ASSESSMENT AND IMPROVEMENT OF CURRENT SEX ESTIMATION STANDARDS FOR APPLICATION IN HOLOCENE SAN AND KHOEKHOE POPULATIONS

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A B S T R A C T

Skeletal sex estimation is important in biological anthropology. Population-specific sex estimation standards do not exist for southern African Holocene San and Khoekhoe (HS-K) population. Due to their markedly small stature, skeletal gracility, and physically active lifestyle, they exhibit reduced sexual dimorphism. In this study I aimed to assess the accuracy of current sex estimation methods, and to optimise the assessed methods for population-specific application in the HS-K population.

Seven morphological traits (cranial and mandibular) and six metrical parameters (mandibular, humeral, and femoral) were analysed in 175 adult HS-K skeletons. Accuracy was determined by comparison with pelvic sex estimates. Results were analysed using chi-squared tests, univariate statistics, and cross-validated discriminant function analysis. Trait/parameter preservation rates were assessed and reported: Of the traits, supra-orbital margin and glabella were best preserved (90% and 88% respectively), and mandibular shape least (71%). Of the metrical parameters assessed, femoral and humeral vertical head diameters (FVHD and HVHD) were best preserved (89% and 80% respectively), and bicondylar breadth (BB) least (44%). The highest sex classification accuracies obtained were for mastoid process (73%) and mandibular shape (72%), whilst the lowest were for mental eminence (53%) and nuchal crest (53%). Following categorisation by pelvic sex, the highest accuracies in females were for nuchal crest (98%) and mental eminence (95%), and in males, mandibular shape (80%) and gonial eversion/flaring (81%), illustrating differential sexual dimorphic expression for certain traits. All six metrical parameters were sexually dimorphic, with dimensions of FVHD and HVHD being the most discriminatory. The highest discriminant function accuracy for a single measurement (univariate) was 75% for FVHD, and for combined measurements (multivariate) were 77% for direct combination of BB, FVHD and HVHD, and 73% for stepwise combination of FVHD and HVHD.

Whilst all traits/parameters assessed were sexually dimorphic, they produced lower accuracy rates than in other populations. This confirms that the range of sexual dimorphism exhibited by the HS-K does not conform to existing standards, illustrating the need for methodological adjustments. This study identified the most accurate areas to target for sex estimation in the HS-K and generated the first population-specific discriminant functions for sex estimation with known accuracies.

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ABBREVIATIONS

Abbreviation	Definition
BB	Bicondylar breadth
BCB	Bicoronoid breadth
BGB	Bigonial breadth
BL	Body/corpus length
BP	Before present
CH	Coronoid height
DFA	Discriminant function analysis
DFS	Discriminant function score
DNA	Deoxyribonucleic acid
FVHD	Femoral vertical head diameter
GE	Gonial eversion/flaring
HS-K	Holocene San and Khoekhoe
HVHD	Humeral vertical head diameter
LSA	Later Stone Age
MA	Middle-aged adult
ME	Mental eminence
MML	Maximus mandible length
MP	Mastoid process
MS	Mandible shape
NC	Nuchal crest
NPV	Negative predictive value
OA	Old adult
PPV	Positive predictive value
RH	Ramus height
S-K	San and Khoekhoe
SOM	Supra-orbital margin
UCT	University of Cape Town
VHD	Vertical head diameter
YA	Young adult

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CHAPTER 1
INTRODUCTION

Estimating biological sex of an individual from skeletal remains is known as sex estimation. Sex estimation has been proven to serve many purposes in both contemporary society and our understanding of ancient society, however, this process is only useful if it is carried out accurately. The sexually dimorphic differences used to estimate sex exist on a continuum with degrees of overlap. These can be influenced by secular trends and vary between populations. The population-specific nature of sexing traits must be accounted for during the development of sex estimation techniques. Inaccuracies arise when sex estimation techniques derived from one population are applied to remains from a different population (L'Abbé *et al.*, 2011; Oikonomopoulou *et al.*, 2017). Such misclassifications can have knock-on effects on missing persons cases, forensic and bioarchaeological studies, as well as our understanding of human history (Bidmos *et al.*, 2010).

There are many methods of estimating sex. Most rely fundamentally on skeletal morphology and robusticity differences observed between sexes, that occur due to the variable reproductive roles of each sex (Steyn *et al.*, 2012; Oikonomopoulou *et al.*, 2017; Klales, 2020). In recent years, there has been investment to develop population-specific standards for South Africa to cater for our highly diverse population. However, to date no San and/or Khoekhoe-specific sexing standards exist, and as a result, biological anthropologists and bioarchaeologists must rely on unsatisfactory global standards.

Accuracy of sex estimation methods have been investigated in depth in other populations (*e.g.*, Steyn & İşcan, 1997, 1998, 1999; Asala, 2001, 2002; Klales *et al.*, 2012; Kenyhercz *et al.*, 2017; Bidmos & Mazengenya, 2021), yet in the Holocene San and Khoekhoe (hereafter referred to as 'HS-K' or 'S-K' depending on context), only mentions are made regarding the difficulty of applying existing methods to this population (Hausman, 1982; Ginter, 2008). This population is known to exhibit extreme skeletal gracility and lived a highly active lifestyle: factors that greatly affect the application and accuracy of sex estimation methods (Pfeiffer & Harrington, 2011; Pfeiffer, 2012; Davies, 2018; Mokoena *et al.*, 2019). This study assessed the accuracy of existing morphological sex estimation methods when applied to an HS-K skeletal assemblage, discriminant function equations for this sample were

created and it forms the first systematic investigation into the complexities of estimating sex with current methods in this population.

Common internationally recognised sex estimation methods from the cranium, mandible and long bones were applied to an HS-K assemblage. These consisted of a combination of metrical and morphological assessments. Results of these assessments were cross-checked against pelvic sex estimates, the most accurate sex estimation method available. Due to the archaeological nature of the remains being assessed, the actual sex of individuals are unknown. Therefore, only individuals with pelves were assessed (pelvic sex estimates were used as the "true" sex of individuals, to compare against sex estimates obtained using other methods). It was hypothesised that existing methods would perform poorly, as the HS-K population exhibits a reduced degree of sexual dimorphism that does not conform to existing methods of sex estimation. Results were used to identify optimal and problematic non-pelvic areas of the HS-K skeleton, to be considered in future sex estimation efforts, and collected metrical data were used to develop the first population-specific discriminant functions for estimating sex in the HS-K population.

Outcomes from this study better inform areas of the skeleton that are most sexually dimorphic in the HS-K population, which could prove useful for the selection of sexing regions for application of alternative sex estimation methods. Having population-specific sex estimation standards would greatly improve identification rates in archaeological scenarios, which in turn could contribute to a better understanding of ancient societies. This includes but is not limited to, past histories, population practices, gender ratios, reproductive and gender-based problems, as well as division of labour and gender roles in ancient populations, amongst others. The creation of these population-specific standards also hopes to set a precedent for other populations exhibiting morphologically unique features that do not conform to existing sex estimation standards.

Chapter Two of this dissertation ('Background and Literature Review') addresses what sex estimation is, its purpose, impact, and provides a detailed review of the different methods currently used for sex estimation, their accuracies, and the skeletal elements that they are commonly applied to. The application and use of sex estimation are discussed, in both international and South African contexts. This is followed by an introduction to the HS-K population: their history and lifestyle, unique skeletal morphology and explains why better sex estimation methods are required in this population. This chapter ends by detailing the aims and objectives of the study.

Chapter Three (‘Materials and Methods’) goes into more detail regarding this study’s design and the methodology employed to assess the accuracies of sex estimation methods being tested. The methods and skeletal elements selected for assessment are described further, along with explanations of why they were chosen and how they were assessed.

Chapter Four (‘Results’) presents the findings and outcomes of the sex estimation methods assessed and is divided into three sections. Section one addresses the levels of preservation of skeletal elements assessed. Due to the archaeological nature of the sample, this is important to know, as it affects the selection of sex estimation methods that can be used. Section two shows the results observed during the morphological analysis whilst section three does the same for the metrical analysis.

Chapter Five (‘Discussion’) discusses the study’s main findings, the potential reasons behind them, and their relevance. It provides a comparative review of this study’s findings in comparison to other populations and details study limitations. This chapter concludes by detailing the application of the study’s finding in real-life practice and provides suggestions for further research.

The final sixth chapter (‘Conclusion’) re-iterates and summarises the intent of the study and its main outcomes, and comments on the study’s success in achieving its aim to assess the accuracies of existing sex estimation methods when applied to an HS-K assemblage.

CHAPTER 2
BACKGROUND & LITERATURE REVIEW

2.1. Sex estimation

Krishan *et al.* (2016) defines sex as "the biological characterisation of sexually reproducing species based on their reproductive role" (Krishan *et al.*, 2016:165.e2). The functional role of tissue (along with genetic characteristics, biomechanical loading, and stress) determines its final appearance in the body and in skeletal tissue specifically, these factors present as sexually dimorphic differences due to the variable reproductive roles of each sex (Krishan *et al.*, 2016, Klales, 2020).

In humans, sexually dimorphic variation has been identified in nearly every bone of the skeleton (Krishan *et al.*, 2016), with most female skeletal elements generally being smaller in size with more gracile features than their larger, more robust male counterparts; a result of the varying reproductive roles and hormonal differences between sexes (DiGangi & Moore, 2013). Regarding sex estimation, the role of the biological anthropologist is to interpret these sexually dimorphic features present on the skeleton (Klales, 2020). These differences have been of research interest for many years and form the basis for most sex estimation methods.

In both forensic and bioarchaeological fields, sex estimation is an important tool in producing a biological profile/osteobiography (Kjellström, 2004), where accurate sex classifications contribute to positive identification of individuals or more accurate understandings of past populations (Rennie, 2018). Estimating sex is one of the first steps in this process and one of the most important, as subsequent methods used to estimate age, stature and ancestry are often sex-dependent (DiGangi & Moore, 2013).

The process of sex estimation, irrespective of the method used, is limited in outcome to one of two options: male or female. Despite these limited options, estimating sex remains one of the more difficult osteobiographical assessments (Klales, 2020). This is because skeletal sex is a continuum with large overlaps. Additionally, the accuracy of methods employed is impacted by several factors, including: the state of preservation of the remains

(incomplete/fragmentary remains and taphonomy), the range of sexual dimorphism present in the population being assessed, the method used to estimate sex and the skeletal elements to which the selected methods are applied (DiGangi & Moore, 2013).

2.1.1. The value of sex estimation

Sex estimation serves many purposes and holds great value in real-life contexts, including individual identification, describing variation/adaptation in fossil species, describing human variation in bioarchaeological contexts, assessing dietary influences, risks of disease and trauma and understanding past gender roles, to name a few (Bidmos *et al.*, 2010; Maass & Friedling, 2019; Klales, 2020). In forensic settings, sex estimation is carried out in conjunction with other osteobiographical analyses, with the general purpose of individual identification. This is an important tool as it excludes a large percentage of the population (male vs female), narrowing the list of potential positive identifications (Bidmos *et al.*, 2010; Klales, 2020). Sex estimation accounts for 15% of forensic anthropology publications in the Journal of Forensic Sciences in the 21st century, second only to age-at-death publications (16%) (Bethard & DiGangi, 2019). Internationally, sex estimation has also been used to demonstrate instances where one sex has been preferentially targeted in human rights abuses (Baraybar & Gasior, 2006; Klinkner, 2008; Szleszkowski *et al.*, 2015). Whilst an important tool in forensic fields, sex estimation also holds great value in bioarchaeological contexts.

Klales (2020) states that the bioarchaeological approach consists of adding context to remains by coupling osteological information (that one would find in a biological profile) with archaeological excavation information. Sex estimates provide researchers with a better understanding of the sex-specific activities and palaeodemography of past populations (Kelly & Ardren, 2016; Agarwal & Wesp, 2017).

The Black Death epidemic of 14th-century Europe is an example of how sex estimation can be used to better understand past populations (DeWitte, 2009, 2010, 2015; DeWitte & Kowaleski, 2017; DeWitte & Wood, 2008). DeWitte used sex estimation on pre- and post-Black Death cemeteries to infer sex-specific mortality patterns in medieval English populations (DeWitte, 2009, 2010, 2015). Her findings supported sources stating the Black Death was an indiscriminate killer, irrespective of sex (DeWitte, 2009). However, after coupling sex data with osteological stress indicators, she found that previous physiological stress exposure

increased the death risk for men, but not women (DeWitte, 2010). This research highlights the importance of sex estimation in making inferences about past populations.

In addition to the above-mentioned uses, bioarchaeologists have also used skeletal sex in combination with burial artefacts and other types of burial data (*e.g.*, location) to attempt to identify and understand gender categories in past populations (Kelly & Ardren, 2016; Agarwal & Wesp, 2017). In these instances, sex estimation enables us to investigate sex-related roles and behaviours in past populations (Wadley, 1997; Stock & Pfeiffer, 2004).

Sex estimation contributes greatly to our understanding of past populations, physiologically, socially, and culturally. This highlights the need for the development of population-specific sex estimation standards. However, for accurate application of these methods, the range of variation and sexual dimorphism expressed in the population need to be considered. Sexual dimorphism varies greatly between populations and has known effects on the accuracy of sex estimation methods, both morphological and metrical (Klales, 2020). Whilst these effects have not been explicitly quantified, the different degrees and patterns of dimorphism, both within and between populations, need to be considered to understand the relationship of overall size vs sexual dimorphism. This can make it particularly difficult to estimate the sex of remains from populations known to exhibit unusual morphologies and sexual dimorphic ranges beyond the 'normal' range, potentially resulting in misclassifications.

2.1.2. The impact of sex misclassification

Misclassification of sex in forensic scenarios has significant medicolegal effects, and consequences of such can result in individual's remaining unidentified. In bioarchaeological scenarios, the effect of sex misclassification is much broader because misclassifications can fundamentally alter interpretations of past populations.

One such example in bioarchaeology is the Andean site, Machu Picchu (Klales, 2020). In 1916, a researcher assessing remains from Machu Picchu concluded that the sample was mostly female (109 females vs 26 males) (Eaton, 1916). This led to Machu Picchu being assumed to be an "aqllawasi", a specialised type of women-only Inka community, the majority of whom were "Virgins of the Sun" (Klales, 2020). Whilst this interpretation was questioned for decades, it was only in 2003, following re-analysis of the assemblage (Verano, 2003), that a publication argued a relatively balanced sex distribution. This study noted that the published

sex bias may have been a result of earlier researchers' lack of familiarity with Andean skeletal remains.

Misclassifications are also believed to occur when applying standard sex estimation criteria to indigenous HS-K people (Wadley, 1997; Kurki *et al.*, 2010; Pfeiffer & Harrington, 2011). The extreme gracility and small stature present in this population puts them amongst the most gracile in recorded history (Pfeiffer, 2012; Davies, 2018; Mokoena *et al.*, 2019). As a result, the sex differences exhibited by this population do not conform to existing methods of sex estimation, which may lead to misclassifications that impact our understanding of this population (Pfeiffer & Harrington, 2011; Mokoena *et al.*, 2019). In addition to this, the available skeletal remains of this population are archaeological in nature. As a result, in-life demographic details are unknown and sex estimation efforts are largely restricted by availability of remains and the state of preservation of skeletal elements.

a. Preservation of skeletal remains

The presence of skeletal elements in archaeological and forensic contexts is the product of bone intrinsic factors (structure and shape) and extrinsic factors of burial environment and taphonomic processes (Henderson, 1987; Child, 1995). Skeletal preservation plays an important role in reconstructing individual and group demographic profiles as it influences the selection of methods for sex (and age) estimation (Jackes, 2000). Waldron (1987) was amongst the first to draw attention to the need for systematic reporting of preservation of human bones in archaeological scenarios. Bone presence and preservation greatly affect the amount of information that can be derived from skeletal remains, and thus, can be a major limiting factor when constructing biological profiles. Bone shape determines how taphonomic processes and other extrinsic factors access the bone (Henderson, 1987). Bone composition greatly impacts preservation with more dense cortical bone preserving better than cancellous, spongy bone (Henderson, 1987). Bone size also influences, not only preservation, but the likelihood that it will be recognised and excavated (Waldron, 1987). Small carpal and tarsal bones preserve well due to their cubical shape and the ratio of cortical to cancellous bone (Henderson, 1987), but they are also the most susceptible to pass unrecognised and uncollected during excavations due to their size (Waldron, 1987).

In addition to extrinsic and intrinsic factors, demography itself is believed to affect bone preservation. Weiss (1972) suggested subadult and female skeletons preserve less well than

adult and male skeletons, but experimental studies since show no correlation between sex and preservation (Henderson, 1987; Nawrocki, 1995). However, adult sex ratios are usually skewed from the expected 1:1 ratio in burials. (Walker *et al.*, 1988). Researchers have noted that male skeletons in archaeological assemblages are overrepresented (on average) by 12%, whilst some have cited errors in sexing methods. Mensforth (1990) stated that the method errors are more likely to misclassify males as females, resulting in increasing numbers of females in archaeological sites. These all are contributing factors that affect how researchers interpret results at a population-level and must be considered to avoid introducing biases into the sample being assessed.

