males and 82% for females; again males, as with the distal breadth for this study, were more likely to be misclassified as females. However, other studies, such as those by Berrizibetia (41) and Mall and collaborators (50), demonstrated much higher percentages of correct classification (96 % and 86%, respectively) for this variable. (41,50)

Additional variables that provided an indication of robusticity such as the minimum midshaft diameter (radius), the minimum and maximum midshaft diameters (ulna) and the maximum olecranon diameter were also selected as being able to distinguish between the sexes with moderate accuracy (82 to 86%), and when considering the maximum olecranon diameter, alone, relatively poor classification (76%) for males, and acceptable classification (83%) for females. The range of accuracy obtained through midshaft measurements varies a great deal, from total inefficacy, (52) to being useful in sex discrimination. (121,123) However, in studies where midshaft variables were found to be very useful discriminators of sex, their classification accuracies were much higher than those observed in South African groups. Singh (123), found that circumference measurements of the radius were almost as good as length measurements (90%), and Sakaue' study of the Japanese (121) revealed the midshaft area of the radius and ulna to discriminate with 91-92% accuracy. (121,123)

From the results of this study, three general inferences can be made. Firstly, the forearm bones of South Africans are sexually dimorphic for maximum length as well as the proximal, distal and midshaft dimensions; secondly, these bones appear to be less sexually dimorphic than forearms of other populations, namely European, Asian and North American groups; and thirdly, male South Africans were consistently misclassified more often than their female counterparts. In order to address a possible explanation for these outcomes, it is necessary to examine the environmental and social circumstances of the population from which this sample was derived, namely that of 20th century black South Africans.

In any research study in which the results (e.g., discriminant function equations) are to be applied to the general population (e.g., unknown skeletal remains of a probable black South African), the sample that is chosen must be an adequate representation of that population, as the results of the research become intrinsically linked to the features that define the group, for example, as being different from that of a Japanese, Indian or American sample. While most researchers understand, and abide by this principle, it is important to mention that it implies more than adequate sample size, but should also include an awareness of temporal change (secular trends) and socioeconomic conditions.

In order to minimize the effects of secular trends, a sample should be selected from the same or similar time period, and should not include a variety of historical remains, as the aim of any osteometric research is to provide a standard of reference for the modern population. In this study, the sample was taken primarily from the 20th century, with the most common date of birth being between 1910 and 1970 (n = 355), with a few born prior to 1909 (n = 36) and even less after 1970 (n = 9) (see Table 2, pg. 21). Throughout most of the world, the fifth decade of the 20th century (1950) has been generally accepted as the "turning point" for many population groups. WWII had ended, industrialization was booming and health care was become more accessible and affordable. (162,163) However, this golden age of prosperity did not necessarily reach Africa, where many countries, including many rural communities in South Africa, remain without modern amenities, such as proper health care, sanitation or running water. (163-165) An exception to this is the case of San communities in the last century. The San who are the original inhabitants of southern parts of Africa, including South Africa and Botswana have survived practiced a traditional hunter-gathering economy for a few millennia. Fair-skinned and small built with an average stature of 157cm for males and 146cm for females, (158) these people lived off the meager offerings of the arid Kalahari desert landscape. In the early 20th century with an increased exposure to western lifestyle, the San switched from a traditional hunting and gathering to an agro-pastoralist economy lifestyle, and this appeared to improve not only their standard of living but also their health, stature and longevity. Measuring San communities from 1967 to 1980, researchers observed a significant increase in mean stature of both males and females through time. This was attributed to better nutrition and dietary supplements such as maize meal and milk. (166) Tobias (62) remarked on a positive secular trend in San stature in the 20th century, and has attributed these changes to an improvement in lifestyle and living conditions (62). However, these improvements have not necessarily been observed in other South African groups.

The presence, or absence, of a secular trend, as observed through differences in stature through time, has been a controversial topic, especially when it pertains to black South Africans. (137,138) Stature, because it has been considered a nutritional marker in human populations, is expected to be greater within better nourished populations and to increase through time due to dietary improvements. (83,88) Although some amount of change was noted in cranial dimensions for black South Africans, the length measurements of the femur and tibia of the same population showed no increase in stature. (137) Tobias also noted no improvement in stature for 20th century black South Africans, and coined the phrase the ‘negative secular trend’ indicating a reverse, or absence of change. (62) Similarly Price and associates (137) observed no increase in maximum femoral length from 1880 to 1934 in South African males. These authors attribute the absence of change to insufficient improvements in nutrition, health care and living conditions of black South Africans.

In 1991, Jansen van Rensburg and colleagues investigated the possibility of a positive secular trend in South African ‘Cape coloured’ children from the poorest region of the Western Cape, known as the Little Karoo, as well an equally poor counterpart in the metropolitan area of Cape Town. The research focused on taking annual measurements of these children over a 6 to 9 year period. The results indicated that while development occurred at a later stage in rural children as opposed to their urbanized counterparts, there did not appear to be much of a positive secular trend in either the rural or urban group. (167) These results appear to corroborate those of Tobias. (59,62) Again, the authors attribute the absence of change to a lack of poverty relief among the lower socio-economic groups in the country. Henneberg and van den Berg (134) did observe a positive secular trend in black South Africans during the last century; however, other researchers contest this slight growth as being so minor, when compared to those of Europe or North America during the same period, that it is, in effect, insignificant. (59,62)

Therefore, it appears that the improvements in health and subsequent increase in stature observed among the San in the last century did not necessarily carry-over to other impoverished South African groups, such as black South Africans. In the Raymond A. Dart and Pretoria Bone Collection, middle-aged, black South Africans males comprise the majority of individuals present. Due to the nature in which the remains were received (unclaimed bodies), the situation in which these people found themselves (migrant workers who were detached from a family unit), and, in some cases the cause of their death (e.g., tuberculosis, bronchopneumonia, and, albeit less common, malnutrition and pellagra), it can be inferred that these individuals comprised the lower socio-economic strata of 20th century South Africa.

Knowledge of the socio-economic status, or presumed status, of this study sample is important as it may impact on the inferences made from these results. Studies on health in third world countries have shown that sexual dimorphism decreases, when the body undergoes repeated stress or poor nutrition. (88,138,151) Malnourished populations exhibit a lower degree of sexual dimorphism with adolescent males in a nutritionally deprived environment not reaching their full height and muscle development thus making them appear more gracile. (59,62,138,150,154,168) Females which seem to be less affected in terms of height and body structure, and more so in terms of maturation would be very similar in size to the under developed males, and thus misclassification of males could occur more often. (88,169) Thus, if the individuals used in the current research were indeed underdeveloped as a result of presumed or known pressure associated with malnutrition and/or physical stress, it could lead to a misrepresentation in the sample. If the specimens exhibit less sexual dimorphism, black South Africans will then appear less sexually dimorphic than other populations who may not have been exposed to the same environmental stresses. (88,156)

In the 20th century, South Africa, and the people within her borders, experienced considerable socio-political change from the Anglo-Boer War, World Wars I and II, the Great Depression and Apartheid; these changes would have had an affect on the growth and development of South African children. (138) Secular trends have been mentioned as describing an age, a long period of time; as such secular trends is a process, they do not happen overnight and in the last 100 years, it does not appear that conditions have improved for the majority of black South Africans.

In this study, the earliest date of birth was 1870, an era which saw the beginning of the diamond rush and gold mining, which in turn heralded the start of South Africa's heavy migrant labour history. (170) Although the diamond rushed offered the black farming communities a chance to rise up economically by providing the throng of diggers with sorghum, antelope meat and firewood; these natural resources soon ran out in the face of such massive demand and the only trade item left was that of unskilled labourers and young adults sold to the service of the settlers. (171) Thus started the notion that migrant labourer went where a strong workforce was required and jobs were available. Given the technical difficulties associated with mining gold hundreds of feet below the surface, the only way for mining companies to generate significant amounts of profit was to keep labour costs low, by keeping wages low. (170) Thousands of black men were hired not only on the mines but also to build the infrastructure of trains, harbours and buildings, which would refine, transport and export the gold. Since these early years, unskilled black labourers have left their home and families behind to find work in or near the big cities, a trend that has continued up to today. (162,170,171)

Further complications to the development, or lack of development, of certain population groups in the country came from white and non-white issues with regard to land and land ownership. (172) In 1913, the Native Land Act led to a segregation of lands into white and non-white areas. This act was the first step towards the constitutional implementation of the Apartheid regime in 1948. Under this system, many non-white individuals were removed from their homes and placed on government allotted homelands, which were seen as separate states within the country. (173) With the use of passbooks, passage and residence away from these homelands was strictly controlled. Non-whites could work in the white suburbs but were forbidden from residing in the urban areas. Informal settlements sprang up outside the boundaries of the towns. These townships were small, cramped and could not support the large number of families, which had been forced to reside within its border. The result was deterioration in education, living and health conditions, the repercussion of which can still be seen today. (162,173,174) Along with a change in socio-economic patterns is a change in lifestyle, which has brought about an increase in metabolic diseases, such as hypertension, diabetes, obesity, alcoholism and a variety of cancers, along with the extant infectious and communicable diseases. (162,165,175) The question that remains is whether health, growth, and ultimately sexual dimorphism, has changed for the better for poor, black South Africans in the last 100 years, such that the skeletal sample from the Pretoria Bone and Raymond A Dart collections would differ, considerably, from the modern group to which the results of this, and other osteometric studies, are to be applied.

From the evidence that has been laid forth not only from previous research in secular trends (62,138,151) but also from the general history of living conditions for black South Africans is that over time improvements have been slow. Low socio-economic status, poor health care, and, inadequate living conditions and nutrition, have been used to explain the negative, or weak, secular trend observed in black South Africans in the last 100 years. This same rationalization may also be used to argue for the relatively moderate sexual dimorphism observed in the forearms bones (ulna and radius) in this group, when compared to European, Asian and North American samples;

which in turn, could clarify, the increased number of misclassified males, when compared to females. (146)

With the advent of a more politically modern society in 1994, the situation for black South Africans have slowly begun to change, such that few are entering the echelons of the middle classes and upper classes. As a result, if we are to observe changes in secular trends, and, in turn, changes in sexual dimorphism then it may only become evident in the next fifty years or longer. For this reason, the discriminant function equations developed in this osteometric study (and in previous South African studies) should be considered applicable to black South Africans of the 20th century.

Robinson (159) observed that in a study of discriminant function formula of South Africans of European descent, most of the equations were accurate in determining sex from modern remains; while others, such as the patella, may require further revision. (159) In the future, with a more modern collection, the equations for black South Africans should also be tested.

5.2. Limitations of osteometric research

As is well known, morphological approaches to sex determination have achieved high percentages of accuracy. However, from a legal perspective it may be easier to convince a magistrate with the use of measurements and ‘scientific facts’, which provide statistical weight to interpretations; rather than an argument based purely on personal, albeit expert, opinion. (28) As a result, morphological analyses are often carried out in conjunction with metric techniques. Although osteometry has also received criticism with regard to limitations related to the applicability of the results, that is not say that these studies are not without merit. Some factors to consider during osteometric studies include: population specificity; sample size; sample distribution of age, sex and ancestry; the applicability of foreign samples on modern research; as well as the validity of using a sample to represent a population. These are all issues that need to be taken into account when conducting research as they can have an underlying influence on the results of a study.

The sample, itself, may be the largest source of query, as it may sometimes be difficult to assess what is an adequate sample size, to obtain the correct number of specimens to form part of the sample, and to identify the sample specific characteristics that might affect the results. (96)

Sample size is often queried, and questions have arisen as to what constitutes a good sample size. (95) If the sample is too small it may not be representative of the population under study, and the results may thus appear 'too good to be true' with very highly accurate results. For this reason, it is preferable to use a larger sample size to increase variability; however, the rate of accuracy will subsequently decrease in conjunction with the increased variability. In the event of difficulty in obtaining an adequate number of individuals in the population sample, researchers could look beyond the population specificity guidelines, and proceed to an amalgamation of more than two population groups, which could theoretically increase variability. Such a sample would however defeat the notion of developing population specific standards, for the precise reason that various populations of a same ancestry group exhibit different manifestations of sexual dimorphism, and thus each is unique. (31)

Statistical principles dictate that the larger the sample size, the more accurate the resulting estimates ought to be. There is however certain realities that tend to restrict this type of research to smaller sample sizes, namely availability of skeletal material. Included in this is the presence of a large number of incomplete skeletons for which the particular bone under study is unavailable, or damaged thus rendering certain measurements impossible on that particular specimen. (131) The presence of excessive osteophytic growth, especially in the older skeletons also makes for a reduced sample size as these often distort the measurements. The continued acquisition of recent and complete skeletons, would increase the possibility of studying larger samples and thus enhancing this type of research (69). In South Africa, two large skeletal collections exist (The Raymond A. Dart and Pretoria Bone Collections), both of which continue to grow on a yearly basis, which will aid in keeping osteometric research current in the future.

The levels of accuracy in this study also decrease by looking at bones in isolation (e.g., radius, ulna, femur, tibia) rather than using multiple measurements. As a result, this type of research has been criticized, as by using this bone-by-bone approach one might sacrifice the forest for the tree. As more osteometric data is collected on South Africa samples, this type of multiple regression analysis will become possible.

5.3. Applicability of this research to unknown remains in South Africa

Data acquired through osteometric studies including epiphyseal measurements of long bones, the length of long bones, their diaphyseal diameters and their circumferences have been the subject of research in many fields of study, from paleo-anthropology to military engineering. Anthropologists have utilized osteometric studies to gain an understanding of the physical changes that we as humans and populations have undergone, and still will experience, by studying the fluctuations of population demographics, the reasons motivating these changes over time, and if these changes could be related to secular changes. (150,154,168) The aged and handicapped have benefited from osteometric studies with the design of more comfortable prosthetics in geriatric medicine. (125) Seats, machinery, and cars have been ergonomically designed to fit the human form, so that its users and occupants will place less stress on their bodies by cramming and cramping them, or twisting them in awkward positions. (176) Even the design of physical activities, such as sports or military training and equipment benefit from osteometric studies, to optimize training programs, enhancing performance and limiting stress to the body. (177)

A common thread to all these studies is the notion of the enhancement and comfort of human life, from beginning to end. That is not to say that once life has ended, so too has the usefulness of osteometry. In this study, the measurements obtained will enhance the data already collected on the crania, femur, tibia, and humerus of South African blacks, for the use in determining sex within a forensic context. Forensic Anthropology has become an integral part of the law enforcement process and as such, the importance and need for improved methods to identifying unknown remains has increased. (178,179)

Chapter 6
Conclusion

This research demonstrated that sex determination from measurements of the radius and ulna has proved to be possible with a moderate degree of accuracy in a black South African sample, thus adding to, or continuing along, a previous line of inquiry. Eighteen standard anthropometric measurements were used to calculate discriminant function formulae to aid in sex determination from unknown human remains in general, and fragmented human remains in particular. The sample used in this study (n =400) consisted of unclaimed bodies received from governmental hospitals in and surrounding Pretoria and Johannesburg. These unclaimed remains are from low socio-economic background, which could provide an explanation as to the low level of sexual dimorphism observed in comparison to other modern groups. The low level of sexual dimorphism would also explain why females repeatedly discriminated better than males, as males exhibited a lesser amount of variability in the specimens.

As expected, using all the measurements combined, the highest percentages of accuracy were achieved for both the radius and the ulna. In the current research, the lowest percentages of accuracy were recorded in the distal breadth of the radius (82%) and the maximum olecranon breadth of the ulna (80%) when using these measurements alone; whereas minimum midshaft diameter in both the ulna and the radius scored the highest percentage of accuracy for both sexes with 84%-85% accuracy.

Opportunity for future osteometric research in South Africa is still abundant, with issues such as the presence or absence of the ‘usual secular trend’ still having to be explored. As a developing country, there are still many questions concerning an the socio-economic upgrading of a large portion of the South African population, and how this may translate as the appearance of a positive secular trend in a couple of decades, showing an increase stature and robusticity. If this is the case for the future, how then will these changes be expressed, not only through the various population groups of South Africa, but also with regard to the various echelons of society. Changes in the context of the level of sexual dimorphism, as it is expressed in different South African population groups will also have to be examined in order to keep the data current and applicable to future forensic situations.

Long-term research projects could include the use of multi-factorial multivariate statistics in sex determination, which will determine the best combinations of measurement throughout the entire skeleton; as well as examine these combinations in order to better understand the relationship between sexual dimorphism and the various parts of the skeleton.

APPENDIX A 1

Abbreviation of the measurements.

In order to enter the data in a spreadsheet for analysis, the following five to six letter abbreviations were created for the radius variables:

Radial dimensions

1. **rad_leg**	maximum length of the radius
2. **dist_br**	distal breadth
3. **rms_cir**	circumference at the midshaft
4. **rms_min**	sagittal diameter at midshaft (minimum diameter)
5. **rms_max**	transverse diameter at midshaft (maximum diameter)
6. **veh_hed**	vertical radial head height
7. **rmn_hed**	minimum head diameter
8. **rmx_hed**	maximum head diameter
9. **rcr_hed**	circumference of the radial
10. **rcr_tub**	circumference at the tuberosity

The data was recorded following sex and location of the collection.

Sex:

Sex 1: refers to male specimens

Sex 2: refers to females.