2.1.3. The history of sex estimation

The first studies to explicitly record sex differences of the skeleton date back to the 16th century (Klales, 2020). This is in stark contrast to the first recorded study of skeletal elements, by physician Susruta, in India in 600 BC (Zysk, 1986). Limited osteological knowledge during these times restricted knowledge of skeletal sex differences, until Song T'zu's 13th century text "The Washing Away of Wrongs" mentioned crude methods of differentiating sex of bones by their colour (Cullen, 1982; translated by McKnight, 1981). However, it was not until European anatomists started describing skeletal differences between sexes, that research shifted into exploring sex differences of all bones (Long, 2016). Sexual dimorphism was noted in texts throughout the 16th and 17th centuries, but the first methods of sex estimation emerged only in the 1800s, as a by-product of typological race-based studies (Klales, 2020). The first recorded intentional application of sex estimation comes from Dr Wyman, who used his anatomical knowledge to consult on a highly publicised murder case in the mid-1800s (Ubelaker, 2018). Following him, Dwight, believed to the father of forensic anthropology, and his student, Dorsey, focused on sex differences in a medico-legal context and detailed how the skeleton can be used to generate a biological profile (Dwight, 1894; Dorsey, 1897; Klales, 2020).

In the 19th century, notable anthropologists began consulting on medico-legal cases regularly, which often involved estimating sex for identification purposes, and as a result of their casework, began publishing on the findings (Derry, 1909; Birdsell, 1987). The expansion of typology-based physical anthropology and the growth of skeletal collections from the 1940s onwards contributed to advancing research methods used in generating biological profiles.

Whilst the field has shifted to a biological-based human variation approach, many sex estimation methods developed during this time are still widely used today, albeit with modifications (DiGangi & Moore, 2013; Klales, 2020).

The following sections detail the available methods of sex estimation. Thereafter, a specific section tailored to sex estimation in South Africa is presented, followed by an introduction to the southern African San and Khoekhoe population, their history, and why accurate sex estimation methods are required in this population.

2.1.4. Methods of sex estimation

There are multiple scientific approaches for sex estimation of the skeleton, but methods can be broadly categorised into morphological and metrical methods. The entire skeleton has been assessed for sexually dimorphic traits using both metrical and non-metric/morphological methods, with most research focused on the pelvis (*e.g.,* Phenice, 1969; Rogers & Saunders, 1994; Steyn & Patriquin, 2009; Klales *et al.*, 2012), cranium and mandible (*e.g.,* Konigsberg & Hens, 1998; Jantz, 2001; Williams & Rogers, 2006; Walker, 2008; Krüger *et al.*, 2015), and long bones (*e.g.,* Steel, 1962; Berrizbeitia, 1989; Jantz & Jantz, 1999; Albanese, 2013), which are detailed in depth below.

a. Morphological methods

Morphological methods rely on visual assessments of sexually dimorphic traits to ascertain levels of gracility/robusticity and differences in shape, or in some cases, presence vs absence of skeletal features (Klales, 2020). Morphological methods are valued for their ease of use, yielding quick and accurate classifications (L'Abbé *et al.*, 2011). These methods also allow for a combination of multiple sexually dimorphic traits for a 'majority rule' approach or can be combined with statistical measures of probability (Walker, 2005, 2008; Klales *et al.*, 2012).

Morphological assessments are useful in analysing features that can only be assessed visually (*e.g.,* presence vs absence of features, complicated bone shape/size that cannot be easily quantified, etc.) (Loth & Henneberg, 1996; Patriquin *et al.*, 2003). Some of these visual inspection methods can be quantified using more sophisticated techniques such as geometric morphometrics, that provide mathematical descriptions of biological forms according to geometric definitions of size and shape (Klales, 2020).

However, it is not without its constraints. The range of sexual dimorphism of traits exists in a continuum, yet most morphological assessments represent these ranges qualitatively, using discrete, descriptive categories (L'Abbé *et al.*, 2011; İşcan & Steyn, 2013). The large degrees of overlap often present between categories can make morphological assessments difficult to interpret (L'Abbé *et al.*, 2011; İşcan & Steyn, 2013). In addition to observer subjectivity, these methods require experience with visually categorising sexual dimorphism and tend to work best on intact bones, are mostly used on the pelvis and skull, and methods with these requirements tend to be the most population-specific (Bidmos *et al.*, 2010; Krishan *et al.*, 2016).

b. Metrical methods

An alternative to morphological methods is metric assessment, which uses variability in male and female dimensions, coupled with statistical methods to derive models and equations (Krishan *et al.*, 2016; Oikonomopoulou *et al.*, 2017). Methods used include measurements from skeletal elements (osteometrics), proportions, indices, logistic regression analysis and discriminant function analysis amongst others, with accuracy rates varying based on the statistical method used to assess metrical data and the skeletal element to which it is applied (Krishan *et al.*, 2016; Oikonomopoulou *et al.*, 2017).

Measurement-based sex estimation is frequently analysed using discriminant function analysis (DFA), a statistical method developed in 1936 by Fisher, used to isolate a combination of variables that best discriminate between two or more groups (Fisher, 1936). DFAs are usually highly specific to the population for which they were developed and can be affected by temporal change, thus, requiring revision over time (Bidmos *et al.*, 2010). In forensic contexts, FORDISC (a statistical database package that uses DFAs), has become standard for estimating sex, ancestry, and stature (Jantz & Ousley, 2005; Dirkmaat *et al.*, 2008; Cabo *et al.*, 2012).

These quantitative techniques allow for objective, reproducible results, which are statistically more reliable and do not require an experienced observer as they rely largely on measurements obtained directly from the bone as opposed to subjective visual classifications (Lachenbruch & Goldstein, 1979). However, they are often time-consuming, highly population-specific, require special equipment, and can result in high inter-observer error if skeletal landmarks used for measurements are not well-defined (Krishan *et al.*, 2016; Oikonomopoulou *et al.*, 2017).

To date, there is debate surrounding which methods are better to estimate sex (Garvin, 2012). Klales (2020) reported survey results stating that practicing biological anthropologists prefer to use a combination of both metrical and morphological methods. Studies have also demonstrated correlations between morphological trait expression and metrics (Cheverud *et al.,* 1979; Dirkmaat *et al.,* 2012), suggesting there is no biological basis behind favouring a particular method. Rather the selection of method is usually context-based (*e.g.,* forensic vs bioarchaeological), and is limited by resource availability (*e.g.,* equipment, software, finances, *etc.*) and method suitability (Klales, 2020). However, the greatest limitation when selecting a method is which skeletal elements/traits are available for analysis.

c. Pelves

Of all the skeletal elements in the body, the pelvis is regarded as the best indicator of sex (Stewart, 1954; Genovés, 1959; Phenice, 1969; Krogman & İşcan, 1986; İşcan, 1988; Ubelaker & Volk, 2002), due to differences between sexes related to locomotion and childbirth (Klales *et al.,* 2012). This results in conserved anatomical features in humans irrespective of ancestry, secular trend, body size and population differences, making it well-suited for sex estimation (Genovés, 1959; Ubelaker & Volk, 2002). For these reasons, the pelvis is accepted as the most sexually dimorphic bony element and has been studied extensively (*e.g.,* Phenice, 1969; Tague, 1992; Bruzek, 2002; Kurki, 2007; Steyn & Patriquin, 2009; Betti, 2014; Best *et al.,* 2018; Klales, 2020). Additionally, multiple authors have stated that population-specificity in the pelvis, unlike other skeletal elements, is not a cause for concern as the pelvis is constrained by the need for child-bearing in all populations (Tague, 1992; Kurki, 2007; Steyn & Patriquin, 2009; Kenyhercz *et al.,* 2017). Therefore, pelvic sex estimates have been used as standards against which other sex estimation features are compared (Đuric *et al.,* 2005; Inskip *et al.,* 2018).

One of the most commonly used assessments for sex estimation, is the 'Phenice Method' of the pelvis (Phenice, 1969), a morphological assessment method reported to accurately classify sex with a known confidence of approximately 95% (Steyn *et al.,* 2012; İşcan & Steyn, 2013). The pelvis has also been extensively assessed using metrical methods. In a study conducted by Patriquin *et al.* (2005) to assess sex differences between pelves in black and white South African populations, six functions were developed through stepwise and direct DFA for each population using multiple combinations of nine pelvic measurements. An

accuracy of 96% was recorded when using the function that combined all nine measurements (Patriquin *et al.*, 2005).

Whilst the pelvis is the preferred skeletal element for sex estimation, the pubic bone (upon which the Phenice method is reliant) is reported to be recovered in only 66% of archaeological excavations (Waldron, 1987). If the pelvis is fragmented or only isolated osteological elements are found, high-accuracy, pelvic-specific methods are not applicable, encouraging the use of other secondary skeletal characteristics for sex estimation.

d. Cranium and mandible

The cranium is one of the most studied parts of the human skeleton because it contains population-specific signatures and is a functionally important part of the skeleton. It is accepted that cranial morphology is determined by the complex interplay between genetics (Relethford, 1994; Sparks & Jantz, 2002) and environment (Carlson, 1976; Carlson & van Gerven, 1977; Larsen, 1981, 2002; van Vark *et al.*, 2003). The mandible, the largest and hardest of the facial bones, is well-resistant to post-mortem alterations, making it ideal for sex-estimation (Giles, 1964; Steyn & İşcan, 1998; Hu *et al.*, 2006; Franklin *et al.*, 2008; Wankhede *et al.*, 2015; Sikka & Jain, 2016). Biological changes in a population, genetic or environmental, are often reflected in changes in craniofacial morphological patterns (Stynder *et al.*, 2007a). The cranium is also commonly used in sex estimation as sexually dimorphic variations are well represented (Krogman & İşcan, 1986; Novotny *et al.*, 1993; Walrath *et al.*, 2004; Garvin *et al.*, 2014). Meindl *et al.* (1985) found an accuracy of 98% is achievable when sexing with both the pelvis and cranium.

Walker's (2008) descriptions and scoring of cranial traits are commonly used during cranial assessments. These are based on the traits described in Buikstra & Ubelaker (1994), *i.e.*, nuchal crest, mastoid process, supra-orbital margin, glabella, and the mental eminence. Walker (2008) found that converting Buikstra & Ubelaker (1994) descriptions of cranial traits to logistic regressions produced accuracies ranging between 84%-88% when used to estimate sex. The morphologies of the glabella and mastoid process were identified as the most effective individual traits for sex estimation (>70% accuracy). However, combination of all five traits produced an 89% accuracy. Following this, to create population-specific equations for South African individuals, Krüger *et al.* (2015) modified existing formulae using a sample of contemporary black and white South Africans and recorded accuracies as high as 93%.

For metric-specific cranial analysis, Giles & Elliot (1963) and Giles (1966) derived equations using DFA. These equations, created using a white American sample, produced accuracies of 87%. The same sample was used by Giles (1964) who produced an equation using mandibular measurements. Spradley & Jantz (2011) expressed doubts regarding the cranium being the second-best indicator for sex estimation (after the pelvis). After creating different multivariate equations for several individual skeletal elements (cranial and post-cranial), they found that stepwise DFA equations based on the cranium were fifth and eighth best out of 14 equations for black and white Americans respectively, and that the best skeletal element for metric sex estimation was the radius with an accuracy of 94%.

e. Long bones

Whilst all skeletal elements have been metrically assessed for sex estimation, postcranial sex estimation (after the pelvis) is largely focused on long bones (Rennie, 2018). Femoral head measurements are one of the most common metrics obtained for sex estimation (Asala, 2001) and have been used since the early 20th century. In 1914, using a Medieval British sample, Parsons (1914) analysed multiple femoral measurements and found that femoral vertical head diameter was the most useful, due to its reproducibility and good preservation in archaeological assemblages. Femoral head diameter is a correlate of body size and specifically has been correlated with body mass differences (Stock & Pfeiffer, 2001; Kurki *et al.*, 2010; Ruff *et al.*, 2012; Ruff & Larsen, 2014). It is thought that the growth of weight-bearing joints like the femoral head are influenced by body mass during development. As such they are most highly correlated with body mass at the time of epiphyseal fusion (Kurki *et al.*, 2010; Ruff *et al.*, 2012; Ruff & Larsen, 2014). Parsons (1915) later assessed modern populations and calculated that accuracies of 91%-92% could be obtained with application of multiple femoral measurements, including vertical head diameter, 'length-head' index, transverse shaft diameter and maximum femur length amongst others. Steel (1962) (using multiple long bones) and Steyn & İşcan (1997) (using the femur and tibia) attempted similar osteometric analyses in white South Africans.

Following this, Asala (2002) assessed femoral head metrics to see if higher accuracies could be achieved than in south-eastern Nigerian individuals (who had a reported accuracy range of 30%-55%) (Asala 2002). Unfortunately, these produced an accuracy of only 32% for both white and black South Africans of known sex (Asala, 2002). However, this study aimed to assess the accuracy of demarking points in classifying sex: a cruder sex estimation tool in

comparison to other metrical methods, *e.g.*, DFA, logistic regression, *etc.* Assessments of femoral metrics in other population have since produced higher accuracy rates. Purkait (2003) achieved a 92% accuracy in a central Indian population using vertical and horizontal femoral head diameters when assessed in "in-life position" (*i.e.*, femur assessed in the physiological position it is usually found in during life within the body). Murphy (2005) concluded that the femur can be used in both modern forensic and prehistoric contexts. Post-cranial assessment in combination with other techniques, *e.g.*, radiography, has also shown promising accuracy rates for sex estimation (Harma & Karakas, 2007; Kranioti & Paine, 2011).

f. Molecular sex estimation

Most of the above-mentioned methods are reliant on intact or relatively intact bony elements, but in cases of extensive skeletal trauma, a high degree of fragmentation, extensive taphonomic damage and general poor preservation of skeletal remains, the accuracy rates of traditional methods of sex estimation decrease greatly (Mundorff, 2011). In these instances, DNA analysis can be used to estimate sex (Hsu *et al.*, 1999). DNA analysis can provide sex estimates with higher accuracy than traditional methods with some studies reporting 100% accuracy in tests on known-sex individuals (provided the DNA tested is sufficiently preserved) (Skoglund *et al.*, 2013; Inskip *et al.*, 2018).

Molecular sex estimation is carried out by isolating and amplifying genes in the sex chromosomes (X and Y) and has certain advantages over morphometric methods. It can be used on foetal/juvenile remains and can be done on fragments of bone or teeth (Kholief *et al.*, 2017). However, estimating sex using molecular methods is a costly, time-consuming process, often resulting in extensive backlogs in crime laboratories (Klales, 2020). Currently, ancient DNA analysis for bioarchaeological purposes is not possible on the African continent. Gibbon (2020) notes that research permissions processes regarding ancient DNA samples are tedious to acquire in Africa. Whilst there is good legislation regarding human ethics requirements for research on DNA of living people, no clear guidelines exist for DNA in an archaeological context (Gibbon, 2020).

As such, molecular methods may not be a realistic option when multiple individuals need to be assessed. Additionally, the DNA extraction process has limitations: it can be affected by multiple factors ranging from preservation of remains to the type of testing kit used to assess

the DNA (each with their own documented rates of producing false positive results) (Lindahl, 1993; Alaeddini *et al.*, 2010).

When molecular sexing methods is not possible, practitioners rely on traditional morphometric methods irrespective of preservation states, fragmentation, or context (forensic vs archaeological). Some studies have generated logistic regression equations that can produce high success rates from fragmentary remains (90-97% reported by Albanese *et al.* (2008) for proximal femur and fragmented pelvis), but the international consensus is that the application of methods to compromised skeletal elements increases the risk of misclassifications and should be supplemented with a combination of all applicable methods before a reliable sex estimate can be generated. Before discussing how this translates in a South African context, an explanation of terminology, found below, is needed for the discipline in South Africa.

2.2. Sex estimation in South Africa

2.2.1. Terminology

Morris (1992) states that systems of economy, language and biological make-up show different patterns of variation in South Africa's indigenous populations, making it difficult to find a standardised system of naming population groups in South African biological anthropology. Due to the country's history of institutionalised discrimination and sensitive history regarding human remains curation (Sealy, 2003), labels that define or categorise individuals along lines of racial groups or physical types (and their connotations) are particularly problematic.

During the initial period of Dutch settlement in the Cape region of South Africa, small groups of beachcombers and nomadic herders living close to the Dutch outpost (who subsisted mainly by hunting and gathering), were described in most detail in historical records of this time. Contact with inland hunter-gatherer groups only occurred later through colonial settlers' expeditions into the interior of the country (Penn, 2005). The settlers adopted the name 'Strandlopers' for the beachcombers, and 'Hottentots' for the herders. However, the herders referred to themselves as 'Khoekhoe' (previously Khoikhoi, with 'Khoi/Khoe' being the common gender word meaning 'people'; Khoekhoe is translated as 'Men of men' or 'people of people'), or by their individual clan names. In his journals, Jan van Riebeeck, the first Dutch commander of the Cape, used the word 'Soaqua' for hunter-gatherers (from 'soa-' meaning 'bush' and 'qua-' meaning 'man', or from the Nama word 'Sa' meaning 'to gather/forage') and

‘Quena’ to describe herder groups (meaning ‘people’) (Deacon & Deacon, 1999). The inland hunter-gatherers were also referred to as ‘Bushmen’, ‘Sonqua’, ‘Obiqua’ by the Dutch, or ‘San’ by the Khoekhoe (Barnard, 1992). The term ‘San’ (Sa’, ‘to forage’, and the suffix –n meaning ‘people’) was mostly used by other groups to describe their hunter-gatherer neighbours (Deacon & Deacon, 1999; Black, 2014).

The term “Khoïsan” (later changed to ‘Khoisan’) was a biological term created by Leonard Schultze in 1928, to collectively refer indigenous southern African populations, distinct from Bantu-speaking African populations. Subsequently, the term ‘Khoesan’ was used as a linguistic and cultural label (Barnard, 1992).

To clarify the terminology used in research, an interdisciplinary conference was held in Johannesburg, South Africa, in 1971 to outline the appropriate terms to be used when discussing these groups (conference findings published in Jenkins & Tobias, 1977). The terms ‘San’ for hunter-gatherers, ‘Khoikhoi’ (now ‘Khoekhoe’ or ‘Khoi’/ ‘Khoe’) for herders and ‘Khoisan’ (‘Khoesan’) for combined populations were recommended. Even after being adopted as standard in academic circles, a substantial amount of confusion was evident, specifically with regards to linguistic terms. Terms such as ‘Hottentot’ or ‘Bushmen’ were predominantly used for discussion of linguistics (alongside ‘Bantu’ which referred to languages spoken by African populations of South and East Africa) but were often also used to denote physical or ethnic entities (Morris, 1992; Black, 2014).

After the establishment of the South African San Institute (SASI) in 1996, the term ‘San’ largely replaced ‘Bushman’ (Hitchcock *et al.*, 2006). Some older names such as ‘Strandloper’ have fallen away and, whilst still used colloquially by older Afrikaans-speakers, appear less frequently in current literature. In 2003, at the African Human Genome Initiative conference held in Cape Town, attending San communities explicitly stated that ‘Bushman’ and ‘Khoisan’ were not preferred terms (Schlebusch 2010). Their suggestion was to address individual communities by name (*e.g.* !Xun or /Xam), and that if a collective term is required, the combination of San (hunter-gatherer) and Khoe (hunter-herder/pastoralist) is acceptable.

In recent literature, these populations are referred to as the ‘Khoesan/Khoisan’ populations, yet this term is still met with resistance from descendant communities. However, the ‘Traditional and Khoi-San Leadership Act 3 of 2019’ was approved by South African

parliament in early 2021 with the process advised and facilitated by the National Khoi-San Council, indicating that there are differing opinions regarding preferred terminology.

For the purposes of this study, and as agreed upon by the National San Council of South Africa and representatives of relevant descendant communities, the term 'San and/or Khoekhoe' (S-K) will be used to describe the broader population of foragers (San) and herders (Khoekhoe), both of whom are included in this study. Only when referring to previous research and literature, are the older terms used for clarity of discussion. Additionally, the term 'Bantu-speaking' is used to refer to populations' descendant from the migration of Bantu-speaking agropastoral groups of sub-Saharan Africa around 2 000 BP ('before present'), specifically Bantu-speaking Iron Age farming populations who were known to live in settled villages (Badenhorst, 2010; Sengupta *et al.*, 2020; Choudhury *et al.*, 2021).

2.2.2. Review of sex estimation research in South Africa

The earlier sections provided a general review of sex estimation from an international perspective. Following terminological notes in a local context (and due to the population-specific nature of the methods being explored), sex estimation in South Africa is discussed below.

In 2010, Bidmos *et al.* critically reviewed advances in sex estimation methods in South Africa. They stated that sex estimation method application, and teaching of disciplines that use these methods, occur mainly at major tertiary education institutions across the country. Research and further development of osteobiographical methods is facilitated by skeletal repositories housed in tertiary institutions and museums nationwide. These repositories contain human remains of different contexts (cadaveric, forensic, archaeological, historical) and are made up of many of the sub-populations of South Africa's biologically heterogenous population. Bidmos *et al.* (2010) point out that South Africa's diverse population is the result of a complicated history combined with complex microevolutionary processes, resulting in differing ranges of biological variation within each sub-population. Due to this, population-specific standards are required for the accurate interpretation of skeletal remains.

Whilst South African-specific studies for sex estimation have been present since the 1960s (some as a result of earlier typological-based research (Broom, 1923; Drennan, 1929, 1931; Wells, 1951; Van Reenen, 1964; De Villiers, 1968, 1969), the need for population-

specific standards was first explicitly expressed by Steyn *et al.* (1997), who noted that internationally derived standards were still the most common methods used in South Africa, leading to problems with accuracy. In response, studies were conducted using multiple skeletal elements and multiple methods of sex estimation, with the purpose of developing standards for South African populations.

To date, sex estimation standards have been developed for multiple skeletal elements in non-HS-K South African sub-populations with varying accuracy rates. These include pelves, crania, mandible, humeri, ulnae, radii, femora, tibiae, fibulae, patellae, tali, metatarsals and calcanei, amongst others (Steyn & İşcan, 1997; Bidmos & Asala, 2003; Bidmos & Dayal, 2003; Patriquin *et al.*, 2003; Bidmos *et al.*, 2005; Barrier & L'Abbé, 2008; Steyn & Patriquin, 2009; Vance *et al.*, 2011; Krüger *et al.*, 2017; Fasemore *et al.*, 2018; Rennie, 2018; Mokoena *et al.*, 2019; Bidmos & Mazengaya, 2021).

A landmark South African study of the pelvis includes Patriquin *et al.* (2005), conducted on 400 pelves to develop metrical standards tailored to black and white South African populations. Nine pelvic measurements were chosen based on: sexual dimorphic expression, easily identifiable landmarks, and likelihood of pelvic preservation. From these measurements, six functions were created for each population using stepwise and direct DFA. An accuracy of 90%-98% was recorded when using all measurements together (Patriquin *et al.*, 2005).

Crania are reported as the most frequently recovered skeletal element in South Africa (FARC Annual Report, 2012). Landmark South African cranial studies include de Villiers (1968, 1969) who assessed morphological cranial traits of Bantu-speaking South Africans, and Loth & Henneberg (1996) who assessed mandibular ramus flexure for sex estimation and reported average accuracies between 91% and 99% in a black South African population. Soon after its publication, the method's reliability was questioned by Koski (1996), who argued that ramus flexure is not a useful sexing trait but is also difficult to identify on radiographs. However, studies in other populations have produced results both in favour (Indrayana *et al.*, 1998; Balci *et al.*, 2004) and against (Donnelly *et al.*, 1998; Haun, 2000; Hill, 2000; Kemkes-Grottenthaler *et al.*, 2002) the method. None of these were conducted on South African samples, until 2005 when Oettlé *et al.* used geometric morphometric analysis and concluded that mandibular ramus flexure was not a good sex indicator (Oettlé *et al.*, 2005).

Other skeletal elements have also been extensively explored. Whilst a few South African studies have utilised a geometric morphometric approach (Steyn *et al.*, 2004; Oettlé *et al.*, 2005; Franklin *et al.*, 2006, 2008), most South African sex estimation studies are discriminant function-based analyses (de Villiers, 1968, 1969; Steyn & İşcan, 1998, 1999; Bidmos & Asala, 2003, 2004; Asala *et al.*, 2004, Franklin *et al.*, 2005; Patriquin *et al.*, 2005; Dayal *et al.*, 2008; Steyn & Patriquin, 2009; Mokoena *et al.*, 2017; Fasemore *et al.*, 2018; Mokoena *et al.*, 2019; Bidmos & Mazengaya, 2021).

Bidmos *et al.*'s (2010) review article states that a high degree of accuracy can be achieved by using all the methods investigated in South Africa (metric, morphological, geometric morphometric, molecular), each with their own limitations. Whilst the article was largely focused on methods used in forensic contexts, the same methods are employed in bioarchaeology.

Excluding Mokoena *et al.* (2019) who assessed mixed-ancestry South African individuals, most of the above-cited literature is specific to black or white South African populations. Whilst Rightmire (1970) attempted DFA comparisons (a first in South Africa) between a small sample of S-K individuals and Bantu-speaking individuals, there is little investigation on how to best estimate sex in South Africa's indigenous HS-K populations, even though they are one of the most studied archaeological populations (Pfeiffer & Harrington, 2011; Kurki *et al.*, 2012; Barbieri *et al.*, 2014; Wright & Weintroub, 2014; Irish *et al.*, 2014; Botha & Steyn, 2015; Barnabas & Miya, 2019; Pfeiffer *et al.*, 2020).

Sex estimation in the indigenous HS-K people can be difficult due to their characteristic highly active lifestyle, small stature, and extreme gracility of skeletal trait expression. An active lifestyle increases robusticity of muscle attachment sites and muscle stress markers on the skeleton, leading to a reduction in sexual dimorphism of the associated bones, yet the extreme gracility and small stature present in this population puts them amongst the most gracile in recorded history (Pfeiffer, 2012; Davies, 2018; Mokoena *et al.*, 2019). As a result, robusticity differences that generally distinguish sexes are less prominent and do not conform to existing sex estimation standards (Pfeiffer & Harrington, 2011; Mokoena *et al.*, 2019). This, coupled with the lack of population-specific sex estimation standards, further confound sex estimation efforts in this population and limits our understanding of these past peoples and their practices. Whilst these factors affect the application of sex estimation methods to S-K remains, it is these aspects that makes ancient HS-K biological anthropology of interest to more than just southern

African audiences (Kurki, 2007). The remainder of this chapter will elaborate more on the Holocene and LSA, who the HS-K people are, their history, their presence in literature and why accurate methods of sex estimation are required for this population.

2.3. The HS-K people of southern Africa

2.3.1. The Holocene LSA

Bioarchaeological research into the Later Stone Age (LSA) has been primarily focused on the last 10 000 years BP – the Holocene period (Parkington, 1984), with the prehistoric human skeletal record in southern Africa being most complete during the Holocene LSA. The LSA is the final phase in a three-part division of the southern African Stone Age, following the Early Stone Age and Middle Stone Age (MSA) respectively, and refers to human occupation of southern Africa during the last 40 000 years. Our most detailed knowledge is of the last 10 000 years (the Holocene). During the middle and later parts of the Holocene, expansion of material culture, population movement, and an intensification of resource exploitation occurred in South Africa (Hall, 1990; d'Errico *et al.*, 2012; Schlebusch, 2019). Holocene LSA populations employed foraging as their main subsistence strategy, before herding was introduced in the region approximately 2 000 years ago (Sadr, 1998; Sealy, 2010).

The pre-Holocene (and up to the mid-Holocene) skeletal record is extremely sparse and limited to a handful of mostly isolated fragments (Deacon, 1982; Parkington, 1984; Stynder, 2009), so whilst it is established that S-K populations have a long history in southern Africa, the focus of this thesis is specifically on the later Holocene skeletal record.

2.3.2. History of the southern African HS-K people

The HS-K people are a regionally distinct population in southern Africa, whose roots date deep into African prehistory. As a result of this, they have been the focus of multiple studies in numerous fields; ranging from cultural and biological anthropology to those of modern human origins (Singer & Wymer, 1982; Parkington, 1984; Sealy & van der Merwe, 1985; Sealy *et al.*, 1986; Pfeiffer & Harrington, 2011; d'Errico *et al.*, 2012; Kurki *et al.*, 2012; Barbieri *et al.*, 2014; Irish *et al.*, 2014; Wright & Weintroub, 2014; Botha & Steyn, 2015; Barnabas & Miya, 2019; Pfeiffer *et al.*, 2020).

Morphologically, the S-K people as a population cluster, exhibit several characteristic features, such as marked small stature and gracile skeletal morphology but with markedly robust muscle markers, making them distinct from neighbouring Bantu-speaking groups (Stynder *et al.*, 2007a). It has been stipulated that while HS-K people are divided linguistically, socio-culturally, and economically, both groups share a common genetic ancestor and are essentially biologically identical (Stynder *et al.*, 2007a, 2007b, Morris, 2014; Pakendorf & Stoneking, 2021).

San hunter-gatherers (foragers) were the sole occupants of southern Africa between 10 000 to 2 000 BP (Deacon & Deacon, 1999; Ribot *et al.*, 2010; Sealy, 2010). Historical records indicate they lived in small family-based hunting groups, comprised of approximately 10-30 people (Adhikari, 2010); these are, however, very partial records based only on communities that survived into the relatively recent past. Groups in resource-limited areas were mobile and moved locations regularly based on the availability of food sources (Adhikari, 2010), but groups in resource-rich areas, *e.g.*, along the coastline or rivers, were more sedentary (Sealy, 2006).

The introduction of sheep and cattle in the region founded the Khoekhoe economy and served as the backbone of their ritual and symbolic practices (Sealy, 2010). Khoekhoe hunter-herders (pastoralists) are thought to have originated in north Botswana and migrated southward, reaching the Cape region approximately 2 000 years BP (Kinahan, 1994; Smith, 2008). They relied on domesticated sheep and later, cattle, and were known to live in large groups (Fauvelle-Aymar & Sadr, 2008; Sadr, 2008), whilst continuing to live an active lifestyle of hunting wild animals and gathering edible plants from their surroundings (Sealy, 2010). Due to the arrival of domesticated animals, 2 000 BP marks the approximate time of a subsistence strategy change in southern Africa (Sadr, 2003; Smith, 2008). This period is correlated with population expansions and major cultural shifts. The next major shifts in the area were the arrival of Iron Age Bantu-speaking farming societies in South Africa around 400 AD (Greenberg, 1972; Pakendorf *et al.*, 2011) following their southward migration (starting approximately around 3 000 BP) from West-central Africa, and the arrival of European settlers in 1652 (Davenport & Saunders, 2000).

The first recorded European contact with S-K populations come from brief accounts of Portuguese mariners Bartholomeu Dias and Vasco da Gama's voyages around the southern tip of Africa in 1488 and 1497, respectively. After the Dutch East India company established the

first permanent European settlement in the Cape in 1652, many informative accounts were produced on the lifestyle and culture of S-K populations (Elphick, 1977). Early colonial accounts regarded the beachcombers, nomadic pastoralists, and inland hunter-gatherers as separate populations, each with their own modes of social organisation, material culture and language (Stynder *et al.*, 2007a, 2007b). European colonialism of the Cape in 18th and 19th centuries resulted in the destruction of the S-K societies living in and around the area (Adhikari, 2010).

The S-K groups resisted colonial encroachment but were ultimately fighting a losing battle (Marks, 1972). Those who were left were either forced into labour under European settlers, forced to migrate beyond colonial reach or incorporated themselves into existing groups of different cultures in the region such as neighbouring Bantu-speaking groups (Adhikari, 2010). These circumstances disrupted the general health status, social organisation, diet, and lifestyle of S-K populations (Botha & Steyn, 2016). As a result, an overlap in lifestyle of San and Khoekhoe groups occurred, distorting the boundaries between them. After two centuries of marginalisation, many descendants and groups were described as 'Khoisan', with no reference made to their original standard of living or lifestyle (Penn, 2005). S-K communities that have survived into the present share multiple distinct cultural and biological features (Barnard, 1992).

Today, most S-K individuals in South Africa self-classify according to the legislative category 'Coloured' (Adhikari, 2005; L'Abbé *et al.*, 2006). The 'Coloured' population comprises 49.6% of the total population in the Western Cape Province of South Africa (Census, 2011). In local forensic cases, estimating the biological profile of these individuals has proven challenging (L'Abbé *et al.*, 2006; Maass & Friedling, 2019). This is likely due to the varied origins and great genetic diversity found within this social category (Adhikari, 2005; L'Abbé *et al.*, 2006). Genetic studies have shown a strong maternal S-K contribution to the South African Coloured population (Quintana-Murci *et al.*, 2010), and they have been reported to share anatomical similarities with those seen in archaeological assemblages of their HS-K ancestors (Davies, 2018; Wang *et al.*, 2020).

2.3.3. Previous HS-K biological anthropology research

The distinctive morphology and degree of variation exhibited by prehistoric and contemporary S-K populations have fascinated anthropologists since the late 1800's. HS-K anthropological studies of began in the early 1900s following initial cranial investigations (*e.g.*, Broom, 1923; Drennan, 1929, 1931; Van Reenen, 1964). These studies were focused on identifying differences and variation between San and Khoekhoe groups as they were considered distinct populations (Shrubsall, 1898, 1922; Rightmire, 1970). Whilst accepted to have a large range of variation, certain traits had been associated with the crania of San populations for quite some time (Drennan, 1931). According to Wells (1934), the San were characterised by their small size and markedly short-statured form. They were also said to possess slightly developed supra-orbital ridges and small mastoid processes. But the samples upon which these early studies were based, were often very small and consisted of mixed archaeological and contemporary remains. Additionally, the criteria for classifying skeletal material culturally as either San or Khoekhoe was questionable at best. Most of these studies found no significant differences between crania of the San and Khoekhoe, however, they acknowledged that both San and Khoekhoe crania differed significantly from other African/Bantu-speaking populations and were relatively small in comparison to other populations around the world (Stynder, 2006, 2007b).

Whilst significant progress was made in elucidating patterns of variation in S-K populations, serious methodological shortcomings were identified in later studies, including the inclusion of undated archaeological material and remains of mixed ancestry individuals (Morris, 1986). Research carried out by Morris (1984, 1992) represented the first study of S-K variation that focused exclusively on historic period burials. He employed radiocarbon dates measured directly on the skeletal remains, along with archaeological evidence and burial style to position his samples in a chronological context. His research demonstrated that many protohistoric S-K populations from the interior of South Africa displayed significant admixture, and stated it was unwise to compare them on an equal basis with pre-colonial archaeological samples (in agreement with Hausman 1980, 1982).