Location:

Location 1: refers to specimens in the Pretoria Bone Collection

Location 2: refers to specimens in the Raymond A. Dart Collection

Appendix A1: Data of osteometric variables for the radius

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
1694	1	40	1921	1	251.00	37.70	42.00	11.63	16.10	12.17	25.20	25.71	81.00	49.00
2019	1	20	1944	1	265.00	33.35	47.00	11.85	16.81	11.88	22.53	23.11	73.00	51.00
2786	1	50	1919	1	248.00	36.36	47.00	12.56	15.73	10.60	21.41	22.41	69.00	55.00
2788	1	80	1889	1	249.00	32.84	41.00	11.91	12.51	8.45	20.07	20.84	65.00	54.00
2813	1	81	1888	1	271.00	34.44	46.00	13.15	15.67	9.36	22.71	23.82	74.00	54.00
2855	1	55	1914	1	283.00	35.36	45.00	12.46	15.40	9.97	20.76	22.16	70.00	52.00
2858	1	22	1947	1	221.00	29.55	42.00	10.49	15.08	9.31	18.46	19.73	60.00	50.00
2865	1	60	1909	1	261.00	33.42	41.00	11.30	14.78	9.66	22.61	23.88	75.00	48.00
2885	1	60	1909	1	217.00	30.63	41.00	10.43	16.23	9.74	19.16	19.84	63.00	48.00
2889	1	34	1935	1	227.00	34.19	43.00	11.86	15.30	9.37	21.68	22.30	71.00	52.00
2906	1	50	1919	1	242.00	35.66	47.00	15.31	17.34	8.87	21.20	21.78	68.00	49.00
2940	1	80	1890	1	259.00	35.15	41.00	11.19	14.01	10.15	20.63	21.77	68.00	52.00
2991	1	43	1927	1	259.00	34.72	36.00	9.96	12.77	8.53	21.68	22.37	70.00	41.00
3003	1	70	1900	1	249.00	35.50	39.00	10.90	13.74	12.53	24.02	24.91	78.00	48.00
3004	1	46	1924	1	241.00	34.66	46.00	11.25	16.18	10.31	22.37	23.95	73.00	56.00
3006	1	35	1935	1	236.00	31.90	42.00	11.13	15.67	11.09	21.41	22.59	71.00	49.00
3008	1	70	1900	1	321.00	35.74	44.00	11.79	15.80	9.59	21.79	22.99	71.00	50.00
3023	1	48	1922	1	275.00	35.63	42.00	11.80	13.84	9.86	22.35	23.57	74.00	50.00
3066	1	70	1900	1	246.00	32.18	40.00	11.18	13.43	9.07	20.70	21.49	66.00	49.00
3096	1	28	1942	1	252.00	33.79	45.00	11.53	16.73	11.42	22.20	23.69	72.00	56.00
3561	1	36	1936	1	243.00	31.83	37.00	9.91	12.74	10.37	20.22	21.34	67.00	47.00
3670	1	62	1911	1	247.00	32.04	43.00	11.92	14.79	10.85	21.35	23.15	70.00	48.00
3676	1	58	1915	1	281.00	36.75	48.00	13.46	16.70	10.55	25.48	26.18	83.00	54.00
3718	1	30	1943	1	280.00	36.40	45.00	11.78	16.41	9.64	21.68	22.75	70.00	54.00
4196	1	45	1933	1	242.00	31.36	40.00	11.17	13.72	9.34	20.33	21.48	67.00	49.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
4236	1	30	1948	1	244.00	33.05	40.00	10.90	14.43	10.80	20.91	22.18	68.00	48.00
4258	1	55	1923	1	277.00	36.55	51.00	14.16	17.77	12.82	25.18	26.63	84.00	67.00
4265	1	55	1923	1	264.00	34.81	40.00	11.39	13.24	8.68	19.82	21.28	65.00	44.00
4396	1	65	1914	1	262.00	33.80	41.00	11.66	14.13	9.76	20.36	21.50	67.00	48.00
4405	1	69	1910	1	239.00	29.10	41.00	11.31	14.31	9.74	19.61	20.41	63.00	49.00
4421	1	42	1937	1	263.00	34.24	48.00	13.27	16.82	8.12	20.79	21.52	67.00	50.00
4487	1	49	1930	1	221.00	32.34	40.00	10.38	14.83	8.64	19.16	20.12	63.00	49.00
4500	1	55	1924	1	282.00	32.82	44.00	11.60	14.23	9.78	22.24	23.04	72.00	49.00
4522	1	30	1950	1	282.00	31.55	43.00	12.36	14.84	9.56	21.15	22.62	70.00	51.00
4535	1	29	1951	1	238.00	33.63	40.00	10.91	13.78	12.90	23.21	24.76	76.00	45.00
4542	1	60	1920	1	284.00	34.22	44.00	12.53	14.50	9.91	22.39	23.49	73.00	49.00
4592	1	28	1953	1	227.00	30.20	42.00	10.85	14.70	9.48	19.50	20.48	63.00	46.00
4599	1	60	1921	1	256.00	34.49	48.00	13.11	17.31	11.26	22.79	23.80	73.00	51.00
4602	1	60	1921	1	244.00	29.06	38.00	10.97	12.42	9.15	19.69	20.55	64.00	47.00
4606	1	68	1913	1	272.00	34.62	40.00	10.83	14.03	12.44	22.33	22.96	72.00	50.00
4609	1	50	1931	1	283.00	38.59	51.00	13.27	19.13	13.04	24.11	25.39	79.00	59.00
4613	1	61	1920	1	253.00	36.90	44.00	11.34	16.02	11.62	23.45	24.67	77.00	56.00
4014	1	53	1928	1	232.00	35.03	46.00	11.64	16.83	10.30	21.77	22.36	70.00	49.00
4617	1	53	1928	1	257.00	35.87	44.00	12.36	14.77	8.83	22.23	22.96	72.00	48.00
4731	1	60	1923	1	251.00	35.25	43.00	11.87	14.73	11.00	22.36	22.85	74.00	52.00
4790	1	61	1922	1	247.00	31.39	45.00	11.37	16.07	11.29	20.96	21.91	68.00	57.00
4794	1	40	1943	1	242.00	36.11	42.00	11.39	14.40	9.98	21.61	23.39	72.00	52.00
4986	1	56	1928	1	236.00	39.75	49.00	13.00	17.92	13.12	24.60	25.26	80.00	55.00
4927	1	72	1912	1	245.00	38.10	48.00	13.73	16.65	10.90	22.02	22.90	71.00	48.00
4946	1	96	1889	1	269.00	34.87	43.00	11.06	14.97	11.18	23.24	23.90	75.00	50.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
4947	1	66	1919	1	278.00	37.10	48.00	13.11	16.98	10.30	21.80	23.12	73.00	56.00
4959	1	55	1929	1	252.00	37.02	46.00	11.74	16.55	10.69	22.91	24.12	75.00	50.00
4968	1	34	1951	1	264.00	33.38	46.50	13.07	17.15	9.61	20.63	22.25	68.00	55.00
4969	1	64	1921	1	255.00	37.59	51.00	11.69	19.40	10.45	23.33	25.83	78.00	60.00
4970	1	55	1930	1	249.00	33.74	42.00	11.65	14.43	11.78	21.41	22.78	70.00	47.00
4979	1	55	1930	1	268.00	33.76	40.00	11.54	13.66	11.63	22.83	23.54	74.00	54.00
4980	1	70	1915	1	279.00	36.35	46.00	12.16	15.90	11.01	23.82	26.05	81.00	54.00
4983	1	55	1930	1	260.00	32.20	44.00	12.17	14.62	8.94	21.98	23.40	72.00	59.00
4984	1	51	1934	1	250.00	36.43	47.00	12.72	16.03	10.83	24.05	26.30	80.00	60.00
4995	1	53	1932	1	222.00	31.28	43.00	10.89	15.52	8.81	19.29	20.15	63.00	46.00
5004	1	70	1915	1	249.00	33.76	44.00	11.27	15.78	10.16	21.29	22.33	70.00	49.00
5007	1	72	1913	1	255.00	39.52	51.00	13.65	18.80	12.72	24.43	25.31	79.00	57.00
5010	1	40	1945	1	286.00	36.86	40.00	11.31	13.71	11.29	21.95	22.93	72.00	52.00
5012	1	65	1920	1	258.00	36.74	45.00	11.69	15.75	10.54	25.17	26.90	83.00	51.00
5014	1	55	1930	1	277.00	35.23	40.00	11.32	17.13	10.03	20.95	21.76	68.00	45.00
5019	1	70	1915	1	242.00	35.02	45.00	11.70	16.63	11.35	23.56	24.26	76.00	54.00
5020	1	70	1915	1	246.00	32.67	41.00	11.27	13.96	7.56	19.73	21.25	65.00	50.00
5022	1	41	1944	1	270.00	32.38	43.00	11.97	14.24	9.95	20.96	22.53	70.00	48.00
5024	1	70	1915	1	246.00	34.68	46.00	12.90	16.35	10.98	21.74	23.43	72.00	50.00
5025	1	40	1945	1	247.00	37.66	42.00	11.24	14.78	10.62	24.62	26.05	81.00	48.00
5027	1	55	1930	1	240.00	34.39	40.00	10.51	14.28	12.08	19.81	20.70	64.00	50.00
5030	1	34	1951	1	268.00	33.09	42.00	11.79	14.48	11.73	22.15	22.54	71.00	48.00
5031	1	29	1956	1	257.00	34.08	45.00	11.85	15.77	11.01	22.90	23.62	74.00	54.00
5032	1	55	1930	1	257.00	37.86	43.00	11.51	15.77	11.30	23.56	24.85	76.00	48.00
5037	1	42	1943	1	261.00	35.64	38.00	10.73	12.75	12.50	23.65	24.90	77.00	50.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
5045	1	70	1915	1	268.00	34.55	45.00	12.03	15.88	9.79	21.93	23.24	72.00	50.00
5050	1	57	1929	1	252.00	34.14	50.00	11.93	18.57	7.88	21.76	22.87	69.00	46.00
5051	1	52	1934	1	252.00	35.12	53.00	12.58	20.01	10.67	21.56	22.47	70.00	58.00
5063	1	58	1928	1	272.00	37.19	41.00	11.76	13.45	8.70	22.34	22.68	71.00	49.00
5065	1	54	1932	1	265.00	34.70	44.00	12.57	15.05	10.78	24.02	24.38	77.00	50.00
5075	1	70	1916	1	281.00	34.50	47.00	13.10	16.37	11.60	22.24	23.57	73.00	58.00
5080	1	45	1941	1	268.00	40.40	46.00	12.34	16.62	8.66	24.25	25.18	79.00	51.00
5081	1	65	1921	1	242.00	33.47	44.00	11.14	16.14	11.43	22.69	23.62	74.00	47.00
5082	1	43	1943	1	262.00	33.54	40.00	11.30	13.60	10.36	35.00	25.55	77.00	47.00
5109	1	65	1921	1	227.00	34.29	46.00	12.28	15.62	11.28	20.89	21.99	68.00	49.00
5123	1	48	1938	1	255.00	37.24	46.00	11.66	17.10	10.09	22.83	23.15	74.00	53.00
5130	1	44	1942	1	247.00	34.46	43.00	11.44	16.01	10.55	21.58	23.35	72.00	53.00
5139	1	64	1923	1	262.00	33.96	40.00	11.48	13.23	9.74	22.86	24.13	75.00	52.00
5141	1	60	1927	1	248.00	37.30	45.00	11.23	15.97	10.05	21.89	22.76	71.00	50.00
5144	1	60	1927	1	257.00	35.04	41.00	10.96	14.92	11.83	20.95	22.07	69.00	50.00
5149	1	86	1901	1	272.00	34.24	41.00	11.15	14.87	9.66	22.52	23.70	73.00	51.00
5152	1	24	1963	1	256.00	33.18	39.00	10.44	14.06	9.56	20.21	20.92	65.00	48.00
5154	1	50	1937	1	265.00	33.79	46.00	12.47	15.74	9.41	21.32	22.30	70.00	52.00
5160	1	62	1925	1	261.00	35.77	43.00	12.18	14.45	8.67	22.03	23.07	72.00	51.00
5162	1	82	1905	1	243.00	33.95	42.00	11.48	13.48	10.33	22.68	23.65	78.00	55.00
5164	1	70	1917	1	248.00	33.76	40.00	11.35	15.09	11.36	22.89	23.48	74.00	55.00
5167	1	64	1923	1	258.00	30.11	40.00	11.11	12.96	8.48	20.25	21.16	66.00	51.00
5169	1	67	1920	1	247.00	33.90	44.00	11.73	15.29	10.39	22.41	24.07	74.00	48.00
5175	1	55	1932	1	270.00	32.31	45.00	12.56	15.40	11.14	21.57	22.53	70.00	51.00
5177	1	57	1930	1	260.00	35.98	49.00	12.42	18.42	10.00	21.80	22.98	72.00	56.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
5178	1	80	1907	1	243.00	38.90	43.00	10.02	16.28	10.61	23.17	24.15	75.00	54.00
5192	1	43	1944	1	262.00	37.71	49.00	13.72	16.97	11.09	24.77	25.71	81.00	58.00
5202	1	60	1927	1	269.00	33.35	46.00	12.73	16.21	8.76	21.62	22.40	71.00	55.00
5214	1	60	1927	1	250.00	35.35	42.00	11.20	14.42	9.96	20.56	22.07	68.00	49.00
5244	1	63	1925	1	260.00	37.30	51.00	13.94	18.20	10.11	21.96	22.75	72.00	56.00
5250	1	62	1926	1	248.00	33.39	44.00	11.29	15.27	11.29	20.80	21.41	68.00	52.00
5254	1	49	1939	1	270.00	35.34	44.00	11.34	16.25	9.56	22.81	23.65	74.00	51.00
5262	1	37	1951	1	242.00	35.94	44.00	11.57	15.67	9.97	21.82	23.42	72.00	55.00
5269	1	60	1928	1	252.00	33.54	43.00	11.57	14.73	11.08	21.36	22.16	70.00	51.00
5272	1	66	1922	1	250.00	39.47	46.00	12.19	17.20	12.01	22.53	23.80	74.00	53.00
5273	1	65	1923	1	242.00	32.21	40.00	11.46	13.07	9.97	19.50	20.61	64.00	45.00
5276	1	68	1920	1	267.00	37.23	48.00	13.20	16.71	11.17	23.28	23.90	75.00	54.00
5293	1	27	1961	1	262.00	34.37	44.00	11.49	16.19	8.90	21.81	23.81	72.00	53.00
5309	1	68	1920	1	270.00	34.79	47.00	12.21	17.15	12.03	21.41	22.23	69.00	51.00
5333	1	60	1928	1	237.00	32.84	43.00	10.83	15.28	9.08	19.24	20.10	62.00	45.00
5354	1	56	1932	1	254.00	34.46	41.00	10.89	14.86	9.89	20.29	21.26	66.00	48.00
5352	1	65	1924	1	250.00	32.34	49.00	12.05	17.87	8.35	23.46	24.65	76.00	58.00
5354	1	40	1949	1	245.00	35.52	48.00	13.00	17.44	10.98	22.41	23.36	73.00	53.00
5358	1	53	1936	1	249.00	33.77	45.00	11.54	16.19	11.88	22.27	23.46	74.00	50.00
5361	1	30	1959	1	252.00	36.70	47.00	12.60	16.45	11.09	22.15	22.67	72.00	56.00
5365	1	50	1939	1	265.00	34.14	44.00	11.15	16.73	10.16	21.43	22.16	70.00	52.00
5368	1	65	1924	1	272.00	34.92	46.00	12.57	16.64	10.31	22.35	24.53	75.00	56.00
5372	1	63	1926	1	247.00	37.26	50.00	13.44	18.13	9.16	22.17	23.14	73.00	57.00
5379	1	70	1919	1	261.00	36.06	42.00	10.85	14.87	10.85	22.22	22.83	72.00	47.00
5392	1	70	1919	1	262.00	35.33	42.00	11.23	14.65	11.15	20.81	22.96	72.00	53.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
5396	1	53	1936	1	260.00	34.47	43.00	11.91	14.31	11.43	21.23	21.82	69.00	47.00
5415	1	38	1952	1	257.00	35.17	46.00	11.37	16.75	10.42	22.20	23.65	72.00	52.00
5419	1	48	1941	1	250.00	34.27	49.00	12.45	17.41	11.64	21.55	22.72	69.00	51.00
5431	1	25	1965	1	258.00	32.70	39.00	10.39	14.20	8.38	21.41	22.32	68.00	46.00
5432	1	49	1941	1	277.00	33.62	48.00	13.20	16.82	10.38	23.96	25.16	77.00	63.00
5447	1	52	1938	1	255.00	38.83	45.00	11.62	16.75	10.36	25.27	26.90	83.00	51.00
5449	1	48	1942	1	261.00	36.66	47.00	11.90	16.72	9.29	24.08	24.54	78.00	54.00
5454	1	54	1936	1	261.00	38.56	48.00	12.60	17.22	12.81	22.33	23.46	74.00	59.00
5461	1	60	1930	1	253.00	35.64	44.00	11.72	14.92	11.46	22.38	23.81	75.00	50.00
5470	1	49	1941	1	253.00	34.96	41.00	11.17	14.44	10.33	23.54	24.45	77.00	47.00
5493	1	40	1950	1	272.00	34.07	41.00	11.45	14.33	10.37	22.81	23.35	75.00	50.00
5513	1	70	1921	1	234.00	32.99	39.00	10.85	13.84	9.95	21.52	22.43	70.00	47.00
5532	1	54	1931	1	270.00	35.99	45.00	12.08	14.84	10.39	23.80	25.31	78.00	58.00
5535	1	50	1941	1	256.00	36.94	51.00	14.24	17.40	8.68	24.40	25.26	67.00	51.00
5540	1	72	1919	1	260.00	35.73	42.00	10.89	14.63	10.22	20.98	21.65	68.00	48.00
5548	1	60	1931	1	254.00	33.79	46.00	12.91	15.73	10.84	20.77	22.04	69.00	51.00
5550	1	60	1931	1	237.00	34.68	39.00	11.53	13.48	11.29	22.59	24.56	75.00	50.00
5561	1	60	1929	1	255.00	35.66	48.00	11.81	17.62	9.71	21.97	22.73	71.00	59.00
5566	1	60	1931	1	235.00	31.50	45.00	10.95	17.39	11.39	20.37	21.95	67.00	49.00
5569	1	23	1968	1	245.00	31.56	37.00	9.94	12.80	12.67	20.40	21.95	69.00	46.00
5579	1	66	1925	1	228.00	33.50	44.00	12.14	15.73	9.53	21.33	22.29	70.00	53.00
5591	1	40	1951	1	256.00	34.06	44.00	11.95	14.84	10.52	22.46	23.67	74.00	54.00
5617	1	48	1943	1	251.00	32.21	40.00	11.04	14.09	11.57	19.72	20.85	65.00	54.00
5627	1	37	1955	1	249.00	33.16	45.00	11.51	15.36	11.39	21.23	22.40	69.00	48.00
5636	1	51	1941	1	284.00	37.36	52.00	13.18	18.39	13.18	22.30	23.34	74.00	57.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
5638	1	35	1957	1	249.00	32.43	42.00	11.30	14.35	9.44	21.77	22.63	71.00	46.00
5646	1	48	1944	1	233.00	32.78	38.00	10.32	14.38	10.51	20.26	21.52	67.00	47.00
5662	1	72	1920	1	260.00	32.81	45.00	12.34	13.96	12.09	23.82	24.33	77.00	52.00
5666	1	63	1929	1	260.00	33.66	44.00	11.08	16.70	11.26	21.03	23.29	71.00	46.00
5670	1	40	1952	1	264.00	33.27	43.00	12.62	15.34	10.64	21.71	22.72	70.00	49.00
5681	1	53	1939	1	268.00	40.80	47.00	12.65	16.39	10.68	25.72	26.20	82.00	57.00
5685	1	69	1923	1	274.00	36.53	47.00	12.48	16.76	11.06	23.17	24.03	77.00	53.00
5691	1	43	1949	1	267.00	34.52	45.00	11.88	15.75	12.11	22.84	24.04	75.00	60.00
5742	1	60	1933	1	260.00	37.29	45.00	12.60	15.54	11.16	24.57	25.55	79.00	52.00
5753	1	55	1938	1	268.00	35.72	47.00	12.40	16.63	10.52	22.34	23.39	74.00	58.00
5760	1	66	1927	1	259.00	35.96	49.00	12.58	17.61	10.59	22.17	23.53	74.00	60.00
5761	1	28	1965	1	250.00	29.84	41.00	11.00	14.62	11.75	20.56	21.85	69.00	52.00
5772	1	65	1927	1	258.00	31.99	48.00	12.21	16.90	10.22	22.49	24.12	74.00	54.00
5819	1	46	1947	1	271.00	37.26	43.00	12.26	15.07	11.74	23.18	24.76	76.00	57.00
5828	1	65	1929	1	229.00	33.87	44.00	11.57	15.91	9.19	19.24	20.49	64.00	55.00
5841	1	64	1930	1	261.00	34.13	45.00	12.58	15.90	8.88	22.69	23.43	74.00	49.00
5854	1	70	1924	1	256.00	35.56	47.00	11.75	17.26	9.55	20.86	22.19	70.00	52.00
5841	1	27	1967	1	254.00	35.61	39.00	11.65	14.23	9.92	21.50	22.90	68.00	44.00
5860	1	54	1940	1	252.00	38.15	43.00	11.11	16.01	10.78	22.60	23.44	74.00	49.00
5879	1	53	1941	1	247.00	31.24	40.00	10.52	14.46	10.04	20.95	22.93	70.00	49.00
5880	1	57	1937	1	247.00	33.90	47.00	12.43	17.69	9.90	21.56	22.79	72.00	57.00
5885	1	32	1962	1	223.00	26.97	38.00	9.78	14.08	7.80	17.04	18.65	58.00	38.00
5886	1	71	1923	1	270.00	34.37	44.00	12.51	15.65	12.43	23.61	24.51	77.00	60.00
5889	1	57	1937	1	271.00	35.84	51.00	13.52	18.05	13.38	23.30	24.63	76.00	56.00
5904	1	31	1963	1	263.00	34.24	42.00	11.37	14.34	11.19	24.14	24.65	78.00	52.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
5905	1	40	1954	1	261.00	36.87	54.00	14.05	19.33	11.97	23.16	24.12	75.00	58.00
5911	1	74	1920	1	251.00	31.76	42.00	11.71	14.38	10.05	21.56	22.16	70.00	48.00
5912	1	37	1957	1	278.00	35.16	45.00	11.92	15.69	10.09	23.19	25.14	76.00	46.00
5940	1	57	1938	1	269.00	37.45	48.00	13.18	16.35	11.04	24.52	25.30	79.00	58.00
5947	1	48	1947	1	245.00	31.81	38.00	10.60	11.42	9.42	20.53	21.59	67.00	45.00
5951	1	60	1935	1	259.00	36.50	50.00	13.42	17.27	9.63	24.11	24.97	78.00	58.00
5952	1	70	1925	1	280.00	34.56	47.00	12.74	16.78	11.57	21.64	22.72	72.00	57.00
5958	1	34	1961	1	270.00	36.42	40.00	11.69	15.70	10.71	22.67	23.61	73.00	59.00
5962	1	72	1923	1	236.00	29.87	47.00	12.27	17.14	7.77	19.27	20.54	65.00	52.00
5974	1	66	1929	1	268.00	38.19	49.00	13.48	16.61	10.92	23.42	24.83	77.00	56.00