The most recent comprehensive study of prehistoric S-K crania comes from Stynder *et al.* (2007a, 2007b), who assessed craniometric variation of 153 dated individuals to investigate genetic continuity during the Holocene. He suggested that craniofacial size/shape fluctuations

were related to changes in environmental factors, and that the obtained results were consistent with long term continuity in South African Holocene LSA populations (Stynder *et al.*, 2007a, 2007b).

Whilst knowledge of the biological adaptation of S-K populations of southern Africa has grown significantly over the past few decades, it remains deficient in comparison to the cultural record of these groups. This is not surprising when one considers that most prehistoric human remains for South Africa represent individual burials, making it difficult to extract population-level biological information. Additionally, these populations are geographically and temporally diverse (Stynder *et al.*, 2009). Despite this, the biological adaptation of this population, particularly over the last 5000 years, is relatively well understood due to the increase in the number of studies of cranial and postcranial remains during the last three decades (Morris, 1992; Churchill & Morris, 1998; Pfeiffer & Harrington 2011; Pfeiffer 2012; Sealy & Pfeiffer 2000; Stock & Pfeiffer 2001; Pfeiffer & Sealy 2006; Stynder *et al.* 2007a, 2007b; Stynder 2009).

It has been suggested that S-K populations' characteristic small stature must be a result of an impoverished Kalahari environment (de Almeida, 1965, Molnar, 1998, Pfeiffer, 2009). Whilst there is evidence for S-K populations in the desert-like Kalahari for centuries (Barham & Mitchell, 2008), site density, specifically throughout the Holocene, suggests a substantially greater population, in coastal areas. Adaptation through natural selection, had it occurred, would have been in response to that coastal environment (Pfeiffer, 2009). However, coastal conditions allow for better preservation of skeletons, with remains more likely to be found due to increased coastal activity. Thus, greater numbers of coastal skeletons do not necessarily mean that most HS-K individuals exclusively resided along the coast.

Bioarchaeological evidence from substantial numbers of LSA skeletons across southern Africa demonstrates that HS-K ancestors were consistently small in stature (Sealy & Pfeiffer, 2000). Adult body size fluctuates temporally and spatially as societies dealt with environmental factors (Pfeiffer & Sealy, 2006), but no group ever exceeded historic S-K statures (Pfeiffer & Harrington, 2011). The antiquity of this pattern is reinforced by evidence that the distinct S-K pelvic shape, still accommodated a functional birth canal despite small external hip dimensions (Kurki, 2007). Whilst external factors could have affected body size, there is also evidence for an ancient genetically modulated range that still retains the 'smallness' associated with S-K populations despite changes (Pfeiffer, 2009).

Body size and stature of S-K people is not due to early maturation, as in African pygmy groups (Pfeiffer & Harrington, 2011; Pfeiffer, 2012). Long bone growth assessment in juveniles revealed that growth rates appear similar to other southern African populations within the first two years of life, but reduced growth of all long bones is seen from year three onwards (Lovejoy *et al.*, 1990; Mosothwane & Steyn, 2004). Whilst small body size and stature have been attributed to chronic disease and malnutrition, slow growth rates observed in S-K populations are now believed to have a strong genetic component (Tobias, 1962; Pfeiffer & Sealy, 2006; Pfeiffer, 2009; Botha & Steyn, 2016).

An alternate behavioural explanation for small stature was generated from the practice of continued breastfeeding of infants for several years (Pfeiffer, 2009). Studies have documented S-K populations breastfed on demand well beyond the first year of an infant's life, with weaning often being completed by four years of age (Lee, 1979; Konner, 2005). Subsequent research of eastern North American hunter-gatherers noted the same prolonged nursing patterns (Schurr & Powell, 2005).

Another well-documented behavioural pattern is the gender-based division of labour in adults. Whilst unrelated to stature, this practise has been shown to affect skeletal muscle markings due to sustained habitual activity. The documented pattern of gendered labour among Kalahari S-K groups, where women forage for plant foods with digging sticks (Pfeiffer, 2009), is believed to be unique (Lee, 1979; Wadley, 1997). Because digging stick use is a biomechanically balanced activity, it is believed to moderate the typical adult pattern of one upper arm being more strongly built than the other (Pfeiffer, 2009). Assessing the strength asymmetry of upper limb bones has demonstrated that adult female skeletons show substantially more symmetrical upper arms, whilst male skeletons show variable asymmetry (Stock & Pfeiffer, 2001, 2004). This is consistent with women working with digging sticks (Pfeiffer, 2009) but is only significant because it contrasts with the pattern seen in men. Study of juvenile arm bones have demonstrated the gradual acquisition of this sex-specific pattern (Harrington, 2008). Unlike prolonged breastfeeding, this pattern has not been found in hunter-gatherer skeletons in other parts of the world (Pfeiffer, 2009).

Despite conserved dimorphism, similar mobility patterns in females and males are expected to result in similar skeletal robusticity (Stock & Pfeiffer, 2001). Reduced sexual dimorphism in a population may be linked to less gender-based division of labour (Collier, 1993; Ruff & Larsen, 2014). Ethnographic models of gender-based labour division, (men as

hunters and women as foragers, have recently been regarded as oversimplifications, insufficient for interpreting subsistence evidence accurately (Wadley, 1996, 1997; Stock & Pfeiffer, 2004).

During the Holocene LSA, as part of the highly active lifestyle of S-K populations, short spears and bows and arrows were a part of the hunting weapons used (d'Errico *et al.*, 2012). This has been regarded as a possible explanation for the lesions and prominent muscle markers found in the shoulder and elbow joints of S-K populations, as hunting practices using these tools require considerable effort. Similarly, terrestrial mobility has been correlated with lower limb robusticity (Stock & Pfeiffer, 2001; Ruff & Larsen, 2014; Stock, 2016). Although the upper limb is suggested to be most involved in daily S-K activities, the lower limb's evidence of activity markers suggests substantial terrestrial mobility.

Additional evidence of the active lifestyle of HS-K populations is found within the axial skeleton. Osteoarthritic lesions are found to be more evident in thoracic and lumbar vertebral regions. Lumbar disc degeneration has previously been associated with strenuous physical work (Lawrence, 1969), representing the effects of increased physicality. Prominent clavicular shaft muscle markers are considered evidence for habitual swimming activity and/or extensive use of digging sticks, relying on upper body strength (Stock & Pfeiffer, 2001). Despite this labour-intensive lifestyle, several studies conducted on the health of S-K individuals/groups in South Africa suggest that in general, hunter-gatherer/herder groups seemed to be in good health (Lee, 1979; Morris, 1992; Pfeiffer & Crowder, 2004; Pfeiffer, 2011, Lindeberg, 2012, Barnard, 2008, Botha & Steyn, 2016).

2.3.4. The need for sex estimation in HS-K populations

Most of what anthropologists know about hunter-gatherer lifestyle has been influenced by studies of recent S-K populations. Contemporary populations such as the Kalahari San have for a long time occupied a central position in hunter-gatherer/herder studies. Similarly, skeletons of contemporary S-K populations have formed the basis of most early anthropological research into the biological origins of these groups (Stynder *et al.*, 2007b, 2009).

Whilst studies on contemporary/proto-historic S-K populations are considered to be the best available analogues for early S-K populations, they cannot replace studies of prehistoric skeletal material. Prehistoric communities occupied vastly different regions, physically and

socially, than contemporary groups (Wright & Weintroub, 2014). Additionally, evolutionary pressures may mask or obliterate patterns present in the past, which is especially problematic if one is looking at phenotypic relationships (Stynder *et al.*, 2007b). It is also well-known that recent populations show evidence of admixture with neighbouring populations (Cavalli-Sforza *et al.*, 1994; Cruciani *et al.*, 2002; Franklin *et al.* 2007, Franklin *et al.* 2010). Ideally, the population structure and evolutionary history of prehistoric and early colonial S-K populations should be studied from their remains.

Research combining bioarchaeological analyses of past populations with ethnographic information provides a less biased understanding of these populations. Past HS-K group studies have been restricted, as analyses have been largely focused colonial-era individuals or site-specific case studies of a few individuals. Sealy (2003) attributes this time periods' lack of extensive research to poorly recorded archaeological associations, resulting in loss of information. Additionally, fragmentation and poor preservation of remains prevent accurate osteobiographical analyses in archaeological contexts (Wright & Yoder, 2003), making it difficult to interpret culture and lifestyle of these past populations. Specifically, sex estimation has proved challenging in multiple previous studies, as the range of sexual dimorphism and general small stature of the S-K populations do not conform to current sex estimation standards (Pfeiffer & Harrington, 2011; Kurki *et al.*, 2012), affecting our understanding of gender-based division of labour, subsistence strategies, burial practices and interpretations of inter-personal violence in these societies, amongst others (Collier, 1993; Wadley, 1996, 1997; Stock & Pfeiffer, 2001, 2004; Pfeiffer & Harrington, 2011; Kurki *et al.*, 2012; Pfeiffer *et al.*, 2019, Gibbon & Davies, 2020).

The active lifestyle of these groups accentuates muscle markers and muscle attachment sites on limbs (Churchill & Morris, 1998), and this can impact cranial morphological traits used in sex estimation methods. Additionally, accurate metrical parameters used for sexing, such as epiphyseal head diameters being correlated with body mass means that it should be a reasonable sex indicator in populations with more significant dimorphism in size (Stock & Pfeiffer, 2001; Kurki *et al.*, 2010; Ruff *et al.*, 2012). However, it is important to assess whether these measurements are dimorphic in the relatively smaller HS-K population. Stock and Pfeiffer (2004) showed that, prior to 2 000 BP, subsistence activity patterns in females are consistent throughout the Holocene. Sealy *et al.* (1992) suggest that after 3 000 BP, gender relationships may have changed due to unequal gender-based access to resources. Whilst

everyone had access to plant foods, based on historical ethnographic sources, these were considered to be the domain of women more than men. Therefore, observed higher occurrence of robust muscle markers in men may not be due to higher activity rates, but rather a genetic and physiological predisposition, which requires further study (Stock & Pfeiffer, 2001; Dewar & Pfeiffer, 2004).

However, none of these aspects of HS-K life can be confidently explored in the absence of accurate sex estimation methods for this population. Previous studies have commented on the unsuitability of contemporary sex estimation methods and have highlighted the need for developing population-specific standards to better understand the lifeways and practices of these people (Pfeiffer & Harrington, 2011; Kurki *et al.*, 2012; Pfeiffer *et al.*, 2019, Gibbon & Davies, 2020).

2.4. Aims and objectives

The aim of the proposed research was to assess the accuracies of existing sex estimation methods when applied to an HS-K assemblage. It was hypothesised that these will produce low classification accuracy rates in the given population, thus, the secondary aim of the study was to use the obtained accuracy results to optimise the sex estimation methods being assessed for HS-K-specific application.

Objectives of the study include:

- Assess which skeletal traits/landmarks are best preserved, to allow for application of sex estimation methods.
- Estimate pelvic sex for all individuals using the most reliable methods with known minimal error rates (*i.e.*, the Phenice method of the pelvis and available molecular sex data), against which subsequent estimates will be compared.
- Estimate sex using multiple methods, namely, morphological assessments of the cranium and mandible, and metric assessments of the mandible and post-crania.
- Determine classification accuracies of the methods used compared to pelvic sex estimates.
- Optimise assessed methods using results obtained from the previous accuracy analyses, *i.e.*, identification of optimal/problematic traits for sexing using obtained morphological data, and generation of population-specific discriminant functions from metrical data.

Through the assessment of the proposed sex estimation methods, this study aims to address the following, that have to date limited sex estimation efforts in the HS-K population:

- Which traits/parameters are best preserved for sex estimation in the HS-K population?
- How accurate are the assessed HS-K morphological cranial and mandibular traits when compared to pelvic sex estimates?
- Which combination of morphological traits produces the highest classification accuracy rate for this population?
- How accurate are the assessed HS-K metrical parameters when compared to pelvic sex estimates?
- The generation of HS-K-specific discriminant function equations.

CHAPTER 3

MATERIALS & METHODS

3.1. Study design

This study was an observational, retrospective study, that involved assessing sex in an archaeological sample, where original data were collected directly from HS-K assemblages and assessed using existing sex estimation methods. This study used both metrical and non-metrical methods in a cross-sectional approach. This was to mimic real-life practices, as a mixture of sex estimation methods are generally employed due to the wide range of available sexing techniques with variable accuracy rates and provides a holistic view of outcomes obtained when global sexing standards are used.

Consent for this study was obtained from the UCT Faculty of Health Science, Human Research Ethics Committee (Ref# 488/2020) as well as the National San Council (Appendix A: Figure A1-A3). The research conducted is in accordance with the San National Code of Research Ethics and curators of all skeletal collections used formally approved the study through their respective institutions' application processes.

3.2. Materials

Research material consisted of HS-K skeletal remains from three established skeletal repositories used for Holocene research within South Africa, namely: Iziko Museum (previously 'South African Museum'), National Museum (Bloemfontein), and University of Cape Town (UCT) Human Skeletal Repository. Skeletal repositories have been shown to hold great value for teaching and research purposes and aided in advancing knowledge in bioarchaeology and forensic anthropology (L'Abbé *et al.*, 2005; Alblas *et al.*, 2018).

3.2.1. Iziko Museum

Iziko Museum (then 'South African Museum') was first formed in 1825 and is the oldest of all human skeletal repositories in South Africa (Morris, 1992). By the 1880's it had become the premier repository for ethnographic and natural history collections, and by the start of the 21st

century it had obtained the majority of what is now the largest assortment of human skeletal remains in the country (Morris, 1992). Iziko museum currently holds the human remains of approximately 1 200 individuals, most with geographical context. The collection is overwhelmingly Cape-oriented with a large proportion of individuals from the West or South Cape Coast (Morris, 1992).

3.2.2. National Museum (Bloemfontein)

A significant proportion of individuals at the National Museum's Skeletal Repository were first obtained through donations of accidental discoveries by members of the public (Morris, 1992). This repository obtained most of their skeletal remains from controlled excavations in archaeological contexts by museum or university staff (Morris, 1992). The National Museum currently houses remains of multiple S-K interments of varied spatial and temporal origin.

3.2.3. University of Cape Town (UCT) Human Skeletal Repository

The Division of Clinical Anatomy and Biological Anthropology in the Department of Human Biology at UCT, houses the UCT Human Skeletal Repository (Gibbon & Morris, 2021). It contains just over a thousand human remains from archaeological, forensic, and cadaveric contexts. These are managed and curated in accordance with the National Health Act (2003) regulated by the inspectorate of anatomy and the South African Heritage Resources Agency (SAHRA), under the graves and burial grounds section 36 of the National Heritage Resources Act No 25 of 1999 (Gibbon & Morris, 2021).

The archaeological human remains in the UCT Repository are predominantly from the Western Cape region of South Africa; however, a wide geographic range from the whole of southern Africa is represented. Of these, approximately 150 S-K individuals have been dated to the Holocene period.

3.3. Study Sample

The study sample consisted of HS-K individuals from the above-mentioned repositories, selected according to the following criteria:

- Adult individuals (exhibiting complete epiphyseal fusion of all long bones, excluding the clavicle).
- Presence of intact pubic bones/fragments allowing for morphological pelvic sex estimation according to the Phenice method, along with one or more skeletal elements identified for secondary sex estimation (*i.e.*, mandible, cranium, humeral or femoral head).
- Ability to assess sex as unambiguously female or male based on pelvic morphology.
- No evidence of trauma or pathology affecting assessed metric proportions of the bones.

A power analysis using 95% confidence level and confidence interval of 10 indicated that a minimum sample size of 96 individuals held adequate statistical power (MacCallum *et al.*, 1996). Individuals included originated from both coastal (within 20 km from the coastline) and inland (further than 20 km from the coastline) spatial contexts (Gibbon & Davies, 2020). Select individuals from the relevant time-period who were not officially classified as S-K in repository records, were included based on burial position and/or associated grave goods, if recorded to be characteristic of S-K populations (Sealy, 2010). The sample also included three recently excavated adult S-K individuals who had not been officially accessioned into the UCT Repository at the time of analysis, and eight unaccessioned individuals temporarily curated at UCT's Department of Archaeology.

3.4. Methods

Overview

- Pelvic sex was estimated using Phenice traits (and molecular sex data, where available), and used as a reference that subsequent estimates were compared to.
- Sex estimation methods being tested (morphological and metrical techniques) were carried out on the same individuals.
- Secondary sex estimates were compared to pelvic sex to assess method accuracy and to improve existing sex estimation methods.
- Morphological results were used to identify non-pelvic areas of the skeleton optimal for estimating sex.
- Metric data obtained were used to create HS-K-specific discriminant functions.

3.4.1. Observer error assessment

To assess the reproducibility of data and consistency of the data collection process, intra- and inter-observer error tests were conducted for all analyses prior to the beginning of systematic data collection. Intra-observer error assessments were conducted on 10 individuals that were assessed according to the data collection process described above. Approximately 24 hours later, this process was repeated to obtain a second set of recordings. Inter-observer error assessments were carried out on the same 10 individuals by a single peer with a higher level of training in the field. Following explanation of the data collection process, they independently collected data according to the study methods (described in greater detail below).

Results obtained from both error assessments underwent statistical analyses to determine the level of agreement. This was done on SPSS Statistics (IBM© Corp, 2020) using Cohen's Kappa testing on the morphological/categorical data and Bland-Altmann plots on the metric/continuous data. Parameters that showed weak or lower kappa levels of agreement (Table 3.1) were excluded from further analysis.

Table 3.1: Cohen's kappa agreement values as interpreted by McHugh (2012).

Kappa value range	Level of Agreement	Percentage of data that are reliable
0 – 0.2	None	0 – 4%
0.21 – 0.39	Minimal	4 – 15%
0.4 – 0.59	Weak	15 – 35%
0.6 – 0.79	Moderate	35 – 63%
0.8 – 0.9	Strong	64 – 81%
Above 0.9	Almost perfect	82 – 100%

3.4.2. Pelvic sex estimation

To assess a method's accuracy, results obtained using that method were compared to a 'known/predicted' result (*i.e.*, study control). If the obtained result matched the control, the method outcome was considered accurate. However, in the case of an archaeological sample, due to the obvious lack of demographic details, the actual sex of an individual (the control) is unknown. Therefore, prior to assessing the accuracies of sex estimation methods, a pelvic sex estimate was generated for all individuals as the 'control' that subsequent sex estimates could be compared to. This was done using the Phenice method (Phenice, 1969) (Figure 3.1A), as well as assessment of other pelvic features (if required) such as the greater sciatic notch and pre-auricular sulcus. Pelvic traits were scored (Figure 3.1B), and results recorded on a

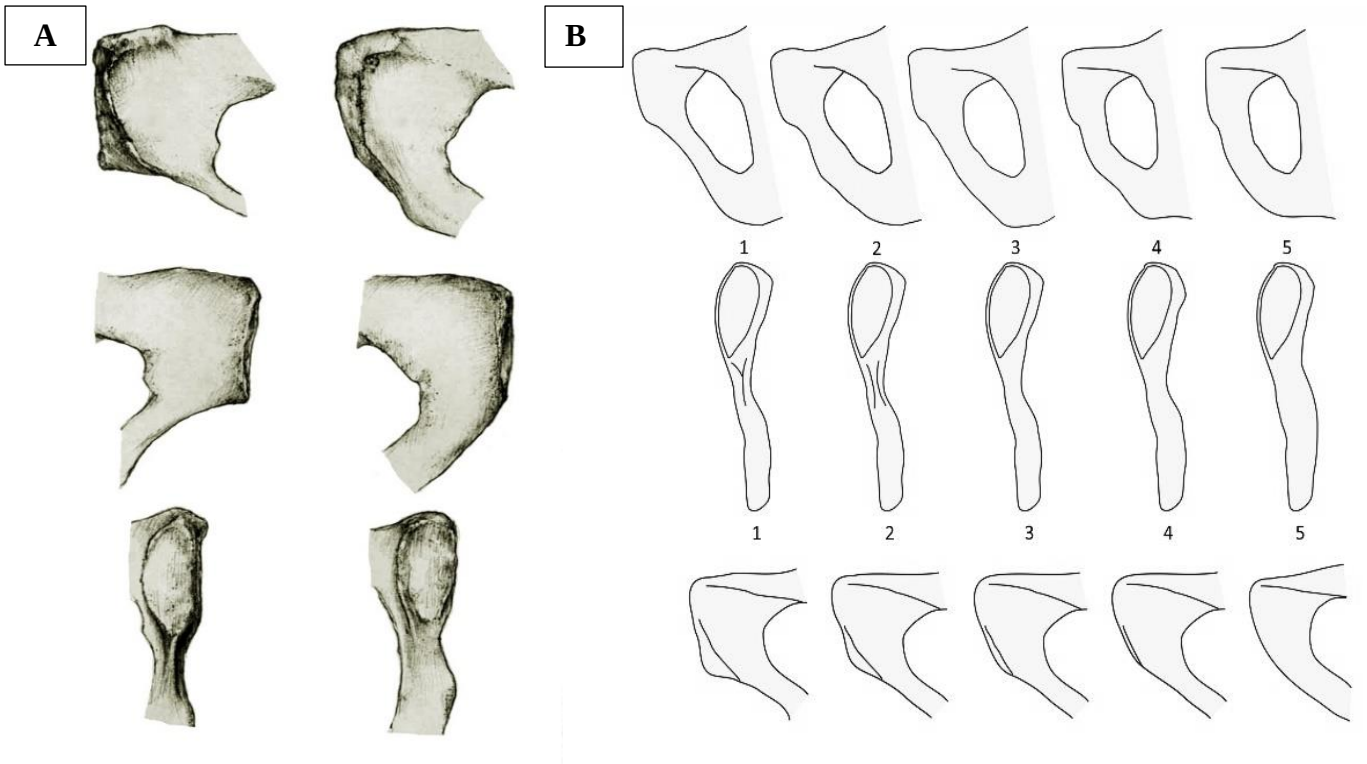

Figure 3.1: Pelvic sex estimation using the Phenice method (1969). **A:** Phenice's (1969) morphological traits of the pubis for the female (left) and male (right) form. From top to bottom: ventral arc, the subpubic concavity, and the medial aspect of the ischio-pubic ramus. (Image from Klales *et al.*, 2012; adapted from Phenice, 1969). **B:** Diagram of 5-grade scoring scheme of Phenice method traits proposed by Klales *et al.* (2012) (Calculated using the global model defined by Kenyhercz *et al.*, 2017). Phenice traits from top to bottom: sub-pubic concavity, medial aspect of the ischio-pubic ramus, ventral arc. Trait scoring key: 1 – 2: female, 3: indeterminate, 4-5: male.

spreadsheet to await statistical analysis. 'Known' molecular sex data (available for 17 individuals) were obtained through ancient DNA analyses conducted during previous studies.

The analysis of DNA is the most accurate method for sex estimation (Bašić *et al.*, 2017) and the Phenice method has a known accuracy rate of 95% with the pelvis providing the most reliable basis for sex estimation (Steyn *et al.*, 2012; İşcan & Steyn, 2013). Using techniques such as these, with known minimal error-rates, provides a confident sex estimate to be used as a reliable reference for the remainder of the study. Individuals presenting ambiguous sex results after pelvic assessment were excluded from further analysis. This approach, to include only individuals whose sex is unambiguous based on pelvis morphology, follows that of previous studies (MacLaughlin & Bruce, 1985; Dittrick & Suchey, 1986; Murphy, 2005; Dabbs, 2010; Marlow, 2016).

Observer scores of the relevant traits were recorded on categorised spreadsheets. A sex estimate was assigned to all individuals based on the average of all pelvic traits analysed. To

avoid biasing/influencing subsequent results, pelvic sex data were not viewed until the end of other data collection.

3.4.3. Accuracy assessment of sex estimation methods

Secondary sex estimations using multiple sex estimation methods were conducted on non-pelvic regions of the skeleton. Skeletal elements and the methods used to assess them were selected after considering several factors, namely: level of sexual dimorphism displayed by the skeletal element, literature reports of sexing accuracy of methods used, and preservation/recovery rates of skeletal elements.

For the morphological assessment, the cranium and mandible were selected. Sex was estimated on the crania using the five morphological traits described by Buikstra and Ubelaker (1994), *i.e.*, glabellar area, supra-orbital margin, mastoid process, nuchal area, and mental eminence, according to the ordinal 5-grade scoring system described by Walker (2008) (Figure 3.2A).

For the mandible, mandibular shape and gonial flaring were visually assessed (Brickley & McKinley, 2004; Hu *et al.*, 2006). Square/U-shaped mandibular curvature was recorded as masculine whilst rounded was recorded as feminine, and presence of gonial flaring was recorded as masculine whereas absence/inversion was recorded as feminine (Figure 3.2B) (Hu *et al.*, 2006; Singh *et al.*, 2015; Inskip *et al.*, 2018). All morphological data recorded were transferred to a spreadsheet to await statistical analysis.

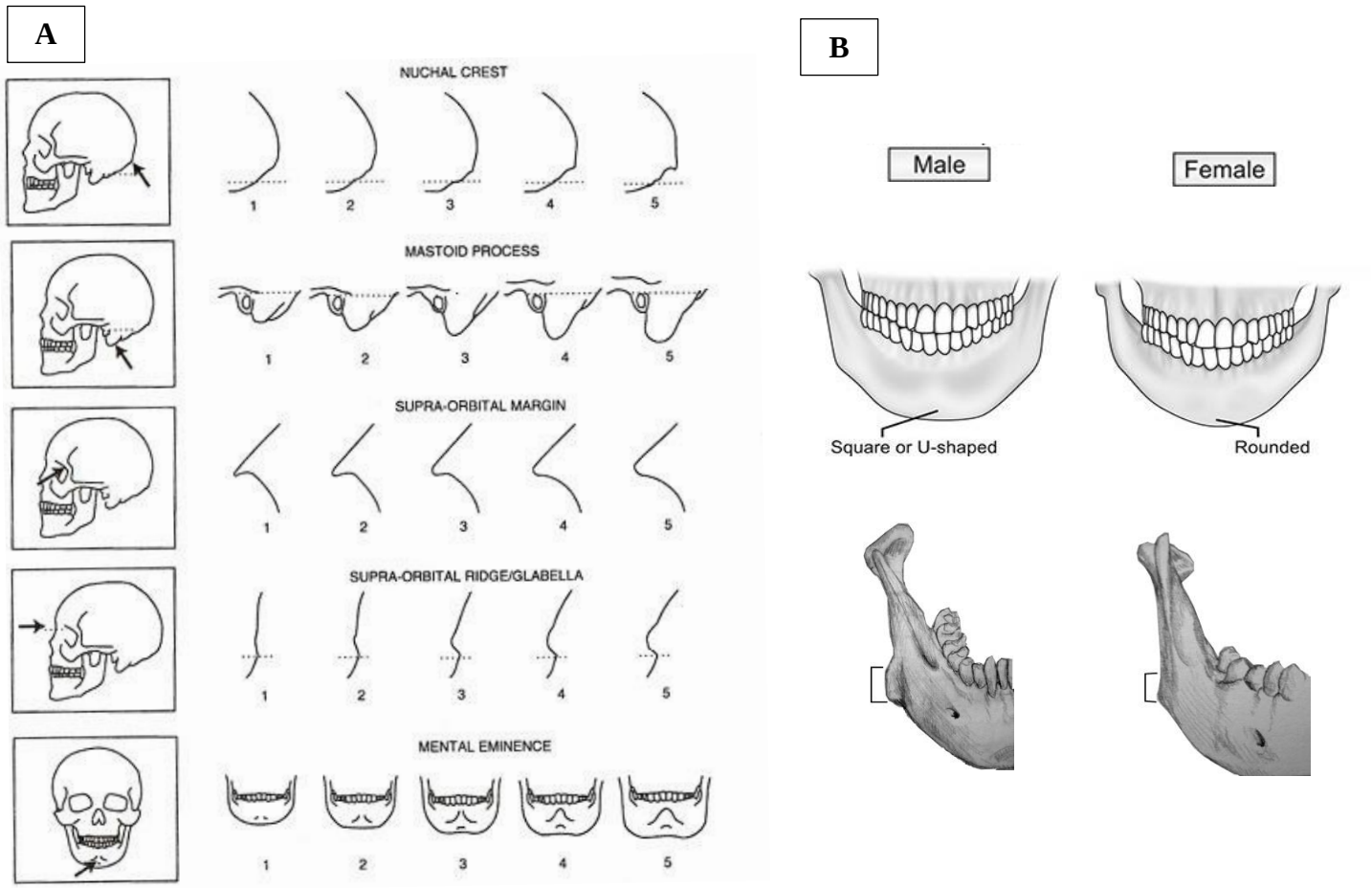

Figure 3.2: Morphological sex estimation using cranial and mandibular traits. **A:** Ordinal 5-grade scoring system described by Walker (2008) for the five morphological cranial traits described by Buikstra and Ubelaker (1994), *i.e.*, nuchal crest, mastoid process, supra-orbital margin, glabellar and mental eminence. **B:** Masculine and feminine morphological variation of mandibular traits. Upper = Mandibular shape, Lower = Gonial flaring (Images obtained from Biswas (2012): Mandibular shape images created by Rajesh Singh).

For the metrical mandibular assessment, seven common mandibular parameters described in literature to be sexually dimorphic and to estimate sex with high accuracies (Table 3.2), were measured in accordance with previous studies (Steyn & İşcan, 1998; Franklin *et al.*, 2006; Franklin *et al.*, 2008; Sikka & Jain, 2016). Chosen landmarks (Figure 3.3) correspond to those commonly used in traditional metrical methods (Table 3.2) (de Villiers, 1968; Buikstra & Ubelaker, 1994). Due to the population-specific nature of metrical methods, the unique morphology of the HS-K population, and the lack of HS-K specific discriminant function equations, it was assumed that existing discriminant functions would perform poorly in this population. As such, the chosen metrical measurements were used to calculate new discriminant function formulae (using DFA) for this sample.

Table 3.2: Definitions of mandibular landmarks and parameters used in this study (Franklin *et al.*, 2006)

Landmark	Abbreviation	Definition
Bilateral Landmarks		
Coronion	Co	The most superior point on the coronoid process
Condylion superior	Cs	The most superior point on the mandibular condyle
Condylion laterale	Cdl	The most lateral point on the mandibular condyle
Gonion	Go	The most lateral external point of junction of the horizontal and ascending rami lower jaw
Midline Landmarks		
Pogonion	Pg	The most projecting point of the chin in the standard sagittal line

Parameter	Abbreviation	Landmarks
Bicondylar breadth	BB	cdl – cdl
Bicoronoid breadth	BCB	co – co
Bigonial breadth	BGB	go – go
Body/corpus length	BL	go – pg
Coronoid height	CH	co – go
Max. mandible length	MML	cs – pg
Ramus height	RH	cs – go

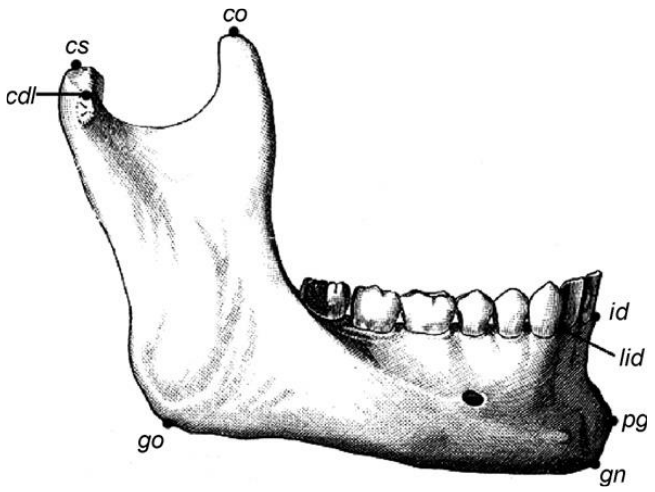

Figure 3.3: Mandibular landmarks commonly used in metric analysis of the mandible (see Table 3.2 for key) (Image from Franklin *et al.*, 2006).

For the post-cranial metrical assessment, humeral and femoral vertical head diameter were metrically assessed (shown to be sexually dimorphic and provided accurate sex estimation in other populations) (Steyn & İşcan, 1997, 1999; Vance *et al.*, 2011). Humeral head diameter was measured from the most superior to inferior margins of the articulation surface, whilst femoral head diameter was measured at the longest dimension occurring anywhere around the circumference of the head (Figure 3.4). Like with the mandibular metrical assessment, the chosen measurements for the post-cranial epiphyses were also used to calculate new discriminant function equations for this sample.

The metrical assessment of the mandible, humeral and femoral heads were carried out using specialised osteometric equipment, *i.e.*, digital Vernier callipers. Each measurement was recorded twice (to the nearest 0.1 mm), averaged, and then transferred to spreadsheets for statistical analysis.

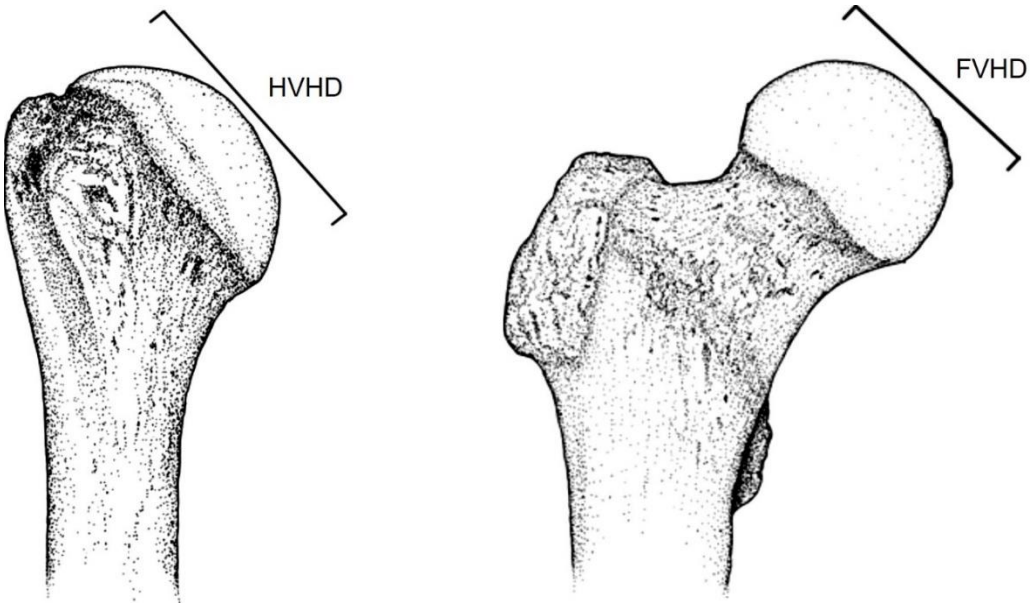

Figure 3.4: Humeral and femoral head diameter measuring convention. Left: Humeral head diameter, measured from the most superior to inferior margins of the articulation surface. Right: Femoral head diameter, with the longest dimension occurring anywhere around the circumference of the head. (*Image not to scale - adapted from Milner and Boldsen, 2012*).