5976	1	70	1925	1	246.00	30.93	39.00	10.58	13.23	10.11	20.08	20.93	66.00	48.00
5977	1	28	1967	1	252.00	34.46	39.00	11.02	13.64	9.15	21.96	22.70	71.00	44.00
6058	1	30	1966	1	242.00	34.13	45.00	12.24	15.54	7.86	22.72	23.45	73.00	51.00
6087	1	44	1953	1	227.00	30.59	36.00	9.68	11.73	10.52	20.97	22.06	69.00	42.00
6119	1	26	1971	1	252.00	34.55	47.00	12.45	16.76	12.04	22.51	23.85	75.00	54.00
6137	1	40	1957	1	255.00	37.01	47.00	12.11	17.06	12.37	25.19	25.86	82.00	53.00
6142	1	43	1954	1	244.00	35.70	46.00	12.68	16.26	10.89	24.04	25.07	78.00	52.00
6173	1	60	1928	1	259.00	32.34	41.00	11.59	13.24	11.55	22.46	23.70	74.00	49.00
6188	1	25	1973	1	233.00	32.99	44.00	11.47	15.00	12.40	22.15	23.05	73.00	50.00
6195	1	46	1952	1	245.00	33.19	42.00	10.74	15.33	8.73	22.11	23.79	73.00	52.00
6197	1	67	1931	1	264.00	33.38	46.00	12.71	16.00	11.32	22.47	23.70	75.00	56.00
6199	1	27	1971	1	260.00	36.98	45.00	12.65	17.20	10.47	22.87	23.82	75.00	53.00
6200	1	60	1938	1	257.00	34.70	47.00	12.70	17.32	9.79	22.51	23.14	73.00	59.00
6201	1	50	1948	1	252.00	36.53	45.00	12.22	15.11	9.13	22.97	23.85	75.00	49.00
6211	1	58	1940	1	255.00	39.63	44.00	12.38	16.33	12.17	23.20	23.78	74.00	51.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
1543	2	40	1921	1	220.00	32.07	42.00	10.71	13.40	8.50	19.03	20.78	67.00	63.00
1696	2	79	1882	1	227.00	31.82	37.00	9.66	14.10	9.86	20.08	20.84	64.00	44.00
1803	2	60	1902	1	210.00	30.00	36.00	10.01	13.22	9.62	19.69	20.61	64.00	40.00
2632	2	50	1918	1	239.00	32.64	43.00	10.71	16.41	12.90	22.17	23.54	73.00	52.00
2866	2	33	1936	1	224.00	31.22	34.00	9.38	11.49	7.70	18.15	19.02	58.00	44.00
2900	2	60	1909	1	245.00	31.43	37.00	9.50	13.57	7.68	19.68	20.91	66.00	44.00
2905	2	49	1920	1	235.00	31.68	42.00	11.14	15.13	9.11	19.70	20.24	64.00	50.00
2939	2	70	1900	1	232.00	31.68	38.00	9.42	12.89	9.60	20.69	22.55	69.00	49.00
2980	2	49	1921	1	213.00	30.46	36.00	9.49	13.00	11.53	20.27	20.68	65.00	48.00
3015	2	70	1900	1	215.00	30.00	36.00	9.07	12.61	8.09	19.28	19.86	63.00	49.00
3041	2	30	1940	1	232.00	32.53	41.00	10.92	14.20	8.79	21.39	22.32	70.00	53.00
3120	2	42	1928	1	230.00	32.92	37.00	10.02	13.24	10.81	20.96	21.98	68.00	42.00
3154	2	40	1931	1	219.00	30.05	34.00	9.37	11.61	7.97	18.35	19.48	61.00	43.00
3266	2	28	1943	1	217.00	29.07	33.00	9.99	12.36	7.96	17.23	17.42	54.00	38.00
3385	2	36	1935	1	228.00	28.80	34.00	9.56	11.34	8.90	18.16	19.17	60.00	42.00
3609	2	44	1928	1	252.00	32.16	38.00	10.71	12.47	8.55	20.61	21.05	67.00	50.00
3843	2	40	1935	1	244.00	30.12	41.00	10.88	14.12	7.46	18.34	19.29	61.00	46.00
3854	2	40	1935	1	218.00	28.74	36.00	10.10	12.35	9.62	19.58	19.96	63.00	41.00
4198	2	35	1943	1	221.00	31.67	37.00	9.95	12.94	9.17	20.08	20.80	65.00	43.00
4256	2	42	1926	1	231.00	28.51	41.00	10.71	14.94	8.66	18.36	19.72	62.00	45.00
4417	2	60	1919	1	222.00	29.84	41.00	9.72	15.09	10.22	20.06	20.53	65.00	50.00
4436	2	37	1942	1	251.00	32.05	41.00	11.07	14.82	9.39	19.23	20.16	63.00	50.00
4492	2	48	1931	1	242.00	31.47	42.00	11.43	15.36	7.54	21.71	22.71	71.00	53.00
4565	2	47	1933	1	236.00	31.74	47.00	9.68	13.84	9.74	21.35	22.64	70.00	43.00
4575	2	33	1947	1	227.00	30.00	34.00	11.57	15.50	8.09	19.51	20.48	64.00	47.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
4598	2	32	1949	1	242.00	31.22	39.00	10.57	13.24	12.29	19.96	20.67	66.00	49.00
4786	2	30	1953	1	231.00	28.73	39.00	10.70	13.52	10.97	19.08	19.49	62.00	47.00
4835	2	43	1941	1	234.00	31.23	36.00	8.94	12.98	9.02	17.41	18.55	58.00	45.00
4855	2	65	1919	1	230.00	34.71	46.00	10.41	18.04	10.38	20.05	21.04	67.00	51.00
4956	2	40	1945	1	244.00	31.02	38.00	10.64	13.17	7.86	18.39	19.19	61.00	41.00
4990	2	60	1925	1	238.00	34.33	44.00	11.78	15.62	12.00	21.97	23.08	72.00	47.00
4998	2	63	1922	1	233.00	27.97	39.00	9.90	13.15	7.84	20.22	21.16	66.00	44.00
5005	2	60	1920	1	234.00	30.85	39.00	10.01	12.92	7.62	18.57	19.45	61.00	44.00
5018	2	59	1926	1	237.00	34.23	43.00	10.70	15.86	11.97	21.65	22.34	70.00	48.00
5029	2	19	1969	1	262.00	33.18	42.00	11.76	14.57	11.71	21.68	23.01	72.00	50.00
5033	2	70	1915	1	243.00	33.08	45.00	9.80	17.16	9.38	21.89	23.04	72.00	45.00
5039	2	70	1915	1	249.00	30.27	40.00	11.03	13.75	11.16	18.73	19.86	61.00	45.00
5073	2	70	1916	1	211.00	30.94	35.00	9.75	12.13	7.59	18.15	19.37	60.00	42.00
5079	2	45	1941	1	201.00	31.08	43.00	9.87	16.52	9.49	19.77	19.94	64.00	56.00
5086	2	34	1952	1	223.00	29.42	37.00	10.17	12.24	7.51	18.56	19.78	62.00	46.00
5108	2	68	1918	1	229.00	29.11	36.00	10.10	12.29	8.64	18.92	19.74	62.00	41.00
5148	2	54	1933	1	214.00	30.29	39.00	9.92	14.00	9.63	18.89	20.36	64.00	44.00
5150	2	31	1956	1	232.00	30.53	42.00	11.50	14.91	8.66	19.01	19.38	61.00	46.00
5197	2	82	1905	1	262.00	37.97	52.00	12.81	20.15	11.21	23.87	26.07	81.00	63.00
520	2	45	1942	1	245.00	33.19	41.00	10.60	15.18	9.75	20.02	20.63	77.00	50.00
5292	2	46	1942	1	234.00	31.57	37.00	10.25	12.43	7.77	20.50	21.45	67.00	47.00
5306	2	38	1950	1	211.00	29.26	32.00	8.08	11.50	7.25	17.92	19.15	59.00	45.00
5316	2	41	1947	1	227.00	33.14	42.00	10.82	15.11	9.71	20.75	21.45	68.00	46.00
5323	2	70	1918	1	216.00	31.25	40.00	9.70	15.14	11.08	19.55	20.63	66.00	46.00
5335	2	44	1932	1	236.00	32.70	40.00	10.05	14.92	7.95	20.38	20.84	67.00	48.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
5342	2	57	1931	1	201.00	30.77	40.00	9.54	13.97	6.35	18.73	19.43	61.00	40.00
5384	2	45	1944	1	250.00	34.51	36.00	10.01	12.39	9.88	21.57	22.68	71.00	47.00
5390	2	65	1924	1	218.00	28.54	34.00	8.48	12.63	7.83	19.39	20.06	63.00	42.00
5602	2	55	1936	1	228.00	31.02	39.00	10.41	13.31	7.37	19.81	20.90	64.00	45.00
5629	2	52	1940	1	220.00	30.56	40.00	9.82	15.18	8.72	18.66	19.87	61.00	46.00
5635	2	50	1942	1	206.00	28.43	35.00	8.64	12.74	9.64	19.62	20.04	63.00	40.00
5654	2	49	1943	1	235.00	30.10	38.00	10.48	12.10	7.82	18.95	19.95	63.00	50.00
5692	2	44	1948	1	244.00	31.62	40.00	9.73	14.91	10.80	19.78	20.35	64.00	43.00
5698	2	50	1942	1	250.00	33.88	43.00	11.31	14.49	11.02	20.80	22.27	70.00	55.00
5705	2	65	1927	1	216.00	30.88	41.00	11.22	14.90	8.54	19.17	20.30	63.00	48.00
5708	2	71	1921	1	211.00	33.59	39.00	10.51	13.46	9.15	20.56	22.60	70.00	46.00
5717	2	55	1937	1	250.00	35.13	42.00	10.72	15.27	10.34	20.85	21.14	66.00	47.00
5734	2	60	1933	1	250.00	33.23	44.00	11.35	15.38	11.04	21.58	22.54	71.00	46.00
5767	2	32	1961	1	229.00	29.16	34.00	8.86	12.10	6.89	16.44	17.25	55.00	40.00
5783	2	42	1951	1	234.00	31.98	40.00	10.52	14.23	10.58	21.66	22.60	70.00	45.00
5785	2	56	1937	1	235.00	33.06	37.00	9.45	12.75	10.34	23.36	24.05	75.00	37.00
5797	2	28	1965	1	227.00	28.79	39.00	10.18	13.66	8.38	19.35	20.49	64.00	48.00
5878	2	32	1902	1	222.00	29.46	36.00	9.90	12.28	8.97	19.11	19.74	61.00	38.00
5932	2	40	1955	1	239.00	31.69	39.00	10.78	13.71	10.96	19.90	20.65	65.00	51.00
5946	2	62	1933	1	206.00	28.77	39.00	10.34	13.74	9.08	18.66	11.63	61.00	44.00
5957	2	29	1966	1	233.00	28.95	38.00	9.85	13.38	8.93	19.30	20.51	64.00	48.00
5980	2	58	1937	1	240.00	32.79	48.00	12.15	17.89	9.60	21.03	12.85	68.00	55.00
6000	2	38	1967	1	227.00	29.78	38.00	10.06	13.24	8.16	21.03	21.52	68.00	41.00
6024	2	65	1931	1	237.00	30.82	38.00	10.58	12.65	10.15	19.87	21.70	67.00	50.00
6094	2	33	1964	1	240.00	30.25	39.00	10.90	12.76	8.57	20.22	21.34	66.00	44.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
6123	2	60	1937	1	226.00	29.58	36.00	9.63	13.20	11.15	20.10	21.35	66.00	43.00
6139	2	38	1959	1	220.00	31.89	37.00	10.23	13.47	11.13	19.51	20.16	63.00	45.00
6144	2	50	1947	1	250.00	33.62	37.00	10.31	12.25	9.29	19.80	20.81	65.00	48.00
6156	2	65	1933	1	223.00	28.87	37.00	9.29	12.62	7.73	18.31	19.10	60.00	45.00
6157	2	30	1968	1	211.00	29.63	36.00	9.52	13.05	8.37	18.84	19.33	61.00	42.00
6172	2	53	1945	1	210.00	28.97	37.00	9.26	13.51	10.57	20.87	22.05	68.00	44.00
6177	2	23	1975	1	259.00	33.31	39.00	10.69	13.91	6.62	20.99	22.04	67.00	49.00
6192	2	22	1976	1	217.00	30.50	35.00	9.17	12.72	10.26	18.92	19.71	62.00	44.00
6234	2	25	1974	1	242.00	30.70	43.00	10.85	16.18	10.31	21.06	22.13	69.00	43.00
6237	2	56	1943	1	243.00	31.72	37.00	10.44	12.59	8.16	18.82	19.65	62.00	43.00
6256	2	32	1967	1	235.00	34.22	39.00	10.19	13.96	10.00	19.76	21.27	65.00	44.00
6290	2	24	1976	1	252.00	31.84	41.00	11.31	14.58	9.86	19.60	20.55	64.00	44.00
6315	2	64	1936	1	245.00	31.20	39.00	10.93	13.26	9.51	18.28	19.25	61.00	45.00
6328	2	47	1953	1	251.00	33.13	46.00	12.04	17.33	10.34	21.67	22.53	71.00	57.00
6358	2	37	1964	1	227.00	31.40	41.00	10.19	15.30	10.34	20.30	21.35	66.00	49.00
6369	2	52	1949	1	209.00	28.66	36.00	9.32	12.35	9.02	18.70	19.48	61.00	41.00
6370	2	60	1941	1	256.00	30.40	35.00	9.22	12.20	9.68	17.64	18.89	58.00	41.00
6372	2	38	1963	1	248.00	30.52	40.00	9.61	15.01	12.07	19.90	22.01	67.00	46.00
6388	2	47	1954	1	246.00	30.10	31.00	8.74	10.60	10.63	20.26	20.89	66.00	39.00
6390	2	24	1977	1	235.00	32.58	40.00	10.31	14.53	8.75	19.81	20.86	65.00	46.00
2576	2	60	1895	2	256.00	32.77	41.00	10.46	15.43	9.87	20.69	21.59	66.00	43.00
2630	2	34	1922	2	243.00	31.90	37.00	9.47	13.47	10.31	20.90	21.64	67.00	43.00
2627	2	42	1914	2	230.00	29.61	33.00	9.26	11.72	9.18	19.09	20.24	63.00	44.00
2608	2	36	1920	2	231.00	30.82	40.00	10.44	16.23	9.80	19.14	19.84	62.00	44.00
2667	2	50	1907	2	227.00	30.40	35.00	9.58	12.73	9.39	17.70	19.52	60.00	46.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
2745	2	40	1917	2	209.00	28.95	34.00	9.58	12.43	9.30	17.32	18.03	55.00	38.00
2812	2	56	1902	2	233.00	32.89	38.00	11.04	14.55	11.49	19.73	20.35	63.00	49.00
2921	2	41	1919	2	221.00	30.89	35.00	9.80	13.81	9.61	19.64	20.67	63.00	44.00
3134	2	44	1918	2	227.00	31.40	41.00	10.78	14.28	9.94	18.87	19.93	63.00	49.00
3080	2	50	1911	2	239.00	33.24	39.00	9.92	13.14	9.65	22.10	22.64	71.00	49.00
3344	2	30	1934	2	215.00	29.67	39.00	11.12	12.45	10.29	20.50	21.03	66.00	39.00
3301	2	38	1925	2	229.00	29.68	40.00	10.25	14.34	10.28	18.30	19.33	61.00	49.00
3297	2	70	1893	2	218.00	29.26	41.00	9.61	15.50	9.66	18.68	19.72	62.00	47.00
3303	2	45	1918	2	233.00	32.66	39.00	10.35	13.85	10.06	20.51	21.57	67.00	48.00
3343	2	45	1919	2	221.00	30.80	38.00	10.10	12.85	8.45	18.76	19.68	62.00	43.00
3473	2	70	1895	2	229.00	32.45	41.00	10.85	13.89	9.75	19.48	19.98	63.00	44.00
3909	2	38	1931	2	234.00	29.72	37.00	9.24	12.96	8.71	19.15	20.46	64.00	44.00
3921	2	23	1946	2	237.00	29.54	39.00	10.16	13.68	9.34	19.25	20.03	63.00	43.00
4514	2	38	1936	2	226.00	28.20	38.00	9.80	13.71	9.40	18.33	19.23	61.00	44.00
4521	2	37	1937	2	217.00	28.19	38.00	9.34	12.45	9.26	19.62	20.36	64.00	46.00
4694	2	23	1952	2	248.00	32.66	38.00	10.11	13.05	9.74	20.87	21.68	68.00	45.00
4712	2	39	1937	2	228.00	30.17	41.00	10.83	14.07	9.79	19.99	20.68	65.00	48.00
4771	2	43	1933	2	228.00	30.94	40.00	10.56	14.13	8.13	19.73	20.00	65.00	46.00
4700	2	36	1939	2	242.00	31.76	40.00	9.71	14.65	9.85	20.48	21.50	68.00	45.00
4819	2	74	1903	2	219.00	32.06	40.00	9.43	15.48	10.04	19.24	19.63	63.00	44.00
4844	2	38	1939	2	230.00	33.15	42.00	11.02	14.77	8.51	20.00	21.79	68.00	49.00
4929	2	38	1940	2	242.00	32.20	42.00	11.82	13.88	12.36	20.85	21.60	66.00	50.00
5490	2	49	1934	2	234.00	31.91	37.00	9.67	13.40	10.69	22.30	23.03	73.00	46.00
5728	2	33	1952	2	229.00	31.69	42.00	9.67	16.04	10.96	20.72	22.17	69.00	51.00
5808	2	55	1930	2	239.00	33.12	37.00	9.54	13.61	10.73	21.82	23.32	72.00	47.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
5737	2	30	1955	2	219.00	28.32	37.00	9.36	13.98	9.23	18.57	19.53	60.00	43.00
5883	2	59	1927	2	230.00	31.78	40.00	10.42	13.84	7.99	19.86	20.76	66.00	47.00
6021	2	86	1901	2	220.00	32.42	39.00	9.78	14.28	9.14	19.25	19.78	63.00	52.00
6042	2	30	1957	2	237.00	30.16	42.00	11.30	14.23	9.70	22.04	23.30	72.00	47.00
6161	2	87	1901	2	230.00	32.75	37.00	9.39	13.34	10.57	20.90	22.20	71.00	44.00
6195	2	60	1928	2	238.00	32.15	42.00	10.71	14.84	10.50	20.94	21.65	68.00	48.00
6245	2	78	1911	2	208.00	30.58	42.00	10.08	14.63	8.08	19.87	20.64	65.00	51.00
6258	2	49	1940	2	249.00	32.60	38.00	10.57	13.45	11.07	21.89	22.85	71.00	46.00
6263	2	37	1952	2	236.00	33.86	42.00	10.59	14.72	10.75	21.95	20.60	64.00	46.00
6207	2	38	1950	2	245.00	34.43	40.00	10.53	14.15	10.63	21.60	22.20	70.00	48.00
6239	2	50	1938	2	250.00	34.50	41.00	10.04	14.90	10.18	19.10	20.49	65.00	41.00
6370	2	40	1949	2	230.00	28.88	37.00	9.65	13.22	8.08	18.18	18.84	60.00	42.00
6585	2	20	1970	2	238.00	31.42	41.00	10.38	14.85	10.71	19.73	21.45	66.00	43.00
2427	2	65	1888	2	233.00	32.40	43.00	11.09	15.35	13.16	20.97	21.92	69.00	52.00
2460	2	69	1884	2	203.00	28.33	33.00	8.11	10.02	8.37	17.57	18.62	59.00	37.00
2407	2	37	1916	2	234.00	31.65	39.00	9.76	14.13	9.49	18.49	19.64	61.00	48.00
2451	2	51	1902	2	235.00	28.88	36.00	9.35	11.08	8.41	18.80	20.33	63.00	44.00
2517	2	32	1923	2	215.00	29.66	38.00	9.47	13.33	7.29	18.17	18.76	60.00	42.00
2515	2	28	1926	2	237.00	30.37	40.00	10.63	13.18	9.95	19.57	20.58	64.00	47.00
2505	2	70	1884	2	207.00	29.06	38.00	10.02	11.87	7.72	17.65	18.86	59.00	43.00
2577	2	40	1915	2	221.00	28.64	38.00	10.05	12.57	9.25	19.12	20.29	65.00	46.00
2584	2	30	1926	2	218.00	30.17	38.00	9.90	12.94	8.05	18.36	19.69	62.00	43.00
2345	2	50	1902	2	242.00	32.50	44.00	10.44	15.59	9.36	22.42	23.08	73.00	52.00
2715	2	45	1912	2	219.00	28.34	38.00	10.18	11.80	8.72	19.42	20.00	63.00	45.00
2726	2	44	1913	2	236.00	34.63	45.00	11.55	15.73	11.22	20.39	20.97	67.00	51.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
3063	2	60	1901	2	210.00	29.64	41.00	9.75	14.87	8.75	18.08	18.86	60.00	46.00
3161	2	60	1902	2	245.00	31.98	41.00	10.21	13.77	10.80	21.42	22.55	71.00	46.00
3196	2	28	1935	2	237.00	31.15	41.00	10.79	13.82	10.25	22.08	23.03	73.00	54.00
3334	2	54	1908	2	231.00	33.06	43.00	10.77	15.25	11.00	20.51	21.51	68.00	55.00
3374	2	21	1943	2	208.00	27.54	34.00	8.75	11.26	9.31	16.90	17.25	56.00	38.00
4503	2	30	1944	2	217.00	29.78	40.00	10.80	13.24	9.34	19.68	20.56	65.00	51.00
4649	2	39	1936	2	223.00	28.04	41.00	10.48	13.62	9.13	18.97	19.59	62.00	54.00
4580	2	29	1945	2	223.00	29.15	39.00	8.78	14.10	10.24	18.32	19.57	66.00	45.00
4884	2	58	1920	2	238.00	34.33	42.00	11.05	14.20	9.53	22.26	23.04	73.00	48.00
4874	2	58	1919	2	239.00	31.89	40.00	10.08	13.33	10.77	21.14	21.34	68.00	47.00
5433	2	32	1950	2	229.00	32.41	37.00	10.22	11.32	9.08	18.77	19.92	63.00	42.00
5874	2	75	1911	2	260.00	37.12	43.00	11.65	14.45	11.36	19.93	23.80	66.00	54.00
6264	2	85	1904	2	221.00	29.35	35.00	9.07	11.70	10.99	17.16	18.30	58.00	42.00
6056	2	28	1959	2	223.00	27.79	35.00	9.46	11.44	8.06	17.75	18.39	59.00	39.00
6543	2	43	1947	2	219.00	31.32	44.00	11.72	13.78	7.98	19.92	20.87	67.00	56.00
6469	2	33	1957	2	241.00	32.04	40.00	9.11	13.95	10.65	20.40	22.04	68.00	45.00
6667	2	48	1943	2	232.00	29.94	36.00	10.07	13.40	8.83	18.27	19.42	62.00	44.00
6790	2	42	1950	2	233.00	30.97	41.00	10.63	14.17	8.22	20.37	21.51	67.00	45.00
6604	2	48	1946	2	248.00	33.00	44.00	10.80	15.31	11.05	22.03	22.77	73.00	53.00
2445	2	80	1873	2	239.00	34.42	43.00	10.93	15.08	8.42	19.93	21.23	68.00	55.00
2492	2	45	1909	2	211.00	31.59	43.00	10.76	15.54	10.83	20.54	21.03	67.00	48.00
2665	2	45	1912	2	209.00	29.26	34.00	9.56	10.44	8.50	18.70	19.30	59.00	38.00
2610	2	35	1921	2	238.00	31.18	40.00	10.30	13.06	11.29	20.74	21.09	68.00	47.00
2802	2	48	1910	2	220.00	34.28	48.00	11.33	17.35	11.77	22.49	23.16	74.00	55.00
3141	2	47	1915	2	215.00	29.58	41.00	9.62	14.45	8.26	17.68	18.47	59.00	49.00

Appendix A1: Data of osteometric variables for the radius (cont.)

Specimen	sex	age	birth	location	rad_leg	rad_dist	rms_circ	rms_min	rms_max	rad_veh	rmn_hed	rmx_hed	rcr_hed	rcr_tub
3928	2	67	1903	2	268.00	34.41	40.00	11.12	13.97	9.85	20.83	21.45	67.00	51.00
3990	2	50	1920	2	219.00	30.95	38.00	9.24	13.80	8.19	19.58	20.58	65.00	46.00
4843	2	56	1921	2	231.00	29.56	35.00	9.49	12.78	7.90	17.22	18.60	57.00	40.00
5134	2	50	1930	2	241.00	32.18	44.00	11.79	15.50	11.02	20.24	21.68	64.00	44.00
5690	2	45	1940	2	225.00	29.65	35.00	10.13	13.03	9.66	20.31	20.71	63.00	48.00
5859	2	56	1930	2	228.00	30.70	39.00	10.07	12.59	8.92	18.97	19.99	63.00	45.00
5815	2	65	1920	2	243.00	34.90	45.00	11.58	15.86	10.32	22.08	22.35	73.00	53.00
5973	2	50	1937	2	229.00	32.73	45.00	20.80	15.91	10.23	21.27	22.37	71.00	47.00
685	2	38	1950	2	230.00	29.03	41.00	10.92	14.81	9.72	18.98	19.90	63.00	47.00
6238	2	25	1958	2	216.00	34.33	41.00	10.35	14.57	8.43	19.73	21.15	67.00	50.00
6491	2	25	1965	2	215.00	28.14	39.00	9.18	13.83	8.72	18.89	19.38	63.00	45.00
6271	2	31	1958	2	239.00	32.17	44.00	11.02	15.60	10.40	21.65	21.53	69.00	51.00
3261	2	40	1923	2	238.00	29.20	32.00	8.38	10.17	9.64	18.17	19.00	60.00	40.00
3590	2	40	1926	2	261.00	30.23	48.00	11.58	17.11	9.49	20.07	20.53	67.00	49.00
4137	2	27	1944	2	241.00	29.07	40.00	10.18	14.11	8.12	19.95	21.09	67.00	45.00
4692	2	26	1949	2	225.00	32.35	43.00	10.14	15.14	10.50	20.31	20.63	67.00	50.00
4759	2	32	1944	2	219.00	29.16	38.00	9.66	13.33	8.79	19.48	20.45	65.00	41.00
5590	2	58	1926	2	239.00	31.18	42.00	11.42	14.47	9.37	20.84	21.24	67.00	51.00
5558	2	48	1935	2	229.00	32.67	39.00	9.72	14.34	9.14	18.45	19.73	63.00	47.00
5803	2	31	1954	2	249.00	32.12	39.00	10.13	13.45	10.99	20.51	21.67	67.00	45.00
5800	2	60	1954	2	220.00	27.94	42.00	10.65	13.97	8.84	19.10	18.72	62.00	48.00
5946	2	42	1945	2	247.00	29.78	41.00	10.19	13.86	7.64	18.87	19.34	63.00	46.00
5949	2	46	1941	2	217.00	30.38	39.00	9.99	13.37	10.03	20.02	20.95	66.00	43.00
6620	2	74	1917	2	212.00	30.60	38.00	9.56	13.30	8.35	18.42	19.01	61.00	45.00
3944	2	60	1940	2	261.00	32.70	46.00	10.34	18.19	9.71	19.59	20.93	65.00	46.00

APPENDIX A 2

Abbreviation of the measurements.

In order to enter the data in a spreadsheet for analysis, the following five to six letter abbreviations were created for the radius variables:

Ulnar dimensions

1. **uln_leg**	maximum length of the ulna
2. **ums_min**	anterior-posterior diameter (minimum diameter)
3. **ums_max**	medial-lateral diameter (maximum diameter)
4. **ums_cir**	circumference at midshaft
5. **umn_cir**	minimum circumference of the ulna
6. **ole_br**	olecranon breadth
7. **ole_mbr**	minimum olecranon breadth
8. **ole_hgt**	height of the olecranon

The data was recorded following sex and location of the collection.

Sex:

Sex 1: refers to male specimens

Sex 2: refers to females.

Location:

Location 1: refers to specimens in the Pretoria Bone Collection

Location 2: refers to specimens in the Raymond A. Dart Collection

Appendix A2: Data of osteometric variables for the ulna

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
1694	1	40	1921	1	267.00	264.00	13.71	15.56	47.00	32.00	25.92	19.90	25.10
2019	1	20	1944	1	274.00	273.00	12.42	16.87	46.00	34.00	25.90	21.48	24.42
2786	1	50	1919	1	265.00	263.00	13.18	18.23	50.00	39.00	29.14	18.53	23.05
2788	1	80	1889	1	269.00	267.00	12.33	14.60	45.00	35.00	24.30	15.48	22.50
2813	1	81	1888	1	295.00	292.00	13.56	16.97	50.00	39.00	29.86	21.72	24.59
2855	1	55	1914	1	320.00	320.00	11.67	17.23	48.00	36.00	24.62	17.39	21.56
2858	1	22	1947	1	236.00	232.00	10.88	16.46	45.00	31.00	23.42	18.10	20.45
2865	1	60	1909	1	277.00	274.00	12.86	16.57	47.00	33.00	26.95	18.76	26.44
2885	1	60	1909	1	234.00	234.00	10.72	14.48	43.00	33.00	22.21	17.52	22.30
2889	1	34	1935	1	244.00	243.00	12.24	16.00	45.00	35.00	23.32	17.37	22.35
2906	1	50	1919	1	260.00	255.00	12.51	16.04	46.00	38.00	24.30	19.07	23.36
2940	1	80	1890	1	275.00	272.00	12.67	15.59	45.00	35.00	31.86	20.90	21.07
2991	1	43	1927	1	275.00	271.00	11.05	13.36	39.00	31.00	26.21	18.23	23.08
3003	1	70	1900	1	268.00	263.00	12.40	15.40	45.00	34.00	25.77	21.64	22.58
3004	1	46	1924	1	266.00	262.00	13.24	16.97	48.00	37.00	26.42	16.34	25.03
3006	1	35	1935	1	259.00	258.00	12.96	15.65	47.00	35.00	24.09	21.09	22.89
3008	1	70	1900	1	251.00	249.00	12.35	16.32	47.00	37.00	23.93	17.31	22.12
3023	1	48	1922	1	296.00	292.00	12.91	16.86	47.00	35.00	28.41	21.58	25.49
3066	1	70	1900	1	264.00	257.00	12.57	15.56	44.00	34.00	27.36	20.75	22.05
3096	1	28	1942	1	265.00	262.00	12.17	17.38	47.00	39.00	27.16	18.19	24.28
3561	1	36	1936	1	263.00	260.00	10.21	15.12	42.00	32.00	23.61	17.62	24.62
3670	1	62	1911	1	263.00	262.00	13.63	16.64	49.00	35.00	25.83	18.00	23.00
3676	1	58	1915	1	296.00	294.00	13.76	19.50	53.00	39.00	28.23	24.34	26.45
3718	1	30	1943	1	300.00	295.00	12.40	18.12	49.00	39.00	27.65	19.43	24.58
4196	1	45	1933	1	263.00	263.00	11.96	16.14	46.00	32.00	23.34	15.67	18.83