3.4.4. Age estimation

Age-at-death was estimated using cranial suture closure and pelvic and rib-end morphology. Cranial suture assessment involved estimating age using the ectocranial site analysis technique. Sutures assessed included midlambdoid, lambda, obelion, anterior sagittal suture, bregma, midcoronal suture, pterion, sphenofrontal suture and inferior- and superior- sphenotemporal sutures. Suture sites were grouped into vault and antero-lateral groups, and composite scores were calculated within each group. Suture obliteration was scored based on specified scoring standards for these defined groups (Meindl & Lovejoy, 1985).

Where possible, age was also assessed using rib end modifications and pubic symphyseal surface degeneration (both of which are sex-dependent analyses) (Brooks & Suchey, 1990). Additionally, the pelvic auricular surface was also assessed (Lovejoy *et al.*,

1985). Based on the age estimated by combination of all the above-mentioned methods, individuals were classified broadly as young (YA = 20- 35 years), middle-aged (MA = 35- 50 years) or old adults (OA = >50 years) (Buikstra & Ubelaker, 1994). There are currently no standards for the accurate estimation of age for S-K individuals, as such, age estimations were based on described European standards in accordance with previous similar studies (Pfeiffer, 2011, 2012; Botha & Steyn, 2016; Gibbon & Davies, 2020).

3.4.5. Data analysis

a. Morphological sex estimation

The distribution of scores for morphological traits were analysed to assess the range of sexual dimorphism exhibited by each trait. Levels of gracility/robusticity (masculine vs feminine scores) of each morphological trait were compared to the individual's pelvic sex estimate and recorded as 'concordant', 'discordant', or 'indeterminate'. Traits that had scores corresponding to the individuals reference sex were recorded as concordant observations, whereas mismatches between morphological trait scoring and reference sex was recorded as discordant, *i.e.*, gracile scores (1 or 2) were considered concordant if the pelvic sex of the individual was female, and discordant if the pelvic sex of the individual was male (and vice versa for robust scores of 4 or 5). Scores of 3 were recorded as indeterminate/ambiguous. The same was done for combined cranial and mandibular sex estimates.

The combined cranial sex estimate was determined by combination of all Walker (2008) traits (*i.e.*, nuchal crest, mastoid process, supra-orbital margin, glabella, mental eminence), and the combined mandibular sex estimate was determined by combination of all mandibular traits assessed.

The number of concordant observations out of the total number of observations were used to calculate percentage classification accuracies of the assessed traits, to identify those that had the greatest accuracy for sex estimation. Accuracy rates vary if indeterminate/ambiguous results are included or excluded. Inskip *et al.* (2018) address both approaches and state that some argue that these results should be left out of calculations of accuracy, as it is not technically an incorrect estimation. The counterargument was that if a high quantity of "indeterminate" estimates is produced by a trait/s, this may reveal important information regarding the trait's usefulness, as well as the degree of sexual dimorphism in a group, thus should be reported.

For clarity, both accuracy rates were calculated and reported. “Concordance accuracy” assessed the accuracy of concordant results in comparison to all observations, (including indeterminate and incorrect/discordant observations); whilst “classification accuracy” assessed the accuracy of concordant results in comparison to confidently classified sex estimates (feminine vs masculine scores), excluding indeterminate counts from the total amount of traits observed.

All analyses were assessed in the total pooled sample and in female and male samples individually. Due to the unequal number of male and female individuals, weighted percentages were used for all sex-specific analyses. The collated data were transferred to datasheets in SPSS Statistics (IBM© Corp, 2020). Due to the categorical nature of the morphological assessments, this data was assessed using chi-squared tests with 95% confidence intervals where *p*-values of ≤0.05 indicated statistical significance.

b. Trait sensitivity, specificity, and predictive value for estimating sex

Sensitivity and specificity values were calculated to assess the range of sexual dimorphism exhibited by each trait by assessing the trait’s probability of classifying an individual as either female or male. Positive predictive values (PPV) and negative predictive values (NPV) were calculated to assess how accurately the observed range of sexual dimorphism estimates sex when individual traits are assessed (Curate *et al.*, 2016; Carvallo & Retamal, 2020).

Sensitivity and specificity are concerned with the accuracy of a test relative to a reference standard (in this case: pelvic sex), with the main question being: do the results on a test (*i.e.*, trait sex estimation) correspond to the results on the reference standard (pelvic sex)? In this case, ‘sensitivity’ was defined as a trait’s gracility bias (likelihood/probability of a trait classifying an individual as female), whereas ‘specificity’ refers to robusticity bias (likelihood/probability of male classification). It is emphasised that these are used here as measures of probability (Dangvard Pederson *et al.*, 2019), rather than precision. Confidence in a test’s ability to differentiate successfully between male and female is different. ‘PPV’ refers to the accuracy of a trait’s sensitivity score/gracility bias in comparison to the individual’s pelvic sex, while ‘NPV’ refers to the accuracy of a trait’s specificity score/robusticity bias in comparison to pelvic sex (Curate *et al.*, 2016; Dangvard Pederson *et al.*, 2019; Carvallo & Retamal, 2020). Sensitivity, specificity, PPV and NPV values were calculated for each trait using the 2x2 table format below (Table 3.3).

Table 3.3: Trait sensitivity, specificity, and predictive value calculations using a 2x2 table.

		Pelvic Sex		*Totals*
		Female	***Male***	
Trait Sex Estimate	***Female***	**A**: True positive	**B**: False positive	***A+B** = Total trait-classified females*
	Male	**C**: False negative	**D**: True negative	***C+D** = Total trait-classified males*
	Totals	***A+C** = Total females in sample*	***B+D** = Total males in sample*	***A+B+C+D** = Total sample*
Sensitivity/Gracility bias = A / (A+C) x 100. Specificity/Robusticity bias = D / (B+D) x 100. Positive predictive value (PPV) = A / (A+B) x 100. Negative predictive value (NPV) = D / (C+D) x 100.				

c. Metrical sex estimation

For the metrical analyses, general descriptive statistics (means and standard deviations) were calculated for each of the parameters assessed. Metrical variables assessed, whilst continuous, were obtained from a death assemblage (not reflective of a living population) (Wood *et al.*, 1994; Jackes, 2011) and a limited sample size, thus normal distribution was not assumed (Siebert & Siebert, 2018). Additionally, some parameters assessed were not normally distributed (prior to identification and removal of outliers). As a result, non-parametric *t*-tests (*i.e.* Mann-Whitney U tests) were used to assess whether significant differences existed (*p*-value ≤ 0.05) between female and male groups of each measurement (Siebert & Siebert, 2018).

Measurement distribution of each parameter were assessed to identify any sex-specific trends. Demarking points (average of mean values for each sex) were calculated for each variable. These are a quick way of estimating sex from individual measurements (where measured values higher than the demarking point = male, and lower values = female) (Robinson & Bidmos, 2009, 2011; Mokoena *et al.*, 2019). Average classification accuracies were calculated for each variable by using the demarking points to estimate sex and comparing this estimate to the individual's pelvic sex.

Sexual dimorphism ratios were calculated to assess general patterns of dimorphism (sexual dimorphism ratio = male mean/female mean × 100) (Asala *et al.*, 2004). Following this, univariate and multivariate (stepwise and direct) DFA were performed to find functions that can discriminate between sexes with known accuracy. DFA is used to develop an index of maximum discrimination between two groups (here, sex) where variation is maximum among groups and minimum within groups (Sikka & Jain, 2016). During the DFA process, an additional "Test of Equality of Group Means" was conducted to further confirm if significant

differences between means existed, rendering parameters suitable for discriminant function analysis despite their initial non-parametric nature. The discriminant function formulae developed here are the first of their kind for S-K populations.

- In univariate analysis, each measurement was individually subjected to discriminant function analysis.
- In direct discriminant analysis, four groups of measurements were entered into SPSS:
    - Mandibular parameters only
    - Post-cranial (humeral and femoral) parameters only
    - All parameters combined
    - Best performing parameters (determined from prior univariate analysis).

  Direct discriminant functions were derived for each group assessed.
- In stepwise discriminant function analysis, the same four groups of variables above were entered, but SPSS selected the best combination of measurements in each group and four stepwise functions were derived.

From these analyses, coefficients and constants were obtained, which are useful in calculating discriminant function scores (DFS) through the derived discriminant equations. The original samples used in the creation of the equations were cross-validated and a "leave-one-out" classification procedure was applied to determine final accuracy rates of the generated equations. The cross-validation procedure successively classifies all cases but one, to develop a discriminant function, and then categorizes the case that was left out (and is repeated with each case being left out in turn) (Bidmos & Mazengenya, 2021). This process is believed to produce a more reliable function. The argument being that the case you are trying to predict should not be used as part of the categorisation process. Whilst it is ideal to have an independent test sample, this is not always practical. This method of using the data sample as a test sample as well is a good alternative. Overall, predictive accuracy often decreases with cross-validation but is considered acceptable if cross-validated accuracy rates are much larger than what could be obtained by chance (Bidmos & Dayal, 2003; Bidmos & Mazengenya, 2021).

When these equations are applied to bone measurements, classification can occur depending on whether the DFS is greater or less than the sectioning point (sectioning point = average of male and female centroids (means)). *E.g.*, if the male mean of measurement is greater than the female mean, and the discriminant function score is greater than the sectioning point, the bone is classified as male. Conversely, if the discriminant function score is less than

the sectioning point, the bone is classified as female. The further the DFS is from the sectioning point, the greater the reliability in correctly assigning sex (Thieme & Schull, 1957; Dayal *et al.*, 2008; Robinson & Bidmos, 2009, 2011; Wankhede *et al.*, 2015; Mokoena *et al.*, 2019).

All data were assessed using IBM© SPSS Statistics for Windows, version 27 (IBM© Corp, 2020) and statistical significance was observed at p-values≤ 0.05. *(All data recorded during data collection and analysis are summarised in Appendix B).*

CHAPTER 4

RESULTS

4.1. Study Sample

Following a survey of South African skeletal repositories for HS-K individuals, a total of 175 individuals met criteria for inclusion in the study. Of these, 35% (61/175) were from Iziko Museum, 8% (14/175) were from the National Museum, and 57% (100/175) from the UCT Repository (Table 4.1).

The power analysis conducted (95% confidence level, confidence interval = 10) indicated that a minimum sample size of 96 individuals held adequate statistical power (MacCallum *et al.*, 1996). Therefore, the sample size selected for this study is deemed statistically sufficient.

Table 4.1: Study sample distribution divided by repository.

Skeletal Repository	Number of individuals (n)	Percentage of sample (%)
Iziko Museums	61	35
National Museum (Bloemfontein)	14	8
UCT Skeletal Repository	100	57
Total	175	100
Of the 100 individuals from UCT, 92 were derived from the UCT Skeletal Repository in the Faculty of Health Sciences and 8 were unaccessioned individuals temporarily curated UCT's Department of Archaeology.		

4.2. Observer Error

Morphological scores for inter-observer error analyses showed moderate Cohen's kappa levels of agreement (greater than 0.6). Those for intra-observer error analyses showed almost perfect Cohen's kappa levels of agreement (greater than 0.9) (Appendix C). The high agreement levels of the morphological scores obtained in both observer assessments speak to the reliability and repeatability of the methods being used. As such, the work continued as planned, using the proposed morphological methods.

Of the assessed metrical parameters, inter-observer error analysis identified three measurements that showed consistently low agreement between observers when assessed using Bland-Altmann plots (Appendix C), namely: ramus height (cs – go) (18% of recordings exceeded 95% agreement levels), body/corpus length (go – pg) (17% beyond 95% agreement

levels), and bigonial breadth (go – go) (8% beyond 95% agreement levels). For intra-observer error analyses, two measurements showed consistently low agreement between repeats, namely: ramus height (cs – go) (9% of recordings exceeded 95% agreement levels), and body/corpus length (go – pg) (8% beyond 95% agreement levels). Thus, low agreement levels were found specifically in connection with the gonion or pogonion landmarks. This suggests a degree of subjectivity in locating these landmarks. As such, the three parameters with the highest combined intra- and inter-observer error scores (*i.e.*, lowest agreement) were excluded from further use during the study, namely, ramus height (cs – go) (14% non-agreement), body/corpus length (go – pg) (13% non-agreement) and bigonial breadth (go – go) (8% non-agreement), leaving six metrical parameters for inclusion.

4.3. Sample demographics

Based on a combination of pelvic sex estimates and molecular sex data, 55% (97/175) of the sample was male and 45% (78/175) female (Table 2). Molecular sex results were available for 10% (17/175) of the sample. Of these, 12 individuals had matching pelvic sex estimates, and 5 had molecular sex results only (*i.e.*, lacked assessable pelves).

Hypothesis-testing using a one-sample chi-squared test showed no significant differences between the numbers of male and female individuals in the sample. Similar pelvic sex distributions were observed when individual repositories were assessed separately. The Iziko Museum sub-sample was 61% (37/61) male and 39% (24/61) female, the National Museum sub-sample had equal numbers of males and females (50%, 7/14), and the UCT Repository had 53% male (53/100) and 47% female individuals (47/100) (Table 4.2).

Table 4.2: Sex distribution of sample based on pelvic morphology.

Pelvic sex	**Repository**						**Total**	
	Iziko Museums		**National Museum**		**UCT Skeletal Repository**			
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Female	24	14	7	4	47	27	78*	45
Male	37	21	7	4	53	30	97*	55
Total	61	35	14	8	100	57	175	100

Molecular sex results were available for 17 individuals from UCT Skeletal Repository (12 males, 5 females), 12 of which had corresponding pelvic sex estimates and the remaining 5 having only molecular sex results. Values that meet statistical significance (p-value≤0.05) are denoted by *.

For age estimation, 47% (83/175) of the sample was classified as MA, 10% (18/175) as YA, and 5% (9/175) as OA (Table 3). Due to the nature of age estimation and the multiple methods applied, the age ranges obtained for 34% (60/175) of the sample were large enough to span more than one of the age categories defined by Buikstra & Ubelaker (1994). These individuals were designated YA/MA (20-50 years) or MA/OA (35-50+ years), making up 21% (37/175) and 13% (23/175) of the sample, respectively. Age estimates could not be obtained for the remaining 3% (5/175) of the sample due to lack of skeletal elements/observable skeletal traits required for the methods applied (Table 4.3). Hypothesis-testing using a one-sample chi-squared test confirmed that the age categories do not occur with equal probabilities (*p*-value = 0.000). The same trend was observed when repositories were analysed separately. Chi-squared crosstabulations showed no significant associations between sex and age (Table 4.3).

Table 4.3: Age-at-death distribution of sample.

Age category	Pelvic sex	Repository						Total	
		Iziko Museums		National Museum		UCT Skeletal Repository			
		n	%	n	%	n	%	n	%
YA	Female	2	1	3	2	4	2	9	5
	Male	5	3	0	0	4	2	9	5
	Total	7	4	3	2	8	4	18	10
YA/MA	Female	3	2	1	1	7	4	11	7
	Male	11	6	3	2	12	7	26	15
	Total	14	8	4	3	19	11	37	22
MA	Female	12	7	1	1	31	18	44	26
	Male	10	6	2	1	27	15	39	22
	Total	22	13	3	2	58	33	83	48
MA/OA	Female	7	4	0	0	1	1	8	5
	Male	10	6	1	1	4	3	15	10
	Total	17	10	1	1	5	4	22	15
OA	Female	0	0	2	1	2	1	4	2
	Male	1	1	1	1	3	2	5	4
	Total	1	1	3	2	5	3	9	6
Could not be assessed	Female	0	0	0	0	2	1	2	1
	Male	0	0	0	0	3	2	3	2
	Total	0	0	0	0	5	3	5	3
Total	Female	24	14	7	4	47	27	78	45
	Male	37	21	7	4	53	30	97	55
	Total	61	35	14	8	100	57	175	100

YA = Young adult (20-34 years old); MA = Middle-aged adult (35-49 years old); OA = Older-aged adult (50+ years old) (Buikstra & Ubelaker, 1994). YA/MA and MA/OA categories refer to individuals with age-at-death estimates extending across more than one of the Buikstra & Ubelaker (1994)-defined age categories. Values that meet statistical significance (*p*-value≤0.05) are denoted by *.