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
4236	1	30	1948	1	260.00	257.00	11.75	14.88	43.00	37.00	24.42	18.05	19.60
4258	1	55	1923	1	293.00	291.00	13.62	21.83	56.00	41.00	28.81	17.48	25.29
4265	1	55	1923	1	282.00	280.00	12.53	15.20	45.00	33.00	25.27	16.72	23.61
4396	1	65	1914	1	281.00	278.00	13.26	15.23	46.00	36.00	23.73	17.17	23.90
4405	1	69	1910	1	259.00	257.00	14.57	19.14	53.00	31.00	21.23	19.05	22.08
4421	1	42	1937	1	275.00	274.00	13.55	18.19	50.00	36.00	26.26	20.31	25.47
4487	1	49	1930	1	243.00	238.00	12.04	14.10	43.00	35.00	22.07	19.70	21.22
4500	1	55	1924	1	297.00	297.00	12.63	15.32	46.00	35.00	24.91	19.84	23.60
4522	1	30	1950	1	307.00	301.00	13.16	15.90	47.00	34.00	23.86	13.21	20.76
4535	1	29	1951	1	254.00	249.00	11.59	15.73	44.00	30.00	23.93	13.19	23.00
4542	1	60	1920	1	303.00	301.00	13.87	18.00	50.00	40.00	27.37	16.21	22.38
4592	1	28	1953	1	245.00	242.00	10.68	14.63	42.00	37.00	23.29	20.12	20.10
4599	1	60	1921	1	278.00	275.00	13.48	17.74	51.00	48.00	26.19	19.52	22.73
4602	1	60	1921	1	259.00	257.00	10.46	14.65	41.00	33.00	23.18	16.21	22.22
4606	1	68	1913	1	294.00	291.00	14.45	17.36	50.00	34.00	23.70	16.96	24.71
4609	1	50	1931	1	302.00	300.00	15.08	19.84	57.00	46.00	30.39	23.81	26.50
4613	1	61	1920	1	272.00	270.00	12.55	16.29	47.00	36.00	26.96	20.06	22.10
4014	1	53	1928	1	250.00	246.00	12.78	15.66	47.00	36.00	27.30	19.47	23.72
4617	1	53	1928	1	279.00	275.00	12.33	15.08	45.00	38.00	26.47	20.96	24.03
4731	1	60	1923	1	269.00	268.00	13.80	17.59	50.00	34.00	26.32	16.45	22.35
4790	1	61	1922	1	265.00	264.00	12.90	14.97	46.00	35.00	23.76	17.83	23.65
4794	1	40	1943	1	258.00	256.00	13.47	16.19	48.00	38.00	25.82	19.60	23.06
4986	1	56	1928	1	250.00	250.00	14.18	17.76	52.00	39.00	30.34	20.74	28.27
4927	1	72	1912	1	260.00	257.00	15.26	19.29	55.00	43.00	27.22	17.16	23.04
4946	1	96	1889	1	285.00	283.00	13.28	16.95	49.00	32.00	25.56	16.38	22.67

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
4947	1	66	1919	1	294.00	289.00	12.81	18.04	51.00	38.00	27.10	21.53	24.94
4959	1	55	1929	1	264.00	262.00	15.01	18.35	52.00	39.00	25.72	19.95	23.27
4968	1	34	1951	1	288.00	283.00	14.03	18.22	52.00	39.00	25.06	16.72	23.55
4969	1	64	1921	1	275.00	269.00	13.05	18.41	51.00	36.00	29.60	20.45	22.61
4970	1	55	1930	1	274.00	270.00	13.02	18.74	52.00	46.00	26.96	20.91	24.06
4979	1	55	1930	1	286.00	285.00	12.68	15.71	45.00	34.00	25.25	17.28	23.28
4980	1	70	1915	1	302.00	297.00	13.51	18.99	54.00	38.00	27.03	21.10	24.80
4983	1	55	1930	1	269.00	268.00	13.12	16.89	48.00	40.00	23.27	21.10	23.91
4984	1	51	1934	1	269.00	265.00	14.60	19.65	54.00	42.00	29.36	21.08	25.87
4995	1	53	1932	1	237.00	234.00	11.58	14.90	43.00	32.00	22.26	15.10	20.40
5004	1	70	1915	1	271.00	268.00	12.94	16.12	47.00	37.00	27.04	18.45	23.76
5007	1	72	1913	1	275.00	268.00	16.14	19.70	48.00	40.00	28.46	21.82	21.57
5010	1	40	1945	1	307.00	302.00	13.00	15.93	46.00	34.00	25.44	18.24	23.98
5012	1	65	1920	1	272.00	272.00	13.21	14.62	45.00	35.00	25.97	19.67	21.42
5014	1	55	1930	1	290.00	289.00	12.19	17.74	48.00	36.00	22.06	18.50	22.38
5019	1	70	1915	1	258.00	256.00	14.19	17.21	51.00	37.00	25.55	19.32	25.38
5020	1	70	1915	1	264.00	264.00	11.87	14.63	42.00	35.00	23.76	16.43	22.24
5022	1	41	1944	1	291.00	287.00	12.81	16.60	47.00	34.00	25.19	20.85	22.22
5024	1	70	1915	1	267.00	266.00	14.38	15.83	49.00	40.00	24.56	19.71	22.98
5025	1	40	1945	1	260.00	258.00	12.46	17.06	48.00	34.00	25.65	17.63	26.85
5027	1	55	1930	1	258.00	254.00	11.83	14.43	42.00	30.00	25.54	14.93	20.77
5030	1	34	1951	1	279.00	278.00	11.22	14.65	43.00	40.00	24.88	17.93	21.14
5031	1	29	1956	1	282.00	279.00	13.49	16.59	48.00	37.00	29.03	21.44	25.03
5032	1	55	1930	1	274.00	269.00	12.91	17.68	50.00	35.00	27.30	18.16	24.32
5037	1	42	1943	1	279.00	274.00	13.08	16.32	47.00	37.00	27.46	20.28	27.66

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
5045	1	70	1915	1	285.00	282.00	12.95	15.89	47.00	36.00	25.19	15.02	21.44
5050	1	57	1929	1	268.00	264.00	13.21	16.63	48.00	37.00	26.90	18.27	19.44
5051	1	52	1934	1	269.00	265.00	14.92	18.56	54.00	38.00	25.46	17.68	23.78
5063	1	58	1928	1	288.00	288.00	12.24	15.79	45.00	36.00	26.21	15.92	25.84
5065	1	54	1932	1	282.00	281.00	14.05	16.73	49.00	37.00	27.59	18.54	22.94
5075	1	70	1916	1	299.00	296.00	13.70	18.55	51.00	36.00	27.01	19.97	24.20
5080	1	45	1941	1	291.00	286.00	13.55	19.17	51.00	41.00	32.71	21.14	25.96
5081	1	65	1921	1	269.00	262.00	13.28	17.52	51.00	37.00	25.23	18.60	22.82
5082	1	43	1943	1	279.00	274.00	13.96	17.96	51.00	35.00	29.52	24.86	19.52
5109	1	65	1921	1	259.00	255.00	13.78	16.98	49.00	35.00	25.93	19.93	23.09
5123	1	48	1938	1	272.00	269.00	14.41	17.17	50.00	35.00	26.82	21.59	24.73
5130	1	44	1942	1	269.00	264.00	12.29	16.88	47.00	35.00	26.20	18.35	25.67
5139	1	64	1923	1	278.00	278.00	11.73	18.21	49.00	36.00	28.05	20.93	22.21
5141	1	60	1927	1	267.00	265.00	14.37	16.49	50.00	36.00	26.99	21.32	23.62
5144	1	60	1927	1	278.00	274.00	12.93	16.83	48.00	35.00	26.67	19.83	22.60
5149	1	86	1901	1	289.00	286.00	11.56	15.37	44.00	32.00	23.81	17.97	23.98
5152	1	24	1963	1	273.00	270.00	11.95	16.07	45.00	35.00	23.75	19.55	21.46
5154	1	50	1937	1	289.00	286.00	11.56	15.37	44.00	32.00	23.81	17.97	20.78
5160	1	62	1925	1	281.00	277.00	13.18	16.51	49.00	35.00	26.92	19.57	24.34
5162	1	82	1905	1	265.00	259.00	14.13	17.84	50.00	37.00	25.77	17.45	25.17
5164	1	70	1917	1	266.00	264.00	12.79	16.09	46.00	31.00	25.25	17.49	25.93
5167	1	64	1923	1	280.00	278.00	12.94	15.60	46.00	32.00	23.00	18.49	22.72
5169	1	67	1920	1	269.00	266.00	13.23	17.82	49.00	36.00	25.07	18.66	23.99
5175	1	55	1932	1	289.00	286.00	13.42	18.32	49.00	37.00	26.64	20.25	25.38
5177	1	57	1930	1	280.00	279.00	12.38	16.34	47.00	37.00	24.80	16.77	23.42

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
5178	1	80	1907	1	261.00	258.00	13.98	16.41	50.00	34.00	25.26	15.65	25.00
5192	1	43	1944	1	278.00	278.00	14.49	19.85	56.00	37.00	28.45	21.17	23.31
5202	1	60	1927	1	291.00	287.00	15.88	18.50	55.00	42.00	26.75	22.46	24.87
5214	1	60	1927	1	273.00	271.00	12.51	16.71	48.00	40.00	23.81	19.14	22.66
5244	1	63	1925	1	273.00	168.00	15.98	19.52	57.00	37.00	16.37	19.33	21.93
5250	1	62	1926	1	267.00	265.00	12.85	16.57	48.00	34.00	25.23	19.84	21.84
5254	1	49	1939	1	282.00	277.00	13.20	15.17	47.00	34.00	25.11	15.98	21.55
5262	1	37	1951	1	258.00	255.00	13.00	16.85	49.00	32.00	21.83	16.47	22.11
5269	1	60	1928	1	275.00	270.00	14.09	15.93	49.00	42.00	25.82	19.76	21.82
5272	1	66	1922	1	270.00	268.00	13.75	17.18	51.00	38.00	24.28	19.71	27.29
5273	1	65	1923	1	263.00	258.00	12.81	14.60	45.00	32.00	23.75	17.60	19.79
5276	1	68	1920	1	290.00	285.00	14.27	16.78	51.00	35.00	25.74	21.08	24.79
5293	1	27	1961	1	279.00	277.00	12.28	16.03	46.00	34.00	24.46	16.87	23.03
5309	1	68	1920	1	278.00	278.00	12.81	15.85	46.00	36.00	27.42	19.39	23.17
5333	1	60	1928	1	251.00	248.00	11.95	14.56	42.00	31.00	22.97	17.06	21.81
5354	1	56	1932	1	274.00	273.00	13.08	16.46	47.00	36.00	23.60	19.07	22.05
5352	1	65	1924	1	274.00	265.00	13.97	18.11	53.00	41.00	27.28	20.80	23.52
5354	1	40	1949	1	266.00	258.00	14.74	17.76	54.00	41.00	27.19	20.58	22.51
5358	1	53	1936	1	272.00	270.00	12.40	19.83	52.00	39.00	28.08	16.32	23.49
5361	1	30	1959	1	272.00	270.00	13.79	18.64	53.00	41.00	27.24	21.58	23.20
5365	1	50	1939	1	277.00	277.00	13.48	15.59	48.00	36.00	26.12	18.94	20.89
5368	1	65	1924	1	291.00	189.00	14.88	18.67	55.00	40.00	27.12	19.47	24.99
5372	1	63	1926	1	268.00	265.00	14.76	19.60	56.00	41.00	27.34	21.54	21.48
5379	1	70	1919	1	283.00	281.00	13.65	16.98	49.00	32.00	27.50	16.41	20.84
5392	1	70	1919	1	279.00	279.00	12.23	16.27	47.00	32.00	27.99	16.52	19.84

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
5396	1	53	1936	1	274.00	274.00	13.47	16.51	48.00	36.00	27.20	17.55	25.53
5415	1	38	1952	1	267.00	266.00	12.57	16.83	50.00	36.00	27.11	22.75	23.80
5419	1	48	1941	1	268.00	268.00	12.49	16.93	48.00	38.00	27.10	20.58	21.08
5431	1	25	1965	1	274.00	271.00	11.78	14.91	44.00	36.00	24.02	21.29	18.19
5432	1	49	1941	1	299.00	293.00	14.54	17.99	52.00	42.00	26.83	16.40	20.65
5447	1	52	1938	1	268.00	267.00	14.88	17.53	52.00	38.00	31.87	21.26	24.62
5449	1	48	1942	1	281.00	276.00	12.31	19.02	51.00	39.00	26.17	21.00	22.62
5454	1	54	1936	1	284.00	276.00	14.96	18.14	55.00	43.00	25.73	21.14	22.10
5461	1	60	1930	1	267.00	264.00	13.83	17.28	51.00	38.00	27.13	15.64	23.51
5470	1	49	1941	1	270.00	269.00	13.20	15.85	47.00	32.00	23.81	17.54	20.81
5493	1	40	1950	1	289.00	287.00	13.36	16.14	48.00	38.00	25.43	18.07	22.27
5513	1	70	1921	1	254.00	249.00	12.22	15.69	46.00	34.00	24.20	19.15	18.25
5532	1	54	1931	1	288.00	287.00	13.69	18.92	52.00	39.00	26.35	19.70	24.27
5535	1	50	1941	1	267.00	264.00	16.22	19.96	58.00	44.00	26.21	19.53	24.66
5540	1	72	1919	1	280.00	277.00	12.52	16.89	48.00	34.00	25.86	18.09	20.79
5548	1	60	1931	1	269.00	265.00	14.55	17.00	51.00	35.00	25.63	19.01	25.96
5550	1	60	1931	1	265.00	261.00	12.76	19.24	52.00	33.00	23.01	18.64	19.86
5561	1	60	1929	1	280.00	272.00	13.35	19.82	54.00	40.00	26.06	16.28	21.68
5566	1	60	1931	1	250.00	247.00	12.65	16.27	47.00	35.00	26.40	19.57	24.89
5569	1	23	1968	1	261.00	259.00	11.21	14.36	42.00	33.00	23.44	17.56	22.93
5579	1	66	1925	1	244.00	240.00	14.86	16.50	51.00	44.00	27.11	20.94	21.39
5591	1	40	1951	1	275.00	272.00	14.02	16.62	50.00	35.00	25.75	18.01	26.24
5617	1	48	1943	1	268.00	264.00	10.73	14.79	42.00	32.00	24.42	18.75	20.34
5627	1	37	1955	1	272.00	270.00	13.00	15.28	47.00	37.00	23.26	20.04	22.75
5636	1	51	1941	1	307.00	303.00	14.94	19.36	54.00	40.00	26.10	17.04	25.24

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
5638	1	35	1957	1	265.00	263.00	12.32	13.78	42.00	37.00	21.28	16.78	23.83
5646	1	48	1944	1	246.00	245.00	12.19	15.09	47.00	38.00	23.27	16.48	19.99
5662	1	72	1920	1	274.00	273.00	12.68	19.46	52.00	40.00	24.32	21.13	21.99
5666	1	63	1929	1	278.00	278.00	13.80	17.94	52.00	38.00	25.04	18.69	27.09
5670	1	40	1952	1	272.00	269.00	14.63	18.16	53.00	41.00	25.16	19.64	24.62
5681	1	53	1939	1	287.00	285.00	16.15	19.53	57.00	42.00	29.16	20.32	25.11
5685	1	69	1923	1	289.00	284.00	13.03	17.32	49.00	42.00	27.52	17.57	22.69
5691	1	43	1949	1	285.00	281.00	12.77	16.74	49.00	38.00	27.45	20.78	22.04
5742	1	60	1933	1	280.00	276.00	15.61	17.55	53.00	46.00	26.20	21.29	23.72
5753	1	55	1938	1	293.00	290.00	15.88	17.73	54.00	40.00	25.70	20.74	24.21
5760	1	66	1927	1	285.00	275.00	14.65	18.40	53.00	39.00	27.26	20.15	25.80
5761	1	28	1965	1	273.00	270.00	13.01	17.07	49.00	37.00	24.61	16.77	22.71
5772	1	65	1927	1	273.00	270.00	14.18	18.06	52.00	36.00	27.12	18.23	24.27
5819	1	46	1947	1	294.00	289.00	15.24	18.16	53.00	40.00	27.22	20.49	23.35
5828	1	65	1929	1	243.00	243.00	13.29	16.39	49.00	37.00	22.22	18.86	22.82
5841	1	64	1930	1	282.00	277.00	13.51	17.06	50.00	41.00	27.13	21.50	22.25
5854	1	70	1924	1	272.00	268.00	13.80	15.65	47.00	37.00	23.94	16.00	22.14
5841	1	27	1967	1	270.00	270.00	13.10	16.34	47.00	38.00	24.00	17.82	22.62
5860	1	54	1940	1	273.00	269.00	13.71	17.76	51.00	38.00	25.46	19.47	25.75
5879	1	53	1941	1	268.00	264.00	13.53	17.82	51.00	35.00	22.91	16.38	21.54
5880	1	57	1937	1	273.00	267.00	13.25	15.59	47.00	36.00	26.52	19.88	23.54
5885	1	32	1962	1	238.00	237.00	10.32	14.32	40.00	29.00	19.95	16.23	20.96
5886	1	71	1923	1	302.00	285.00	13.95	15.70	48.00	36.00	26.30	14.77	20.79
5889	1	57	1937	1	288.00	285.00	14.49	18.18	53.00	39.00	28.07	18.96	24.36
5904	1	31	1963	1	285.00	280.00	13.44	16.11	47.00	38.00	25.18	18.80	24.92