4.4. Which traits/parameters are best preserved for sex estimation in this sample?

4.4.1 Morphological trait preservation

Of the 155 individuals available for morphological assessment, pelvic sex for 54% (84/155) of the sample was male, and 46% (71/155) female. Not all morphological traits-of-interest could be assessed on each individual due to differential preservation (Table 4.4). Traits with the highest preservation rates in the pooled sample were the supra-orbital margin, observable in 90% (139/155) of individuals, and glabella, observable in 88% (136/155) of individuals. The trait with the lowest preservation rate was mandibular shape, observable in 71% (110/155) of individuals, due to the many fragmented and half-mandibles encountered during the data collection process.

Table 4.4: Preservation rates of morphological sex estimation traits of the cranium and mandible.

Individual traits	Pelvic sex	Total		Assessed**		Could not be assessed	
		n	%	n	%	n	%
Nuchal crest*	Female	71	46	**62**	**87**	9	13
	Male	84	54	**73**	**87**	11	13
	Total	155	100	**135**	**87**	20	13
Mastoid process*	Female	71	46	**61**	**86**	10	14
	Male	84	54	**74**	**88**	10	12
	Total	155	100	**135**	**87**	20	13
Supra-orbital margin*	Female	71	46	**64**	**90**	7	10
	Male	84	54	**75**	**89**	9	11
	Total	155	100	**139**	**90**	16	10
Glabella*	Female	71	46	**60**	**85**	11	15
	Male	84	54	**76**	**90**	8	10
	Total	155	100	**136**	**88**	19	12
Mental eminence*	Female	71	46	**54**	**76**	17	24
	Male	84	54	**63**	**75**	21	25
	Total	155	100	**117**	**75**	38	25
Mandibular shape*	Female	71	46	**51**	**72**	20	28
	Male	84	54	**59**	**70**	25	30
	Total	155	100	**110**	**71**	45	29
Gonial eversion/flaring*	Female	71	46	**54**	**76**	17	24
	Male	84	54	**70**	**83**	14	17
	Total	155	100	**124**	**80**	31	20

Not all traits were observable in the 155 individuals available for morphological sex estimation analysis.
Values that meet statistical significance (p-value≤0.05) are denoted by *.
**Only counts of assessed traits were included in subsequent analyses.

In females, the highest preservation rates were for the supra-orbital margin (90%, 64/71) and nuchal crest (87%, 62/71), whilst the lowest was mandibular shape (72%, 51/71). In males, the highest preservation rates were for the glabella (90%, 76/84), supra-orbital margin (89%, 75/84) and mastoid process (88%, 74/84), whilst the lowest was mandibular shape (70%, 59/84).

Overall, similar preservation rates were observed for all traits in both sex categories (Table 4.4), with the largest preservation rate differences being 7% (female = 76%, male = 83%) for gonial eversion/flaring, and 5% (female = 85%, male = 90%) for glabella. Hypothesis-testing using a one-sample chi-squared test confirmed that preservation categories do not occur with equal probabilities (p-value ≤ 0.05).

4.4.2 Metrical parameter preservation

Of the metrically assessed individuals, pelvic sex for 56% (97/174) was male and 44% (77/174) female. Not all metrical parameters-of-interest were assessed on each individual due to differential preservation (Table 4.5). Parameters with the highest preservation rates in the pooled sample were femoral vertical head diameter (FVHD), observable in 89% (155/174), and humeral vertical head diameter (HVHD), observable in 80% (140/174). The parameters with the lowest preservation rates were bicondylar breadth (BB) (cdl-cdl), observable in 44% (76/174) of individuals, and bicoronoid breadth (BCB) (co-co), observable in 53% (91/174) of individuals, due to the many fragmented and half-mandibles encountered during the data collection process. Only counts of assessed traits were included in subsequent analyses.

Table 4.5: Preservation rates of metrical sex estimation parameters of the mandible, humerus and femur.

Metrical parameters		**Pelvic sex**	**Total**		**Assessed****		**Could not be assessed**	
			n	%	N	%	n	%
Mandibular	BB	Female	77	44	**36**	**47**	41	53
		Male	97	56	**40**	**41**	57	59
		Total	174	100	**76**	**44**	98	56
	BCB	Female	77	44	**43**	**56**	34	44
		Male	97	56	**48**	**49**	49	51
		Total	174	100	**91**	**53**	83	47
	CH*	Female	77	44	**60**	**78**	17	22
		Male	97	56	**68**	**70**	29	30
		Total	174	100	**128**	**73**	46	27

	MML*	Female*	77	44	**51**	**66**	26	34
		Male	97	56	**55**	**57**	42	43
		Total*	174	100	**106**	**61**	68	39
Humeral	HVHD*	Female	77	44	**60**	**78**	17	22
		Male	97	56	**80**	**82**	17	18
		Total	174	100	**140**	**80**	34	20
Femoral	FVHD*	Female	77	44	**70**	**91**	7	9
		Male	97	56	**85**	**88**	12	12
		Total	174	100	**155**	**89**	19	11

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter.
Values that meet statistical significance (p-value≤0.05) are denoted by *.
Only counts of assessed parameters were included in subsequent analyses.**

When assessed by sex, in both female and males, the highest preservation rates were for FVHD (Females = 91%, 70/77; Males = 88%, 85/97), whilst the lowest were for BB (Females = 47%, 36/77; Males = 41%, 40/97) (Table 4.5).

Overall, similar preservation rates were observed for all traits in both sex categories (Table 4.5), with the largest preservation rate differences being 9% (female = 66%, male = 57%) in maximum mandible length (MML) (cs-pg), and 8% (female = 78%, male = 70%) in coronoid height (CH) (co-go). Statistical significance (p-value ≤ 0.05) (showing rates of preservation do not occur by chance) was found for all parameters except BB (male, female, and pooled samples), BCB (male, female, and pooled samples), and the MML male sample.

4.5. Morphological sex estimation

Of the total sample, 89% (155/175) had the skeletal elements required for morphological sex estimation, *i.e.*, crania and/or mandibles (in addition to pelves used in pelvic sex estimation) (Appendix B: Skeletal element survey). All morphological sex estimation results listed below were obtained using this sub-sample of 155 individuals.

4.5.1. How accurate are the assessed HS-K morphological cranial and mandibular traits when compared to pelvic sex estimates?

a. Trait score distribution

Table 4.6 shows the distribution of scores for assessed traits. Of the five cranial traits, except for the supra-orbital margin, scoring distribution was skewed towards the lower, more gracile end of the spectrum. This was most pronounced in the nuchal crest, where 83% (112/135) of

scores were 1 or 2 (highly gracile) and only one was 5 (highly robust). Similarly, high proportion of scores 1 and 2 were observed for the mental eminence and glabella, with 63% (74/117) and 61% (83/136) respectively. The supraorbital margin had the largest proportion of intermediate/indeterminate 3-scores (29%, 40/139) and robust 4 and 5 scores (38%, 53/139). An opposite pattern was observed in the mandible, *i.e.*, gonial eversion/flaring and mandibular shape, where both traits showed a larger proportion of masculine/robust 4 and 5 scores (73%, 90/124 and 60%, 66/110, respectively) (Table 4.6).

Table 4.6: Summary of cranial and mandibular morphological trait scoring (for each sex individually and both sexes pooled).

Individual traits	Pelvic sex	Total assessed		1 (feminine)		2		3 (indeterminate)		4		5 (masculine)	
		n	%	n	%	n	%	n	%	n	%	n	%
Nuchal crest	Female	62	46	38	61	17	27	6	10	1	2	0	0
	Male	73	54	35	48	22	30	6	8	9	12	1	1
	Total	135	100	73	54	39	29	12	9	10	7	1	1
Mastoid process	Female	61	45	26	43	16	26	14	23	4	7	1	2
	Male	74	55	7	9	15	21	21	28	21	28	10	14
	Total	135	100	33	24	31	23	35	26	25	19	11	8
Supra-orbital margin	Female	64	46	10	16	20	31	18	28	15	23	1	2
	Male	75	54	2	3	14	19	22	29	32	43	5	7
	Total	139	100	12	9	34	24	40	29	47	34	6	4
Glabella	Female	60	44	28	47	25	42	0	0	6	10	1	2
	Male	76	56	12	16	18	24	17	22	20	26	9	12
	Total	136	100	40	29	43	32	17	13	26	19	10	7
Mental eminence	Female	54	46	19	35	18	33	15	28	2	4	0	0
	Male	63	54	9	14	28	44	19	30	7	11	0	0
	Total	117	100	28	24	46	39	34	29	9	8	0	0
Mandibular shape	Female	51	46	32	63	-	-	-	-	-	-	19	37
	Male	59	54	12	20	-	-	-	-	-	-	47	80
	Total	110	100	44	40	-	-	-	-	-	-	66	60
Gonial eversion/flaring	Female	54	44	21	39	-	-	-	-	-	-	33	61
	Male	70	56	13	19	-	-	-	-	-	-	57	81
	Total	124	100	34	27	-	-	-	-	-	-	90	73

Not all traits were observable in the 155 individuals available for morphological sex estimation analysis. *Only counts of assessed traits were included in subsequent analyses.
Walker (2008) traits (nuchal crest, mastoid process, supra-orbital margin, glabella and mental eminence) were assessed using the 5-score system directly.
Mandibular shape and gonial eversion/flaring were assessed as either gracile/female or robust/male, based on trait morphology, and thus lack intermediate categories.

When assessed by sex, most nuchal crest scores for both males and females were 1 or 2: 88% (55/62) of female scores and 78% (57/73) of males. A similar distribution was observed when assessing mental eminence, but with a higher proportion of indeterminate 3-scores (28% (15/54) in females, and 30% (19/63) in males).

Females

The pooled sample distribution of cranial trait scores (skewed towards the gracile scores, apart from the supra-orbital margin) were well-retained in the female sample (Table 4.6). This pattern, like both pooled and male-only samples, was most pronounced in the nuchal crest where 89% (55/62) of the traits scored either 1 or 2, followed by the glabella, with 88% (53/60). However, unlike the pooled and male-only sample, mandibular traits only had a greater 4 and 5-score proportion in gonial eversion/flaring (61%, 33/54), whilst mandibular shape had a larger 1 and 2-score proportion (63%, 32/51) (Figure 4.1).

Males

In males, scores of 4 or 5 were recorded for 81% (57/70) of individuals for gonial eversion/flaring and 80% (47/59) for mandibular shape (Table 4.6), similar to the high proportions of 4 and 5 scores for mandibular traits in the pooled sample (Figure 4.1). However, the tendency towards low scores (1 or 2) for cranial traits were observed only for the nuchal crest (78% 57/73) (most pronounced, like the pooled and female-only sample), mental eminence (58%, 37/63), and glabella (39%, 30/76) in males.

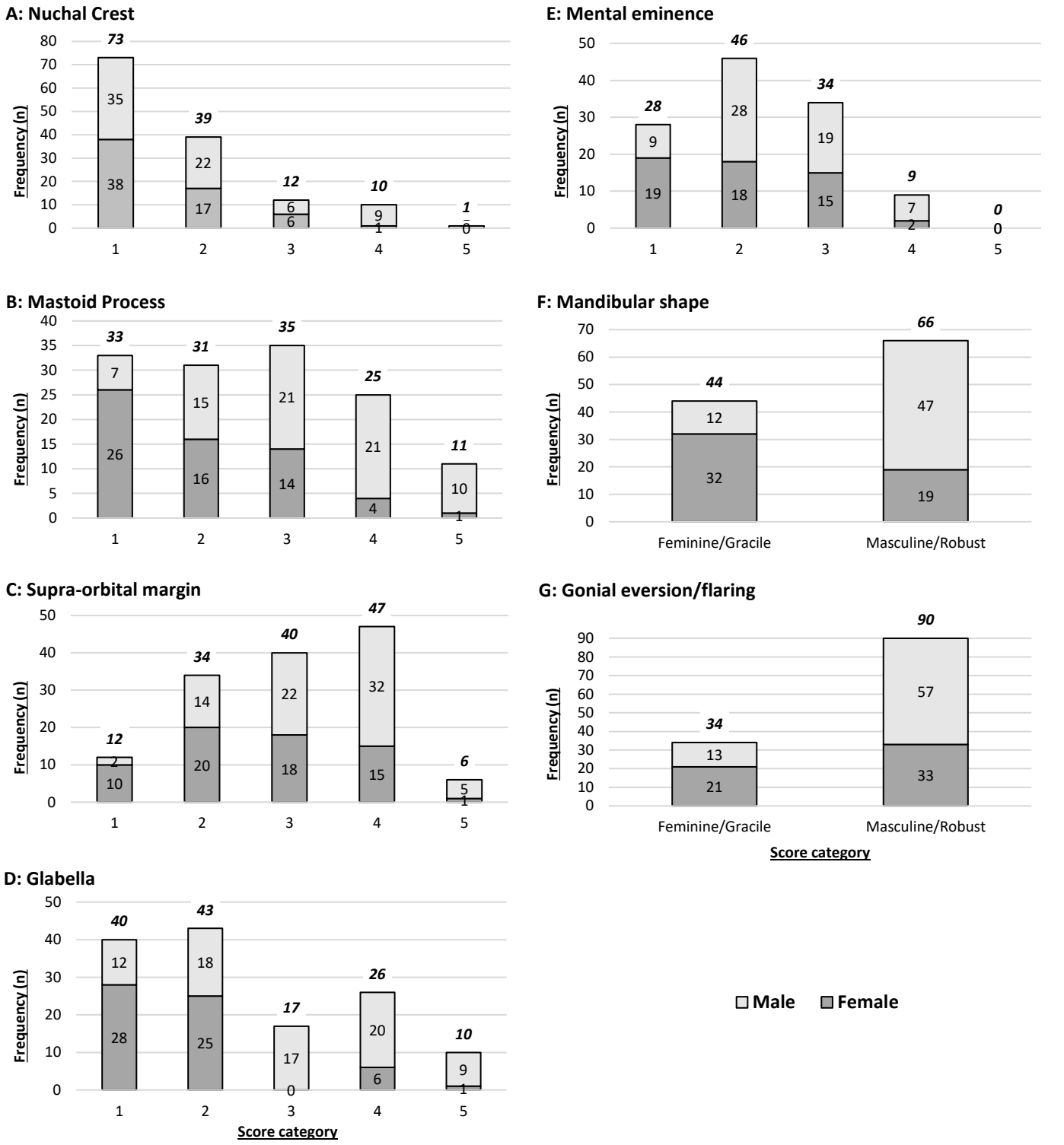

Figure 4.1: Score distribution of assessed morphological traits. A to E = cranial morphological traits scored on a 5-point scale described by Walker (2008) (1 and 2 = gracile/feminine, 3 = indeterminate/intermediate, 4 and 5 = robust/masculine); F and G = mandibular morphological traits (mandibular shape: rounded = feminine, U-shaped/square = masculine; gonial eversion/flaring: absence of eversion/inversion = feminine, eversion = masculine).

b. Trait accuracy

The accuracy rates of each individual trait as well as the combined cranial and mandibular traits are summarised in Table 4.7. 'Concordance accuracy' refers to the accuracy calculated when indeterminate scores are included in the total number of observations (as discordant results), whereas 'Classification accuracy' excludes indeterminate counts and refers to the percentage of traits that were confidently classified as female or male.

Table 4.7: Summary of cranial and mandibular morphological trait accuracy rates (for each sex individually and both sexes pooled).

Individual traits	**Pelvic sex**	**Total assessed**		**Concordant**		**Discordant**		**Indeterminate**		**Total assessed - indeterminate**	**Classification accuracy** (concordant / total assessed - indeterminate)
		n	%	N	%	n	%	n	%		
Nuchal crest	Female	62	46	55	**89***	1	2	6	10	56	**98***
	Male	73	54	10	**14**	57	78	6	8	67	**15**
	Total	135	100	65	**48***	58	43	12	9	123	**53***
Mastoid process	Female	61	45	42	**69***	5	8	14	23	47	**89***
	Male	74	55	31	**42***	22	30	21	28	53	**58***
	Total	135	100	73	**54***	27	20	35	26	100	**73***
Supra-orbital margin	Female	64	46	30	**47***	16	25	18	28	46	**65***
	Male	75	54	37	**49**	16	21	22	29	53	**70**
	Total	139	100	67	**48***	32	23	40	29	99	**68***
Glabella	Female	60	44	53	**88***	7	12	0	0	60	**88***
	Male	76	56	29	**38***	30	39	17	22	59	**49***
	Total	136	100	82	**60***	37	27	17	13	119	**69***
Mental eminence	Female	54	46	37	**69***	2	4	15	28	39	**95***
	Male	63	54	7	**11**	37	59	19	30	44	**16**
	Total	117	100	44	**38**	39	33	34	29	83	**53**
Mandibular shape	Female	51	46	32	**63***	19	37	0	0	51	**63***
	Male	59	54	47	**80***	12	20	0	0	59	**80***
	Total	110	100	79	**72***	31	28	0	0	110	**72***
Gonial eversion/flaring	Female	54	44	21	**39***	33	61	0	0	54	**39***
	Male	70	56	57	**81**	13	19	0	0	70	**81**
	Total	124	100	78	**63***	46	37	0	0	124	**63***
Combined sex estimate											
Cranial sex estimate	Female	69	46	56	**81***	12	17	1	1	68	**82***
	Male	83	54	55	**66***	27	32	1	1	82	**67***
	Total	151	100	111	**74***	39	26	1	1	150	**74***
Mandibular sex estimate	Female	54	44	21	**39***	23	43	10	19	44	**48***
	Male	70	56	57	**81***	9	13	4	6	66	**86***
	Total	124	100	78	**63***	32	26	14	11	110	**71***

'Concordant' refers to the proportion of trait scores in agreement with the individuals' pelvic sex, *i.e.*, gracile scores (1 or 2) were considered concordant if the pelvic sex of the individual was female, and discordant if the pelvic sex of the individual was male (and vice versa for robust scores of 4 or 5). Scores of 3 were recorded as indeterminate.
'Concordance accuracy' refers to the crude accuracy calculated including indeterminate observations (as discordant results), whereas 'Classification accuracy' excludes indeterminate counts from the total number of traits observed and refers to the percentage of traits that could confidently be classified as male or female (accuracies shown in bold).
Accuracies were calculated using weighted averages, considering the number of individuals in each individual group.
Values that meet statistical significance (p-value≤0.05) are denoted by *.