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
5905	1	40	1954	1	282.00	279.00	15.09	17.87	52.00	44.00	24.12	20.58	26.05
5911	1	74	1920	1	271.00	269.00	13.14	17.36	49.00	34.00	26.29	19.16	23.06
5912	1	37	1957	1	295.00	291.00	13.48	16.68	48.00	35.00	24.98	18.13	25.14
5940	1	57	1938	1	284.00	281.00	14.89	16.82	52.00	38.00	29.18	21.29	28.18
5947	1	48	1947	1	262.00	261.00	11.59	14.52	43.00	32.00	21.78	15.63	19.80
5951	1	60	1935	1	282.00	278.00	16.41	20.20	60.00	36.00	28.59	20.19	27.41
5952	1	70	1925	1	297.00	292.00	13.25	19.02	51.00	40.00	26.02	17.61	22.09
5958	1	34	1961	1	276.00	273.00	13.39	17.54	51.00	37.00	25.60	18.46	22.61
5962	1	72	1923	1	256.00	252.00	13.40	17.52	51.00	36.00	21.85	18.93	20.51
5974	1	66	1929	1	292.00	288.00	14.85	20.42	57.00	41.00	29.54	21.50	26.47
5976	1	70	1925	1	270.00	265.00	13.08	14.94	45.00	35.00	23.44	18.42	21.37
5977	1	28	1967	1	270.00	267.00	12.43	14.64	42.00	34.00	23.94	16.94	23.03
6058	1	30	1966	1	258.00	256.00	13.42	16.48	47.00	33.00	28.04	18.74	23.25
6087	1	44	1953	1	243.00	240.00	11.19	12.23	38.00	31.00	22.06	15.97	21.87
6119	1	26	1971	1	271.00	267.00	14.03	17.10	50.00	40.00	24.86	20.16	22.06
6137	1	40	1957	1	267.00	264.00	13.15	18.03	50.00	44.00	29.51	18.67	25.87
6142	1	43	1954	1	262.00	260.00	14.54	17.40	51.00	36.00	28.53	20.72	23.82
6173	1	60	1928	1	281.00	274.00	12.91	16.39	47.00	39.00	25.74	19.53	25.73
6188	1	25	1973	1	245.00	245.00	12.91	17.46	49.00	37.00	24.31	19.41	24.83
6195	1	46	1952	1	263.00	259.00	12.67	18.30	50.00	38.00	25.72	19.08	26.17
6197	1	67	1931	1	283.00	280.00	14.58	17.34	51.00	38.00	26.26	18.88	25.58
6199	1	27	1971	1	281.00	276.00	12.70	17.71	49.00	38.00	26.96	19.82	24.37
6200	1	60	1938	1	273.00	270.00	14.61	18.18	52.00	44.00	27.83	21.24	23.93
6201	1	50	1948	1	272.00	272.00	13.61	15.70	49.00	35.00	25.83	17.74	26.73
6211	1	58	1940	1	279.00	273.00	13.65	16.37	50.00	43.00	28.70	23.53	21.71

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
1543	2	40	1921	1	237.00	235.00	10.47	16.46	45.00	31.00	24.48	17.42	21.76
1696	2	79	1882	1	245.00	243.00	12.29	14.53	41.00	37.00	23.84	17.83	25.01
1803	2	60	1902	1	225.00	223.00	10.40	16.22	40.00	30.00	25.17	16.45	22.76
2632	2	50	1918	1	261.00	256.00	11.66	14.92	43.00	39.00	23.77	14.97	26.87
2866	2	33	1936	1	239.00	236.00	9.30	12.99	38.00	28.00	21.02	14.79	21.28
2900	2	60	1909	1	260.00	255.00	9.46	14.34	39.00	32.00	21.57	16.12	21.10
2905	2	49	1920	1	262.00	260.00	11.83	13.96	41.00	37.00	22.09	17.03	25.25
2939	2	70	1900	1	244.00	243.00	9.92	13.16	38.00	33.00	23.85	17.33	23.67
2980	2	49	1921	1	239.00	237.00	11.15	14.93	41.00	32.00	24.60	16.47	20.36
3015	2	70	1900	1	234.00	232.00	10.27	11.60	36.00	28.00	20.74	13.24	20.26
3041	2	30	1940	1	254.00	250.00	11.09	16.08	43.00	33.00	22.93	15.36	23.80
3120	2	42	1928	1	248.00	245.00	11.11	14.10	40.00	31.00	23.02	18.31	24.09
3154	2	40	1931	1	237.00	235.00	9.62	14.97	40.00	30.00	19.96	15.73	21.03
3266	2	28	1943	1	237.00	234.00	11.08	12.96	39.00	32.00	21.90	17.76	19.91
3385	2	36	1935	1	247.00	243.00	9.19	14.41	38.00	33.00	20.09	15.60	19.17
3609	2	44	1928	1	274.00	270.00	12.53	17.63	47.00	34.00	23.18	18.35	23.45
3843	2	40	1935	1	261.00	257.00	10.03	14.38	39.00	30.00	21.59	16.29	21.91
3854	2	40	1935	1	235.00	231.00	11.31	13.56	40.00	31.00	22.40	19.08	21.01
4198	2	35	1943	1	243.00	238.00	11.66	14.92	44.00	35.00	23.00	18.79	24.85
4256	2	42	1926	1	247.00	245.00	12.21	15.35	45.00	34.00	23.42	15.87	23.73
4417	2	60	1919	1	238.00	237.00	10.31	12.76	37.00	33.00	23.88	17.23	22.27
4436	2	37	1942	1	270.00	266.00	9.85	16.30	43.00	32.00	22.19	17.41	21.19
4492	2	48	1931	1	259.00	255.00	12.66	17.46	48.00	40.00	24.15	16.80	23.79
4565	2	47	1933	1	249.00	247.00	10.82	14.52	40.00	34.00	23.22	16.29	24.99
4575	2	33	1947	1	245.00	244.00	13.15	17.18	50.00	41.00	23.65	19.67	20.60

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
4598	2	32	1949	1	253.00	252.00	10.48	14.46	41.00	31.00	22.89	16.74	22.72
4786	2	30	1953	1	250.00	247.00	11.22	15.92	44.00	34.00	21.11	15.13	21.90
4835	2	43	1941	1	249.00	245.00	9.78	16.14	42.00	35.00	21.63	16.16	22.01
4855	2	65	1919	1	247.00	244.00	11.17	15.22	43.00	34.00	23.97	19.04	22.82
4956	2	40	1945	1	263.00	260.00	11.64	14.90	44.00	32.00	22.85	18.49	21.68
4990	2	60	1925	1	254.00	253.00	11.09	13.46	40.00	28.00	21.93	17.14	21.43
4998	2	63	1922	1	243.00	242.00	10.34	13.20	38.00	30.00	20.17	15.14	21.17
5005	2	60	1920	1	251.00	247.00	12.32	13.52	43.00	31.00	21.83	17.48	23.09
5018	2	59	1926	1	255.00	254.00	12.33	15.79	45.00	31.00	26.57	18.17	17.85
5029	2	19	1969	1	251.00	278.00	12.13	15.16	45.00	34.00	27.80	20.95	23.70
5033	2	70	1915	1	259.00	257.00	12.43	14.62	46.00	28.00	24.53	17.13	26.03
5039	2	70	1915	1	270.00	266.00	10.87	16.89	44.00	36.00	25.21	18.71	19.66
5073	2	70	1916	1	229.00	227.00	10.43	12.70	37.00	31.00	21.84	14.81	22.31
5079	2	45	1941	1	221.00	220.00	10.53	15.12	42.00	35.00	21.45	19.31	20.68
5086	2	34	1952	1	243.00	242.00	12.13	14.99	43.00	33.00	22.98	18.63	22.09
5108	2	68	1918	1	248.00	247.00	11.40	13.57	40.00	30.00	20.86	14.27	19.56
5148	2	54	1933	1	234.00	230.00	11.01	13.45	39.00	34.00	22.46	16.24	21.26
5150	2	31	1956	1	249.00	245.00	11.76	14.72	42.00	36.00	20.63	17.24	22.13
5197	2	82	1905	1	284.00	278.00	13.88	17.74	52.00	44.00	26.62	20.02	26.07
520	2	45	1942	1	263.00	261.00	11.04	14.94	43.00	34.00	25.81	20.93	20.29
5292	2	46	1942	1	256.00	255.00	11.44	14.58	42.00	34.00	21.92	15.98	22.11
5306	2	38	1950	1	228.00	227.00	9.78	13.18	38.00	30.00	20.27	17.06	18.51
5316	2	41	1947	1	242.00	241.00	11.36	14.78	43.00	39.00	22.85	17.91	21.10
5323	2	70	1918	1	235.00	232.00	10.68	14.04	41.00	31.00	23.32	15.91	20.65
5335	2	44	1932	1	253.00	252.00	13.09	16.04	47.00	38.00	22.27	17.34	20.88

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
5342	2	57	1931	1	219.00	215.00	11.34	14.88	42.00	29.00	21.48	17.50	19.54
5384	2	45	1944	1	274.00	270.00	11.43	15.02	42.00	31.00	22.67	17.55	22.47
5390	2	65	1924	1	236.00	234.00	10.49	12.55	38.00	26.00	23.88	14.68	16.71
5602	2	55	1936	1	249.00	247.00	11.38	15.20	44.00	34.00	24.92	16.59	22.90
5629	2	52	1940	1	242.00	242.00	10.82	14.90	41.00	33.00	22.94	16.19	21.27
5635	2	50	1942	1	225.00	223.00	10.08	13.25	38.00	29.00	20.87	14.13	18.28
5654	2	49	1943	1	254.00	250.00	11.66	13.67	41.00	32.00	20.94	17.32	20.25
5692	2	44	1948	1	258.00	256.00	10.05	15.02	41.00	30.00	22.90	16.63	17.14
5698	2	50	1942	1	271.00	267.00	13.25	17.02	49.00	36.00	23.68	20.06	21.98
5705	2	65	1927	1	239.00	235.00	12.00	15.13	43.00	32.00	22.16	13.83	18.64
5708	2	71	1921	1	233.00	232.00	10.45	16.59	42.00	33.00	24.45	15.76	22.54
5717	2	55	1937	1	275.00	271.00	12.29	16.38	47.00	31.00	25.28	16.47	21.32
5734	2	60	1933	1	268.00	264.00	12.75	15.38	45.00	33.00	24.08	16.43	22.58
5767	2	32	1961	1	242.00	241.00	9.84	12.75	37.00	33.00	20.68	16.02	20.51
5783	2	42	1951	1	254.00	251.00	11.59	16.05	44.00	35.00	22.40	17.65	23.42
5785	2	56	1937	1	251.00	246.00	11.47	12.77	40.00	30.00	26.60	15.95	21.10
5797	2	28	1965	1	246.00	241.00	11.72	13.23	41.00	30.00	20.10	16.22	18.81
5878	2	32	1902	1	240.00	238.00	10.49	15.36	42.00	33.00	21.81	14.78	21.11
5932	2	40	1955	1	259.00	257.00	12.46	13.98	43.00	32.00	24.19	12.35	19.36
5946	2	62	1933	1	225.00	221.00	11.30	15.13	43.00	32.00	23.09	14.96	18.65
5957	2	29	1966	1	248.00	247.00	10.44	14.27	40.00	34.00	21.17	16.63	20.73
5980	2	58	1937	1	257.00	253.00	13.35	17.18	49.00	40.00	23.24	19.21	23.61
6000	2	38	1967	1	237.00	235.00	11.44	16.49	45.00	35.00	21.59	16.31	20.27
6024	2	65	1931	1	253.00	250.00	11.46	13.57	40.00	32.00	23.16	18.45	22.67
6094	2	33	1964	1	258.00	254.00	11.10	14.69	42.00	31.00	23.56	17.84	23.83

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
6123	2	60	1937	1	240.00	236.00	11.48	13.45	42.00	33.00	24.68	18.53	20.34
6139	2	38	1959	1	234.00	233.00	11.08	13.94	40.00	37.00	21.77	16.77	19.84
6144	2	50	1947	1	267.00	266.00	11.26	15.38	43.00	34.00	23.64	18.44	19.95
6156	2	65	1933	1	243.00	241.00	10.25	13.55	39.00	28.00	21.25	14.48	19.87
6157	2	30	1968	1	234.00	233.00	10.49	13.03	38.00	32.00	22.41	16.79	20.05
6172	2	53	1945	1	227.00	222.00	11.35	13.87	41.00	35.00	21.86	13.98	21.70
6177	2	23	1975	1	284.00	279.00	10.84	15.61	42.00	32.00	23.82	18.55	21.18
6192	2	22	1976	1	235.00	232.00	11.42	12.45	39.00	33.00	19.89	16.17	21.35
6234	2	25	1974	1	261.00	258.00	11.07	17.18	44.00	33.00	20.00	17.03	24.43
6237	2	56	1943	1	265.00	259.00	11.69	13.75	41.00	33.00	20.75	17.10	21.31
6256	2	32	1967	1	252.00	248.00	12.22	15.17	44.00	33.00	23.95	17.36	21.08
6290	2	24	1976	1	270.00	266.00	11.18	15.40	43.00	33.00	23.22	15.86	21.06
6315	2	64	1936	1	274.00	265.00	11.38	14.05	41.00	31.00	22.12	15.21	19.79
6328	2	47	1953	1	268.00	265.00	13.01	16.15	48.00	39.00	25.44	22.77	25.20
6358	2	37	1964	1	241.00	240.00	12.12	15.00	44.00	32.00	25.28	20.33	19.67
6369	2	52	1949	1	221.00	220.00	11.27	14.47	42.00	29.00	21.44	17.46	20.44
6370	2	60	1941	1	268.00	265.00	9.86	15.24	42.00	30.00	22.56	15.39	20.53
6372	2	38	1963	1	261.00	258.00	10.63	14.77	42.00	32.00	23.57	15.08	22.91
6388	2	47	1954	1	260.00	258.00	10.28	13.08	38.00	32.00	22.96	15.03	20.92
6390	2	24	1977	1	250.00	246.00	11.25	14.21	40.00	33.00	23.21	17.40	23.23
2576	2	60	1895	2	274.00	272.00	10.71	16.65	40.00	31.00	22.25	18.25	21.44
2630	2	34	1922	2	262.00	258.00	12.36	14.04	41.00	34.00	23.78	17.81	21.46
2627	2	42	1914	2	251.00	248.00	9.92	12.76	36.00	32.00	23.64	17.08	20.18
2608	2	36	1920	2	245.00	243.00	10.27	13.23	38.00	29.00	24.74	17.66	20.27
2667	2	50	1907	2	243.00	240.00	11.65	13.30	42.00	31.00	22.31	16.45	20.42

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
2745	2	40	1917	2	229.00	227.00	10.01	12.19	34.00	28.00	19.57	16.71	19.68
2812	2	56	1902	2	257.00	253.00	11.74	18.50	49.00	35.00	22.34	17.35	22.39
2921	2	41	1919	2	237.00	233.00	12.54	13.62	41.00	33.00	22.03	18.91	23.78
3134	2	44	1918	2	248.00	244.00	12.98	15.62	47.00	34.00	21.74	18.69	21.74
3080	2	50	1911	2	252.00	250.00	10.93	14.59	42.00	30.00	23.96	21.06	23.79
3344	2	30	1934	2	233.00	228.00	12.30	14.16	44.00	32.00	20.70	16.00	21.40
3301	2	38	1925	2	247.00	244.00	10.79	13.87	41.00	33.00	21.66	16.31	22.62
3297	2	70	1893	2	239.00	234.00	12.65	14.94	46.00	36.00	20.86	18.89	21.06
3303	2	45	1918	2	256.00	250.00	11.68	15.26	44.00	31.00	22.77	18.84	24.31
3343	2	45	1919	2	241.00	234.00	11.63	12.85	41.00	31.00	23.30	16.34	20.27
3473	2	70	1895	2	246.00	244.00	11.23	14.68	43.00	32.00	22.55	16.40	21.98
3909	2	38	1931	2	249.00	245.00	10.59	13.80	39.00	27.00	20.26	15.22	21.27
3921	2	23	1946	2	259.00	256.00	10.73	13.79	41.00	31.00	21.97	18.13	20.87
4514	2	38	1936	2	244.00	243.00	10.46	12.64	38.00	30.00	21.02	16.64	18.93
4521	2	37	1937	2	236.00	233.00	10.46	15.35	42.00	31.00	20.56	15.47	21.86
4694	2	23	1952	2	263.00	260.00	10.99	14.91	43.00	30.00	25.05	20.88	22.98
4712	2	39	1937	2	242.00	239.00	11.43	13.97	42.00	32.00	22.45	18.04	22.05
4771	2	43	1933	2	241.00	239.00	10.83	13.54	39.00	33.00	22.87	16.35	20.73
4700	2	36	1939	2	262.00	259.00	11.21	14.53	42.00	33.00	23.52	16.35	22.35
4819	2	74	1903	2	238.00	235.00	11.61	14.34	43.00	32.00	23.78	17.20	20.87
4844	2	38	1939	2	256.00	250.00	13.23	15.57	46.00	38.00	22.92	18.11	22.39
4929	2	38	1940	2	262.00	259.00	12.05	15.74	46.00	34.00	24.28	18.50	24.30
5490	2	49	1934	2	247.00	246.00	11.68	14.80	44.00	36.00	23.67	14.88	22.90
5728	2	33	1952	2	243.00	242.00	11.46	16.07	45.00	32.00	22.86	19.86	21.36
5808	2	55	1930	2	259.00	255.00	12.60	16.55	48.00	34.00	22.74	14.84	25.90

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
5737	2	30	1955	2	229.00	226.00	11.00	11.95	39.00	29.00	20.29	13.63	20.49
5883	2	59	1927	2	248.00	242.00	13.23	16.74	49.00	34.00	21.74	15.40	21.25
6021	2	86	1901	2	243.00	238.00	10.61	15.86	44.00	36.00	22.68	17.74	21.20
6042	2	30	1957	2	262.00	259.00	13.49	15.38	46.00	33.00	22.86	17.10	24.68
6161	2	87	1901	2	250.00	248.00	11.02	16.44	48.00	36.00	24.45	19.14	24.68
6195	2	60	1928	2	253.00	248.00	11.76	15.45	44.00	35.00	23.16	15.93	23.60
6245	2	78	1911	2	226.00	223.00	11.64	13.86	43.00	34.00	20.06	16.57	22.08
6258	2	49	1940	2	268.00	265.00	11.83	14.81	44.00	34.00	25.41	17.27	20.36
6263	2	37	1952	2	251.00	148.00	11.05	14.35	42.00	32.00	23.96	16.08	23.95
6207	2	38	1950	2	261.00	259.00	12.65	14.71	48.00	37.00	25.45	18.89	22.62
6239	2	50	1938	2	267.00	264.00	11.21	13.78	41.00	36.00	24.54	18.04	19.62
6370	2	40	1949	2	254.00	252.00	11.19	15.12	43.00	33.00	21.09	18.43	21.30
6585	2	20	1970	2	260.00	255.00	11.55	15.68	43.00	33.00	23.70	17.20	23.27
2427	2	65	1888	2	255.00	253.00	11.07	15.73	45.00	37.00	23.07	16.85	25.44
2460	2	69	1884	2	220.00	216.00	9.83	12.26	38.00	28.00	20.83	16.02	21.17
2407	2	37	1916	2	249.00	247.00	10.18	14.15	41.00	30.00	22.09	18.22	21.88
2451	2	51	1902	2	258.00	255.00	10.14	16.00	43.00	34.00	19.95	16.84	21.95
2517	2	32	1923	2	232.00	229.00	9.82	13.64	40.00	30.00	21.32	16.91	20.58
2515	2	28	1926	2	254.00	251.00	11.44	13.31	42.00	34.00	20.06	15.92	22.76
2505	2	70	1884	2	224.00	222.00	11.31	13.91	43.00	34.00	21.20	14.10	16.90
2577	2	40	1915	2	238.00	237.00	11.14	15.25	44.00	33.00	21.17	15.67	22.38
2584	2	30	1926	2	238.00	234.00	10.85	13.11	40.00	35.00	21.93	17.38	20.08
2345	2	50	1902	2	262.00	260.00	11.57	14.50	45.00	34.00	24.49	17.47	21.62
2715	2	45	1912	2	239.00	236.00	11.10	14.85	43.00	32.00	20.32	15.56	22.63
2726	2	44	1913	2	254.00	251.00	11.83	14.65	44.00	36.00	24.33	18.47	21.07

Appendix A2: Data of osteometric variables for the ulna (cont.)

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
3063	2	60	1901	2	228.00	225.00	11.17	14.14	43.00	31.00	22.87	16.91	18.62
3161	2	60	1902	2	263.00	261.00	12.55	14.27	46.00	36.00	24.84	17.90	23.90
3196	2	28	1935	2	253.00	253.00	11.55	15.04	45.00	35.00	25.88	20.68	22.25
3334	2	54	1908	2	253.00	249.00	12.66	13.40	43.00	37.00	25.71	18.70	25.17
3374	2	21	1943	2	225.00	222.00	9.42	13.20	38.00	32.00	21.14	16.19	18.71
4503	2	30	1944	2	234.00	231.00	10.51	15.55	44.00	32.00	22.39	17.15	22.23
4649	2	39	1936	2	239.00	237.00	11.09	15.15	43.00	34.00	22.36	15.41	20.56
4580	2	29	1945	2	242.00	239.00	10.97	12.91	41.00	31.00	19.57	14.36	19.25
4884	2	58	1920	2	257.00	255.00	11.50	14.46	43.00	34.00	24.08	18.50	23.78
4874	2	58	1919	2	256.00	252.00	10.40	16.44	46.00	35.00	23.38	16.82	23.92
5433	2	32	1950	2	246.00	245.00	12.16	14.74	45.00	35.00	21.46	16.43	22.84
5874	2	75	1911	2	278.00	277.00	12.64	16.06	48.00	36.00	24.97	17.04	23.93
6264	2	85	1904	2	236.00	232.00	10.84	14.26	42.00	29.00	20.00	15.36	21.26
6056	2	28	1959	2	243.00	240.00	10.41	13.01	40.00	32.00	19.26	16.22	20.19
6543	2	43	1947	2	236.00	234.00	11.39	16.05	45.00	35.00	25.06	16.01	21.51
6469	2	33	1957	2	264.00	261.00	10.60	15.24	44.00	33.00	24.07	16.64	21.62
6667	2	48	1943	2	246.00	243.00	10.25	13.67	40.00	37.00	21.39	16.81	21.77
6790	2	42	1950	2	259.00	258.00	12.69	16.03	47.00	36.00	22.67	16.10	21.19
6604	2	48	1946	2	267.00	262.00	11.41	15.55	44.00	39.00	25.84	20.86	25.81
2445	2	80	1873	2	263.00	257.00	13.80	18.62	53.00	42.00	24.74	20.07	22.50
2492	2	45	1909	2	233.00	228.00	12.12	14.40	45.00	34.00	24.57	20.29	25.53
2665	2	45	1912	2	230.00	225.00	10.01	13.76	39.00	30.00	21.30	13.49	19.04
2610	2	35	1921	2	258.00	253.00	10.23	18.69	44.00	33.00	22.93	17.93	21.15
2802	2	48	1910	2	239.00	234.00	13.04	15.76	47.00	38.00	23.72	18.20	24.08
3141	2	47	1915	2	236.00	233.00	11.63	13.57	43.00	36.00	20.95	19.02	20.49

Appendix A2: Data of osteometric variables for the ulna

Specimen	sex	age	birth	location	uln_leg	uln_plg	ums_min	ums_max	umx_cir	umn_cir	ole_br	ole_mbr	ole_hgt
3928	2	67	1903	2	283.00	280.00	13.16	16.12	47.00	32.00	24.78	17.70	22.95
3990	2	50	1920	2	242.00	239.00	11.15	12.76	39.00	31.00	23.48	18.15	24.13
4843	2	56	1921	2	254.00	250.00	12.40	13.20	40.00	30.00	19.52	15.05	21.33
5134	2	50	1930	2	258.00	255.00	11.88	15.11	42.00	33.00	24.12	18.58	22.07
5690	2	45	1940	2	241.00	239.00	10.88	13.00	37.00	30.00	22.01	16.72	19.25
5859	2	56	1930	2	245.00	244.00	13.25	14.40	46.00	34.00	21.63	16.27	20.22
5815	2	65	1920	2	260.00	255.00	12.30	17.95	50.00	41.00	26.94	20.00	23.85
5973	2	50	1937	2	248.00	244.00	12.48	15.95	46.00	36.00	22.93	16.71	23.56
685	2	38	1950	2	250.00	247.00	11.56	15.28	45.00	34.00	22.53	18.70	23.75
6238	2	25	1958	2	230.00	229.00	10.62	13.51	41.00	31.00	21.18	16.01	23.80
6491	2	25	1965	2	234.00	232.00	11.10	12.66	41.00	34.00	21.66	17.01	18.53
6271	2	31	1958	2	263.00	260.00	11.96	17.10	48.00	41.00	23.31	18.68	25.13
3261	2	40	1958	2	253.00	250.00	9.52	11.44	36.00	30.00	22.08	13.33	22.30
3590	2	40	1923	2	280.00	276.00	12.09	15.82	46.00	38.00	24.15	18.71	22.88
4137	2	27	1926	2	257.00	256.00	10.89	14.31	43.00	35.00	23.17	19.76	20.28
4692	2	26	1944	2	246.00	241.00	12.07	14.49	44.00	38.00	23.32	17.20	23.74
4759	2	32	1949	2	236.00	234.00	10.83	13.48	42.00	33.00	20.60	15.27	19.61
5590	2	58	1944	2	259.00	255.00	11.83	18.09	50.00	36.00	22.91	19.23	23.17
5558	2	48	1926	2	253.00	249.00	9.76	15.58	44.00	36.00	23.61	14.52	20.91
5803	2	31	1935	2	263.00	262.00	10.43	12.91	41.00	34.00	23.54	18.37	23.07
5800	2	60	1954	2	240.00	237.00	12.26	12.99	43.00	35.00	22.62	17.84	20.04
5946	2	42	1954	2	271.00	168.00	11.39	13.29	42.00	36.00	19.97	17.10	20.02
5949	2	46	1945	2	237.00	235.00	11.24	13.71	43.00	32.00	22.74	17.23	22.91
6620	2	74	1941	2	239.00	237.00	10.68	12.36	39.00	35.00	21.43	15.78	19.43
3944	2	60	1917	2	279.00	276.00	11.50	16.02	43.00	34.00	23.41	18.31	19.14

REFERENCES

(1) L'Abbé E.N. A case of commingled remains from rural South Africa. Forensic Sci Int. 2005; 151(2-3):201-206.

(2) Bhootra BL, Weiss E. Muti killing: a case report. Med, Sci Law. 2006; 46(3):255-259.

(3) Scholtz HJ, Phillips VM, Knobel GJ. Muti or ritual murder. Forensic Sci Int. 1997; 87(2):117-123.

(4) Steyn M. Muti murders from South Africa: a case report. Forensic Sci Int. 2005; 151(2-3):279-287.

(5) Góes AC, Silva DA, Domingues CS, Sobrinho JM, Carvalho EF. Identification of a criminal by DNA typing in a rape case in Rio de Janeiro, Brazil. Sao Paulo Med J. 2002; 120(3):77-79.

(6) İşcan MY, Solla H.E., McCabe B.Q. Victim of a dictatorial regime: identification of Mr. Roberto Gomensoro Josman. Forensic Sci Int. 2005; 151(2-3):213-220.

(7) Oz C, Levi JA, Novoselski Y, Volkov N, Motro U. Forensic identification of a rapist using unusual evidence. J Forensic Sci. 1999; 44(4):860-862.

(8) Adair TW, Dobersen MJ, Lear-Kraul K. Appearance of chemical burns resulting from the washing of a deceased body with bleach. J Forensic Sci. 2007;52(3):709-711.

(9) Calce SE, Rogers T. Taphonomic changes to blunt force trauma - a preliminary study. J Forensic Sci. 2007;52(3):519-527.

(10) Hunter JR. A Background to Forensic Archaeology. In: Hunter J, Roberts C, Martin A, editors. Studies in Crime: An Introduction to Forensic Archaeology. London: Routledge; 1996.p. 7-23.

(11) Quatrehomme G, İşcan MY. Postmortem skeletal lesions. Forensic Sci Int. 1997; 89:155-165.

(12) Eckert WG. Introduction to Forensic Sciences. Eckert WG, editor. Introduction to Forensic Sciences. St Louis : CV Mosby Company; 1980.p. 1-8.

(13) Stevens PJ. Investigation of mass disaster. In: Mant AK, editor. Modern trends in Forensic Medicine.3rd edition. London: Butterworths; 1973.p. 170-192.

(14) Roberts CA. Forensic Anthropology 1: the contribution of biological anthropology to forensic contexts. In: Hunter J, Roberts C, Martin A, editors. Studies in Crime: An Introduction to Forensic Archaeology. London: Routledge; 1996.p. 101-122.

(15) Stewart TD. Medico-legal aspects of the skeleton. Am J Phys Anthropol 1948; 6(3):315-321.

(16) Byrd JE, Adams BJ. Osteommetric sorting of commingled human remains. J Forensic Sci. 2003; 48(4):717-724.

(17) Ta'ala SC, Berg G, Haden K. Blunt force cranial trauma in the Cambodian Killing Fields. J. Forensic Sci. 2006;51(5):996-1001.

(18) Koff C. The Bone Woman. London: Atlantic Books; 2004.

(19) Ubelaker DH. Bones: A forensic detective's casebook. New York: Harper Paperbacks; 1992.

(20) Alonso A, Martin P, Albarrán C, Garcia P, Fernandez de Simon L, Jesús Iturralde M et al. Challenges of DNA profiling in mass disaster investigations. Croat Med J. 2005; 46(4):540-548.

(21) Berryman H, Gunther W. Keyhole defect production in tubular bone. J Forensic Sci. 2000; 45(2):483-487.

(22) Budimlija ZM, Prinz MK, Zelson-Mundorff A, Wiersema J, MacKinnon G, Nazzaruolo BL et al. World Trade Center human identification project: experiences with individual body identification cases. Croat Med J. 2003; 44(3):259-263.

(23) Cattaneo C, DiMartino S, Scali S, Craig OE, Grandi M, Sokol RJ. Determining the human origin of fragments of burnt bone: a comparative study of histological, immunological and DNA techniques. Forensic Sci Int. 1999; 102(2-3):181-191

(24) Bodowle B, Bieber FR, Eisenberg AJ. Forensic aspects of mass disasters: strategic considerations for DNA-based human identification. Legal Med. 2005;7(4):230-243

(25) Leclair B, Shaler R, Carmody GR, Eliason K, Hendrickson BC, Judkins T et al. Bioinformatics and human identification in mass fatality incidents: the world trade center disaster. J Forensic Sci. 2007; 52(4):806-819.

(26) Bass WM. Developments in the identification of human skeletal material (1968-1978). Am J Phys Anthropol. 1979; 51(4):555-562.

(27) Ferembauch D. Recomendations for age and sex diagnoses of skeletons. J Hum Evol. 1980; 9:517-549.

(28) France DL. Observational and metric analysis of sex in the skeleton. In: Reichs KJ, editor. Forensic Osteology: advances in the identification of human remains. Springfield, Illinois: Charles C Thomas Publisher LTD.; 1998.p. 163-186.

(29) Keough N. Estimation of Age at Death from the Microscopic Structure of the Femur. [dissertation] Pretoria: University of Pretoria; 2007.

(30) Maat GRJ, Maes A, Aarents MJ, Nagelkerke NJD. Histological age at death prediction from the femur in a contemporary Dutch sample* The decrease of nonremodeled bone in the anterior cortex. J Forensic Sci. 2006; (51):230-237.

(31) Novotny V, İşcan MY, Loth SR. Morphological and osteometric assessment of age, sex and race from the skull. In: İşcan MY, Helmer RP, editors. Forensic Analysis of the Skull. Wiley-Liss, Inc; 1993.p. 71-88.

(32) Loth SR, İşcan MY. Sex Determination. In: Siegel JA, Sauko PJ, Knufper GC, editors. The Encyclopedia of Forensic Sciences; 2000. Vol 1.p. 252-260.

(33) Loth SR, Henneberg M. Mandibular ramus flexure: a new morphological sex indicator of sexual dimorphism in the human skeleton. Am J Phys Anthropol. 1996; (99):473-485.

(34) Levy LF. Porter's Neck. Br Med J. 1968;(2):16-19

(35) Jurmain R, Nelson H. Introduction to Physical Anthropology. 6th ed. St Paul's: West Publishing Company; 1994.

(36) Devas M. Stress fractures in athletes. Proc R Soc Med. 1969; 62(9):933-937.

(37) Kadel NJ, Kronmal RA. Stress fractures in ballet dancers. Am J Sports Med 1992; 20(4):445-449.

(38) Kemkes-Grottenthaler A. The reliability of forensic osteology - a case in point case study. Forensic Sci Int. 2001; 117 (1-2):65-72.

(39) Thieme FP, Schull WJ. Sex determination from the skeleton. Hum Biol. 1957; 29(3):242-273.

(40) Asala SA. Sex determination from the head of the femur of South African whites and blacks. Forensic Sci Int. 2001; 117(1-2):15-22.

(41) Berrizbeitia EL. Sex determination with the head of the radius. J Forensic Sci. 1989; 34(5):1206-1213.

(42) Bidmos MA, Asala SA. Discriminant Function Sexing on the Calcaneus of South African Whites. J Forensic Sci. 2003; 48(6):1213-1218.

(43) Bidmos MA, Dayal MR. Sex Determination from the Talus of South African Whites by Discriminant Function Analysis. Am J Forensic Med & Pathol. 2003; 24(4):322-328.

(44) Black TK. A New Method for Assessing the Sex of Fragmentary Skeletal Remains: Femoral Shaft Circumference. Am J Phys Anthropol. 1978; 48(2):227-232.

(45) Dibennardo R, Taylor JV. Assessment of the Femur: A Test of a New Method. Am J Phys Anthropol.1979; 50(4):635-638.

(46) İşcan MY, Loth SR, King CA, Shihai D, Yoshino M. Sexual dimorphism in the humerus: A comparative analysis of Chinese, Japanese and Thais. Forensic Sci Int. 1998; 98(1-2):17-29.

(47) İşcan MY, Shihai D. Sexual Dimorphism in the Chinese Femur. Forensic Sci Int. 1995; 74 (2):79-87.

(48) King CA, İşcan MY, Loth SR. Metric and comparative analysis of sexual dimorphism in the Thai femur. J Forensic Sci. 1998; 43(5):954-958.

(49) Knight B. The International Practice of Forensic Sciences. Introduction to Forensic Sciences. In: Eckert WG, editor. St Louis: CV Mosby Company, 1980.p. 9-16.

(50) Mall G, Hubig M., Buttner A., Graw M., Penning R, Kuznik J. Sex determination and estimation of stature from the long bones of the arm. Forensic Sci Int. 2001; 117(1-2):23-30.

(51) Purkait RS, Chandra H. Sexual Dimorphism in Femora: an Indian study. Forensic Sci comm. 2002; 4(3).

(52) Singh S, Singh G, Singh SP. Identification of sex from the ulna. Indian J Med Res. 1974; 62(5):731-735.

(53) Steyn M, İşcan MY. Osteometric variation in the humerus: sexual dimorphism in South Africans. Forensic Sci Int. 1999; 106(2):77-85.

(54) Davivongs V. The pelvic girdle of the Australian Aborigine; sex differences and sex determination. Am J Physl Anthropol. 1963; 21(4):443-455.

(55) France DL. Sexual dimorphism in the Human Humerus [dissertation]. Boulder: University of Colorado; 1983.

(56) Scheuer L. Application of Osteology to Forensic Medicine. Clin Anat 2002; 15(4):297-312.

(57) Colbourne T, Dumanowski D, Myers JP. Our Stolen Future: Are we threatening our own fertility, intelligence and survival?: a scientific detective story. New York: Dutton; 1996

(58) İşcan MY, Kennedy AR. Reconstruction of life from the skeleton: an introduction. In: İşcan MY, Kennedy AR, editors. Reconstruction of life from the skeleton. New York: Alan R.Liss,Inc.; 1989.p. 1-10.

(59) Tobias PV. The Negative Secular Trend. J Hum Evol. 1985; (14):347-356.

(60) Wolanski, N. The secular trend: microevolution, physiological adaptation and migration, and their causative factors. Proceedings of the 7th International Congress on Nutrition 1966; Hamburg, Germany.

(61) Tanner JM. The secular trend towards earlier physical maturation. Tijdschr Soc Geneeskd. 1966;(44):524-539.

(62) Tobias PV. Stature and Secular Trend among Southern African Negroes and San (Bushmen). S Afr J Med Sci. 1975; 40(4):145-164.

(63) Krogman WM, İşcan MY. Determination of sex and parturition.The Human Skeleton in Forensic Medicine. 2nd ed. Springfield, IL.: Charles C. Thomas; 1986.p.189-267.

(64) L'Abbé EN, Loots M & Meiring JH. The Pretoria Bone Collection: A modern South African skeletal sample. Homo 2005;56(2):197-205.

(65) Asala SA. The efficiency of the demarking point of the femoral head as a sex determining parameter. Forensic Sci Int. 2002; 127(1-2):114-118.

(66) Asala SA, Bidmos MA, Dayal MR. Discriminant function sexing of fragmentary femur of South African blacks. J Forensic Sci. 2004; 145(1):25-29.

(67) Bidmos MA. Metrical and non-metrical assessment of population affinity from the calcaneus. Forensic Sci Int. 2006; 159(1):6-13.

(68) Bidmos MA, Dayal MR. Further evidence to show population specificity of discriminant function equations for sex determination using the talus of South African blacks. J Forensic Sci. 2004; 49(6):1165-1170.

(69) Dayal MR, Bidmos MA. Discriminating sex in South African blacks using the patella. J Forensic Sci. 2005; 50(6):1294-1297.

(70) DeVilliers H. The skull of the South African Negro. S Afr J Sci. 1968; (64):118-124.

(71) Patriquin M, Loth S, Steyn M. Metric analysis of sex differences in South African black and white pelves. Forensic Sci Int. 2005; 147(2-3):119-127.

(72) Steyn M, İşcan MY. Sexual dimorphism in the crania and mandibles of South African whites. Forensic Sci Int. 1998; 98(1-2):9-16.

(73) Steyn M, İşcan MY. Sex determination from the femur and tibia in South African whites. Forensic Sci Int. 1997; 90(1-2):111-119.

(74) White TD. Human osteology. 2nd ed. London: Academic Press; 2000.

(75) Coetzee T. Drennan se Menslike Osteologie . 4th ed. Cape Town: Maskew Miller Longman, 1980.

(76) Scheuer L, Black S. Developmental juvenile osteology. San Diego: Academic Press; 2000.

(77) Price JS, Oyajobi BO, Russel RGGl. The cell biology of bone growth. Eur J Clin Nutr. 2004;28(supp.1):5131.

(78) Scheepers MD, Duminy J, Meiring JH. Practical Osteology. 1999. Pretoria, Department of Anatomy, University of Pretoria.

(79) Brodeur AE, Silberstein MJ, Graviss ER. Radiology of the pediatric elbow. Freiburg im Breisgau: Hyperion-Verlag, 1981.

(80) Choi SC, Trotter M. A statistical study of multivariate structure and race-sex differences of American White and Negro fetal skeletons. Am J Phys Anthropol. 1970; 33(3):307-313.

(81) Pedersen JF. Fetal crown-rump length measurement by ultrasound in normal pregnancy. Br J Obstet Gynaecol 1982; 89(11):926-930.

(82) Bass WM. Human osteology: a laboratory and field manual. 4th ed. Columbia: Missouri Archaeological Society, Inc. Special publication no 2; 1995.

(83) Tanner JM. Growth at adolescence: with a general consideration of the effects of hereditary and environmental factors upon growth and maturation from birth to maturity. 2nd ed. Oxford: Blackwell Scientific; 1978.

(84) Murray PDF. Bones. Cambridge: Cambridge University Press; 1985.

(85) Matshes EV, Burbridge B, Sher B, Mohamed S, Juurlink B. Human osteology and skeletal radiology: an atlas and guide. Boca Raton: CRC Press; 2005.

(86) Drennan MR. A short course on human osteology. 4th ed. Cape Town: Maskew Miller; 1960.

(87) Agur AMR, Ming JL. Grant's Atlas of Anatomy. 10th ed. Baltimore: Lippincott Williams & Wilkins, 1999.

(88) Bogin B. Patterns of Human Growth. In: Lasker GW, Mascie-Taylor CGN, Roberts DF, editors. Cambridge: Cambridge University Press; 1988. (Cambridge Studies in Biological Anthropology).

(89) Krogman WM. A guide to the identification of human skeletal material. FBI Law Enforcement Bulletin 1939; 8(8):1-29.

(90) Mobius PJ. Uber die Verschiedenheit mannlicher und weiblicher Schadel. Arch für Anthropol. 1907; (6):1-7.

(91) Pittard E. Quelques comparaisons sexuelles de cranes anciens. L'Anthropologie. 1900; 11(179):192.

(92) Parsons FG, Keene L. Sexual differences in the skull. J Anat. 1919; 54(pt 1):58-65.

(93) Weisbach A. Der deutsche Weiberschadel. Arch für Anthropol. 1868; 3:59-85.

(94) Stewart TD. Sex determination of the skeleton by guess and by measurement. Am J Phys Anthropol. 1954; 12(3):385-391.

(95) St.Hoyme LE, İşcan MY. Determination of sex and race: accuracy and assumptions. In: İşcan MY, Kennedy AR, editors. Reconstruction of life from the skeleton. New York: Alan R.Liss; 1989.p. 53-93

(96) Lundy J. Physical Anthropology in Forensic Medecine. Anthropol Today. 1986;2(5):14-17.

(97) Kontulainen S, Sievänen H, Kannus P, Pasanen M, Vuori I. Effect of long-term impact-loading on mass, size, and estimated strength of humerus and radius of female racquet-sports players: a peripheral quantitative computed tomography study

between young and old starters and controls. J Bone Miner Res. 2002; 17(12):2281-2289.

(98) Nikander R, Sievänen H, Uusi-Rasi K, Kannus P. Loading modalities and bone structures at nonweight-bearing upper extremity and weight-bearing lower extremity: a pQCT study of adult female athletes. Bone 2006; 39(4):886-894.

(99) Allen JC, Bruce MF, Maclaughlin SM. Sex determination from the radius in humans. Hum Evol. 1987; 2(4):373-378.

(100) Birkby WH. An evaluation of race and sex identification from cranial measurements. Am J Phys Anthropol. 1966; 24(1):21-27.

(101) Case T, Ross A. Sex determination from hand and foot bone lengths. J Forensic Sci. 2007; 52(2):264-270.

(102) Celbis O, Agritmis H. Estimation of stature and determination of sex from radial and ulnar bone lengths in a Turkish corpse sample. Forensic Sci Int. 2006; 158(2-3):135-139.

(103) Dibennardo R, Taylor JV. Classification and misclassification in sexing the black femur by discriminant function analysis. Am J Phys Anthropol. 1982; 58(2):145-151.

(104) Dittrick J, Suchey JM. Sex determination of prehistoric central California skeletal remains using discriminant analysis of the femur and humerus. Am J Phys Anthropol. 1986; 70(1):3-9.

(105) Falsetti AB. Sex assessment from Metacarpals of the human hand. J Forensic Sci. 1995; 40(5):774-776.

(106) Garn S, Nagy J, Sandusky S. Differential sexual dimorphism in bone diameters of subjects of European and African descent. Am J Phys Anthropol. 1972; 37(1):127-129.

(107) Genoves ST. L'estimation des differences sexuelles dans l'os coxal; differences metriques et differences morphologiques. Bull Mem Soc Anthropol Paris. 1959; 10:3-95.

(108) Giles E, Elliot T. Sex determination by discriminant function analysis of crania. Am J Phys Anthropol. 1963; (21):53-68.

(109) Hanihara K. Sexual diagnosis of Japanese long bones by means of discriminant function. J Anthropol Soc Nippon. 1958; 6(717):39-48.

(110) Holman DJ, Benett KA. Determination of sex from arm bone measurements. Am J Phys Anthropol. 1991; (84):421-426.

(111) Introna FJ, Dragone M., Frassanito P., Colonna M. Determination of skeletal sex using discriminant analysis of ulnar measurements. Boll Soc Ital Biol Sper 1993; 69(9):-517.

(112) İşcan MY. Osteometric analysis of sexual dimorphism in the sternal end of the rib. J Forensic Sci. 1985; 30(4):1090-1099.

(113) İşcan MY, Miller-Shaivitz P. Determination of sex from the Tibia Am J Physical Anthropol. 1984; 64(1):53-57.

(114) Kieser JA, Moggi-Cecchi J, Groeneveld HT. Sex allocation of skeletal material by analysis of the proximal tibia. Forensic Sci Int. 1992; 56(1):29-36.

(115) King CA. Analysis of sexual dimorphism in the humerus from Thailand. Presented at the annual meeting of the Florida Academy of Science, Punta Gorda, Florida; 1997 March 13-15. Florida Scientist, 60 (suppl 1):2.

(116) King CA. Osteometric assessment of 20th century skeletons from Thailand and Hong Kong. [dissertation] Florida: Florida Atlantic University; 1997.

(117) King CA. Sex determination from Thai tibia. Homo 1999; 50(2):107-117.

(118) Lazenby RA. Identification of sex from Metacarpals: effect of side symmetry. J Forensic Sci. 1994; 39(5):1188-1194.

(119) Purkait RS. Measurements of Ulna - a new method for determination of sex. J Forensic Sci. 2001; 46(4):924-927.

(120) Riepert T, Dreschler T, Schild H, Nafe B, Mattern R. Estimation of sex on the basis of radiographs of the calcaneus. Forensic Sci Int. 1996; 77(3):133-140.

(121) Sakaue K. Sexual determination of long bones in recent Japanese. Anthropol Sci. 2004; 112(1):75-81.

(122) Scheuer L, Elkington NM. Sex determination from metacarpals and the first proximal phalanx. J Forensic Sci. 1993; 38(4):769-778.

(123) Singh G, Singh S, Singh SP. Identification of sex from the radius. J Indian Acad For Sci. 1973;13(1):10-16.

(124) Stojanowski CM. Sexing potential of fragmentary and pathological metacarpals. Am J Phys Anthropol. 1999; 109(2):245-252.

(125) Suljak-Loncarevic A, Ajanovic M. Osteometry of mandibular joint surface. Bosn J Basic Med Sci. 2006; 6(4):25-28.

(126) Washburn S. Sex differences in the Pubic Bone. Am J Phys Anthropol. 1948; (6):199-207.

(127) Pons J. The sexual diagnosis of isolated bones of the skeleton. Hum Biol. 1955; 27(1):12-21.

(128) Kelley MA. Sex determination with fragmented skeletal remains. J Forensic Sci. 1979; 24(1):154-158.

(129) Knussman R. Vergleichende Biologie des Menschen : Lehrbuch der Anthropologie und Humangenetik. Stuttgart: Fischer; 1980.

(130) Phenice TW. A newly developed visual method of sexing the *Os Pubis.* Am J Phys Anthropol. 1969; 30(2):297-302.

(131) Weiss KM. On the systematic bias in skeletal sexing. Am J Phys Anthropol. 1972; 37(2):239-249.

(132) Gonzalez-Reimers E, Velasco-Vazquez J, Arnay-de-la-Rosa M, Santaloria-Fernandez F. Sex determination by discriminant function analysis of the right tibia in the prehispanic population of the Canary Islands. Forensic Sci Int. 2000; 108(3):165-172.

(133) Rogers TL. A visual method of determining the sex of skeletal remains using the distal humerus. J Forensic Sci. 1999; 44(1):57-60.

(134) Henneberg M, van den Berg ER. Test of Socio-economic Causation of Secular Trend: Stature Changes Among Favored and Oppressed South Africans are Parallel. Am J Phys Anthropol. 1990; 83(4):459-465.

(135) Tal H, Tau S. Statistical survey of the human skulls in the Raymond A. Dart colection of skeletons. S Afr J Sci. 1983; (79):215-217.

(136) Tanner JM. Human growth and Constitution. In: Harrison GA, Tanner JM, Pillbeam DR, Baker PT, editors. Human Biology. Oxford: Oxford Science Publications; 1988.p. 339-427.

(137) Price B, Cameron N, Tobias PV. A Further Search for a Secular Trend of Adult Body Size in South African Blacks: Evidence from the Femur and Tibia. Hum Biol. 1986; 59(3):467-475.

(138) Tobias PV. Growth and Stature in Southern African Populations. Conference Proceedings. The human biology of environmental change; 1971 April 5-12; Baltyre, Malawi.

(139) Angel J. Colonial to modern skeletal change in the USA. Am J Phys Anthropol. 1976; 45(3 pt.2):723-736.

(140) Chiarelli B. On the secular trend in stature: a body constitution interpretation. Curr Anthropol. 1977; 18(3):524-5.

(141) Buikstra JE, Ubelaker DH. Standards for data collection from human skeletal remains. 44 ed. Fayetteville; 1994.

(142) Lang TA, Secic M. How to Report Statistics in Medicine. Philadelphia: American College of Physicians; 1997.

(143) Lasker GW. The place of anthropometry in human biology. In: Ulijaszek SJ, Mascie-Taylor CGN, editors. Anthropometry: the individual and the population. Cambridge: Cambridge University Press; 2005.p. 1-6.

(144) Gustafsson A, Lindenfors P. Human size evolution: no evolutionary allometric relationship between male and female stature. J Hum Evol. 2004; 47(4):253-266.

(145) Ruff C. Mechanical determinants of bone form: insights from skeletal remains. J Musculoskelet Neuronal Interact. 2005; 5(3):202-212.

(146) Hall R. Sexual dimorphism for size in seven 19th century northwest coast populations. Hum Biol. 1978; (50):159-171.

(147) Stini W. Nutritional stress and growth: sex differences in adaptive response. Am J Phys Anthropol. 1969; 31(3):417-426.

(148) Stini W. Malnutrition, body size and proportion. Ecol, Food, Nutr. 1972; (1):121-126.

(149) Greulich W. The growth and development status of Guamanian school children in 1947. Am J Phys Anthropol. 1951; 9(1):55-70.

(150) Tobias PV. Puberty, growth, malnutrition and the weaker sex and two new measures of environmental betterment. The Leech 1970; (40):101-107.

(151) Harris B. Growing taller, living longer? Anthropometric history and the future of old age. Ageing and Soc. 1997; 17(5):491-512.

(152) Rensch B. Evolution above the species level. London: Methuen; 1959.

(153) Gustafsson A, Werdelin L, Tullberg B, Lindenfors P. Stature and sexual stature dimorphism in Sweden, from the 10th to the end of the 20th century. Am J Hum Biol. 2007; 19(6):861-870.

(154) De Beer H. Observations on the history of Dutch physical stature from the late Middle Ages to the present. Econ Hum Biol. 2004; 2(1):45-55.

(155) Eveleth PB, Tanner JM. Differences between ethnic groups in sex dimorphism of adult height. Ann Hum Biol. 1975; 2(1):35-39.

(156) Eveleth PB, Tanner JM. Worldwide variation in Human Growth. 2nd ed. Cambridge: Cambridge University Press; 1990.

(157) Cole TJ. Secular trends in growth. Proc Nutr Soc. 2000;59(2):317-324.

(158) Hiernaux J. Variabilite du dimorphisme sexuel de la stature en Afrique sub-saharienne. In: Saller K, editor. Anthropologie und Humangenetik. Stuttgart: Gustav Fischer Verlag, 1968: 42-50.

(159) Robinson M. Assessment of the reliability of metrical methods of sex determination on the skeletal remains of South Africans of European descent. Poster Presentation. 36th Annual Conference of the Anatomical Society of Southern Africa; 2006 Apr 23-26; Golden Gate, South Africa.

(160) Rösing F, Graw M, Marré B, Ritz-Timme S, Rotschild M, Rötzscher K et al. Recommendations for the forensic diagnosis of sex and age from skeletons. Homo 2007; 58(1):75-89.

(161) Introna FJ, Di Vella G, Campobasso C. Sex determination by discriminant analysis of patella measurements. Forensic Sci Int. 1998; 95(1):39-45.

(162) Yach D. Health status and its determinants in South Africa. Afr Health. 1994 March; (special no):5-8.

(163) Unterhalter B. Inequalities in health and disease: the case of mortality rates for the city of Johannesburg, South Africa, 1910-1979. Int J Health Serv. 1982; 12(4):617-636.

(164) Van Staden D. Health and nutrition among blacks in Venda. S Afr Med J. 1985; 68(12):842.

(165) Walker A. Changes in public health in South Africa from 1876. J R Soc Health 2001; 121(2):85-93.

(166) Hausman A, Wilmsen N. Economic change and secular trends in the growth of San children. Hum Biol. 1985; 57(4):563-571.

(167) Jansen Van Rensburg MS, Kramer B, Henneberg M. Sexual dimorphism in ‘Cape coloured’ children. Persp. Hum Biol. 1999;4(2):113-118.

(168) Maat GRJ. Two millenia of male stature development and population health and wealth in the low countries. Int J Osteoarchaeol. 2005; 15(4):276-290.

(169) Frayer DW, Wolpoff MH. Sexual Dimorphism. Ann Rev Anthropol. 1985; (14):429-473.

(170) Grundlingh AM. Prelude to the Anglo Boer War, 1881-1899. In: T.Cameron, S.B.Spies, editors. An Illustrated History of South Africa. Johannesburg: Jonathan Ball Publishers; 1986.p. 183-199.

(171) Benyon J. The British Colonies. In: T.Cameron, S.B.Spies, editors. An Illustrated History of South Africa. Johannesburg: Jonathan Ball Publishers; 1986.p. 161-180.

(172) Spies SB. Unity and Disunity, 1910-1924. In: T.Cameron, S.B.Spies, editors. An Illustrated History of South Africa. Johannesburg: Jonathan Ball Publishers; 1986.p. 231-247.

(173) Murray BK, Stadler AW. From the Pact to the Advent of Apartheid, 1924-1948. In: T.Cameron, S.B.Spies, editors. An Illustraterd History of South Africa. Johannesburg: Jonathan Ball Publishers; 1986.p. 248-270.

(174) Haffejee IE. Child health in South Africa -- past, present and future. Glob Child Health New Rev. 1995; 3(1):18.

(175) Walker A, Isaacson C, Seqal I. Third World policies and realities. Lancet 1981; 1(8223):779.

(176) Crawford J, Wanibe E, Nayak L. The interaction between lid diameter, height and shape on wrist torque exertion in younger and older adults. Ergonomics 2002; 45(13):922-933.

(177) Beck T, Ruff C, Shaffer R, Betsinger K, Trone D, Brodine S. Stress fracture in military recruits: gender differences in muscle and bone susceptibility factors. Bone 2000; 27(3):437-444.

(178) Tobias PV. History of physical anthropology in South Africa. Am J Phys Anthropol. 2005;28(56)1-52.

(179) Van Rooyen C, L' Abbé EN, Steyn M. Forensic Anthropolgy in South Africa: a profile of cases from 1993 to 2006 at the Department of Anatomy, University of Pretoria. Poster presentation. 37th Annual Conference of the Anatomical Society of Southern Africa; 2007 Apr 22-25; Mount Grace Country House and Spa, South Africa. University of Johannesburg; 2007