Of the individual traits, the highest concordance accuracies were observed for mandibular shape (72%, 79/110), gonial eversion/flaring (63%, 78/124) and glabella (60%, 82/136). The lowest were the mental eminence (38%, 44/117), nuchal crest (48%, 65/135) and supra-orbital margin (48%, 67/139). Sex estimates based on the combined cranial traits had the highest concordance accuracy (74%, 111/151), whilst combined mandibular traits yielded 63% (78/124). Concordant proportions of all traits, except for mental eminence, met statistical significance in the pooled sample (assessed with one-sample chi-squared tests) (Table 4.7).

The highest classification accuracies were observed for the mastoid process (73%, 73/100) and mandibular shape (72%, 79/110); however, significantly lower concordance accuracy of the mastoid process (54%, 73/135) were noted. Traits with the lowest accuracies were the mental eminence (38%, 44/117 concordance accuracy; 53%, 44/83 classification accuracy) and nuchal crest (48%, 65/135 concordance accuracy; 53%, 65/123 classification accuracy) (Figure 4.2).

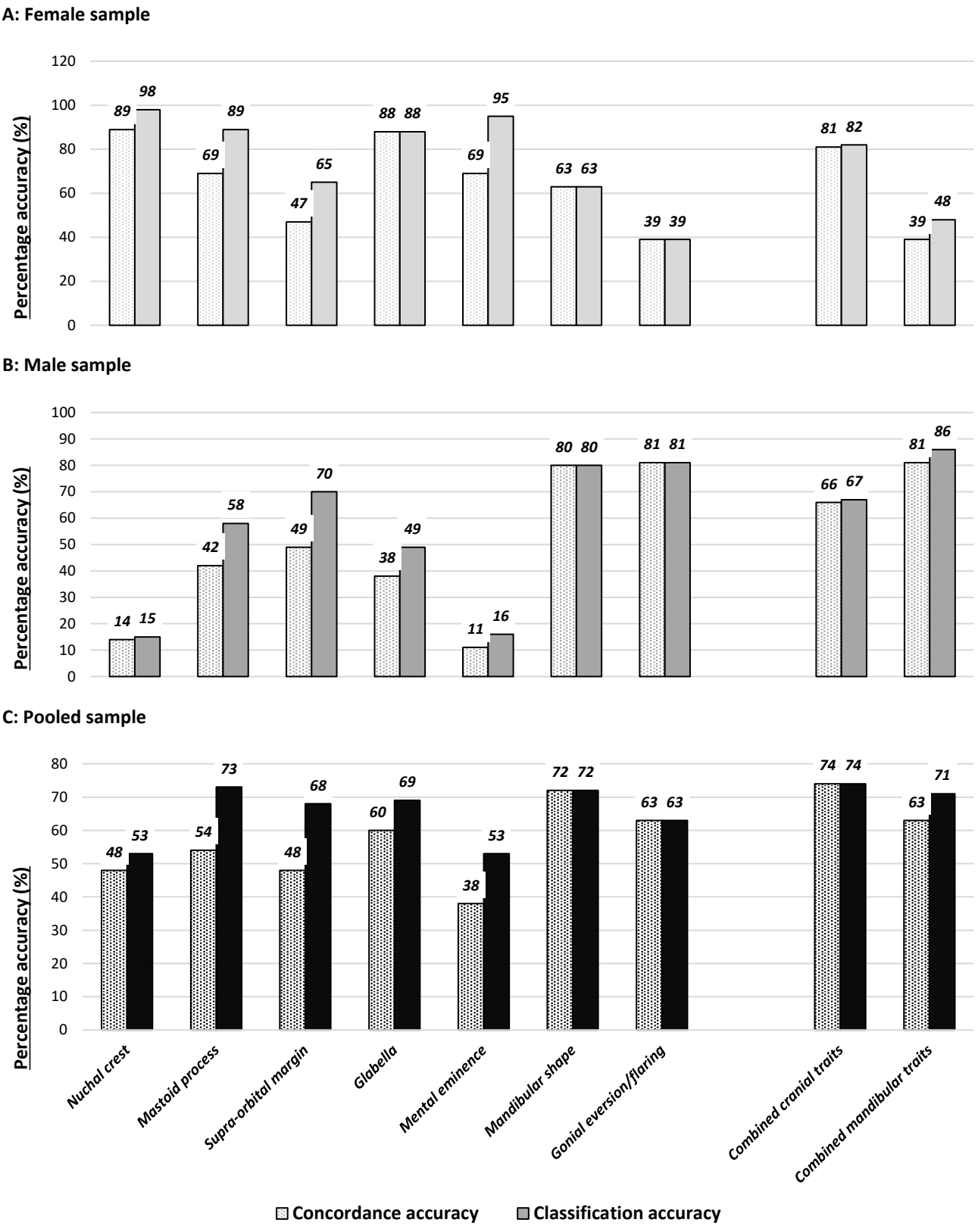

Figure 4.2: Summary of cranial and mandibular trait accuracy rates (for each sex individually and both sexes pooled). 'Concordant' refers to the proportion of trait scores in agreement with the individuals' pelvic sex, i.e., gracile scores (1 or 2) were considered concordant if the pelvic sex of the individual was female, and discordant if the pelvic sex of the individual was male (and vice versa for robust scores of 4 or 5). Scores of 3 were recorded as indeterminate. 'Concordance accuracy' refers to the crude accuracy calculated including indeterminate observations (as discordant results), whereas 'Classification accuracy' excludes indeterminate counts from the total number of traits observed and refers to the percentage of traits that could confidently be classified as male or female.

Females

In the female sample, traits with the highest concordance accuracies were nuchal crest (89%, 55/62), glabella (88%, 53/60), and mastoid process (69%, 42/61), with all these meeting statistical significance. Traits with the lowest concordance accuracies were gonial eversion/flaring (39%, 21/54) and supra-orbital margin (47%, 30/64) (Figure 4.2).

The highest accuracy rate of individual traits in females were observed in the nuchal crest (89%, 55/62 concordance accuracy; 98%, 55/56 classification accuracy) and glabella (88%, 53/60 for both accuracies). The mental eminence and mastoid process also showed high classification accuracies (95%, 37/39 and 89%, 42/47 respectively), but had significantly lower concordance accuracies (69%, 37/54 and 42/61, concordance accuracy for both traits) and larger proportions of indeterminate scores. The highest accuracies for combined sex estimates in females, were observed in the combined cranial sex estimate (81%, 56/69 raw accuracy and 82%, 56/68 classification accuracy). The combined cranial sex estimate had large concordant proportions in both male and female groups (66%, 55/83 and 81%, 56/69 respectively and both statistically significant), but was lower than some individual traits concordance proportions, unlike the pooled sample (Figure 4.2).

Males

In the male sample, traits with the highest concordance accuracies were gonial eversion/flaring (81%, 57/70) and mandibular shape (80%, 47/59), whilst the lowest were nuchal crest (78%, 57/73) and mental eminence (59%, 37/63). Traits that yielded the highest and lowest concordance accuracies in males corresponded with those of the pooled sample (Table 4.7). The mandibular sex estimate had a large concordant proportion in males (81%, 57/70), but overall, the male sample had much higher discordant proportions than the female (Figure 4.2).

The highest accuracy rates in male individual traits were observed in mandibular shape (80%, 47/59) and gonial eversion/flaring (81%, 57/70), for both accuracies. Of the combined cranial and mandibular sex estimates, the highest accuracy rates were observed in the mandibular sex estimate (81%, 57/70 concordance accuracy; 86%, 57/66 classification accuracy) (Figure 4.2).

One-sample chi-squared testing showed statistical significance of all traits when assessed by sex, except for the nuchal crest, supra-orbital margin, mental eminence and gonial eversion/flaring in males (Table 4.7).

c. Trait sensitivity, specificity, and predictive value for estimating sex

The sensitivity, specificity and predictive value assessment of the traits used in morphological sex estimation are summarised in Table 4.8. As previously mentioned, 'sensitivity' here refers to a trait's gracility bias (likelihood/probability of a trait classifying an individual as female), whereas 'specificity' refers to robusticity bias (likelihood/probability of male classification). (Curate *et al.*, 2016; Dangvard Pederson *et al.*, 2019; Carvallo & Retamal, 2020). It should be noted that these are not measures of precision and do not refer to the number of correct classifications, but rather are used as measure of probability (Dangvard Pederson *et al.*, 2019), to show the direction (*i.e.*, male vs female) a specific trait tends towards. 'PPV' refers to the accuracy of a trait's sensitivity score/gracility bias in comparison to the individual's pelvic sex (*i.e.*, correct classifications), whilst 'NPV' refers to the accuracy of a trait's specificity score/robusticity bias (Curate *et al.*, 2016; Dangvard Pederson *et al.*, 2019; Carvallo & Retamal, 2020).

Sensitivity and specificity values were used to identify sex biases of traits and to assess the range of sexual dimorphism exhibited by each trait. PPV and NPV values were used to assess how accurately the observed range of sexual dimorphism estimates sex when individual traits are assessed.

Table 4.8: Sensitivity, specificity, and predictive value assessment of morphological traits (reported in percentages).

Individual traits	Sensitivity (%)	Positive predictive value (PPV) (%)	Specificity (%)	Negative predictive value (NPV) (%)
Nuchal crest	98	49	15	91
Mastoid process	89	66	58	86
Supra-orbital margin	65	65	70	70
Glabella	88	64	49	81
Mental eminence	95	50	16	78
Mandibular shape	63	73	80	71
Gonial eversion/flaring	39	62	81	63
Combined sex estimate				
Cranial sex estimate	83	67	67	82
Mandibular sex estimate	48	70	86	71

'Sensitivity' refers to a trait's gracility bias (likelihood of classifying an individual as female), whereas 'specificity' refers to robusticity bias (likelihood of male classification). 'Positive predictive values (PPV)' refers to the accuracy of a trait's sensitivity score in comparison to the individual's pelvic sex, while 'negative predictive values (NPV)' refers to the accuracy of a trait's specificity score. PPV and NPV values were used to assess how accurately the observed range of sexual dimorphism estimates sex when individual traits are assessed.

Nuchal crest and mental eminence had the greatest gracility bias (sensitivity values of 98% and 95%, respectively) indicating that these traits most frequently produced female sex estimates (*i.e.*, nuchal crest and mental eminence assessment classified 98% and 95% of the sample as female, respectively. This corresponds with the high proportions of gracile scores obtained for these traits – see Table 4.6). However, the significantly lower PPV values (49% and 50%, respectively) indicate that the female sex estimates obtained using these traits are not very accurate (Table 4.8). When viewed together, it can be said that nuchal crest assessment classified 98% of the sample as female, yet only 49% of these female sex classifications were accurate (*i.e.*, had corresponding female pelvic sex), and mental eminence classified 95% of the sample as female, yet only 50% of these classifications were accurate. Thus, nuchal crest and mental eminence frequently misclassify individuals as female. It should be noted that these traits had low robusticity bias/specificity but high NPV values (Table 4.8), implying that robust trait expression, whilst infrequently observed (low specificity), is highly indicative of male sex (high NPV), but gracile trait expression in these traits specifically, does not necessarily mean female sex.

The opposite is observed for mandibular shape, gonial eversion and the combined mandibular sex estimate, which all exhibited a higher robusticity bias (specificity values of 80%, 81% and 86% respectively) (Table 4.8), indicating that assessment of these traits frequently classified individuals as male. Corresponding NPV values (71%, 63%, and 71% respectively) suggests that these male classifications are relatively accurate. However, PPV and NPV values of mandibular shape (73% and 71%) and the combined mandibular sex estimate (70% and 71%) were similar, indicating that these traits had similar accuracies when classifying an individual as either male or female.

4.5.2. Which combination of morphological traits produces the highest classification accuracy rate for this population?

Pairwise-combined (two-trait combination) accuracy rates are tabulated in Table 4.9, whilst Table 4.10 shows cumulative-combined accuracy rates (obtained by stepwise addition of multiple traits, where traits were added in decreasing order of accuracy) (for both sexes pooled and each sex individually).

In the pooled sample, the pairwise combination with the highest accuracy rates was the mastoid process and mandibular shape combination (73%, 152/210), and the supra-orbital margin and mastoid process combination (71%, 140/199) (Table 4.9). This is consistent with these traits having the highest classification accuracies (Table 4.7: Mastoid process = 73%, 73/100; mandibular shape = 72%, 79/110).

In females, the pairwise combination with the highest accuracy rate was the nuchal crest plus mental eminence combination (97%, 92/95). This was consistent with these traits having the highest classification accuracies in the female sample (Table 4.7). The same pattern was observed in males, where the highest pairwise combination (*i.e.*, the gonial eversion and mandibular shape (81%, 104/129)) was also obtained by combining the traits with the highest classification accuracies in the male sample (Table 4.7).

Table 4.9: Pairwise-combined percentage accuracy rates of assessed morphological traits.

	Sample	Nuchal crest (%)	Mastoid process (%)	Supra-orbital margin (%)	Glabella (%)	Mental eminence (%)	Mandibular shape (%)	Gonial eversion/ flaring (%)
Nuchal crest	Female	-	94	82	93	97	81	69
	Male	-	37	43	32	16	48	48
	Total	-	63	61	61	53	63	58
Mastoid process	Female	94	-	77	89	92	76	64
	Male	37	-	64	54	37	69	70
	Total	63	-	71	71	63	73	68
Supra-orbital margin	Female	82	77	-	77	80	64	52
	Male	43	63	-	60	43	75	76
	Total	61	71	-	69	61	70	66
Glabella	Female	93	89	77	-	92	76	64
	Male	32	54	60	-	33	65	65
	Total	61	71	69	-	61	71	66
Mental eminence	Female	97	92	80	92	-	79	67
	Male	16	37	43	33	-	48	49
	Total	53	63	61	61	-	63	58
Mandibular shape	Female	81	76	64	76	79	-	51
	Male	48	69	75	65	48	-	81
	Total	63	73	70	71	63	-	68
Gonial eversion/ flaring	Female	69	64	52	64	58	51	-
	Male	48	70	76	65	49	81	-
	Total	58	68	66	66	58	68	-

Values depicted in the table represent single trait combination, *i.e.*, one trait combined with only one other trait

Table 4.10: Cumulatively combined percentage accuracy rates (by stepwise addition) of assessed morphological traits.

Trait	Accuracy rate (%)							
	Trait only	+ next most accurate trait	+ next 2 most accurate traits	+ next 3 most accurate traits	+ next 4 most accurate traits	+ next 5 most accurate traits	+ next 6 most accurate traits	All traits combined
Female sample		*+ NC*	*+ NC + ME*	*+ NC + ME + MP*	*+ NC + ME + MP + Gl*	*+ NC + ME + MP + Gl + SOM*	*+ NC + ME + MP + Gl + SOM + MS*	*+ NC + ME + MP + Gl + SOM + MS + GE*
Nuchal crest (NC)	98	-	97	94	93	87	83	77
Mental eminence (ME)	95	97	-	94	93	87	83	77
Mastoid process (MP)	89	94	94	-	93	87	83	77
Glabella (Gl)	88	93	94	93	-	87	83	77
Supra-orbital margin (SOM)	65	82	86	87	87	-	83	77
Mandibular shape (MS)	63	81	85	86	87	83	-	77
Gonial eversion/flaring (GE)	39	69	77	80	82	79	77	-
Male sample		*+ GE*	*+ GE + MS*	*+ GE + MS + SOM*	*+ GE + MS + SOM + MP*	*+ GE + MS + SOM + MP + Gl*	*+ GE + MS + SOM + MP + Gl + ME*	*+ GE + MS + SOM + MP + Gl + ME + NC*
Gonial eversion/flaring (GE)	81	-	81	77	72	68	59	53
Mandibular shape (MS)	80	81	-	77	72	68	59	53
Supra-orbital margin (SOM)	70	76	77	-	72	68	59	53
Mastoid process (MP)	58	70	73	72	-	68	59	53
Glabella (Gl)	49	65	70	70	68	-	59	53
Mental eminence (ME)	16	49	59	62	61	59	-	53
Nuchal crest (NC)	15	48	59	62	61	59	53	-
Total sample		*+ MP*	*+ MP + MS*	*+ MP + MS + Gl*	*+ MP + MS + Gl + SOM*	*+ MP + MS + Gl + SOM + GE*	*+ MP + MS + Gl + SOM + GE + NC*	*+ MP + MS + Gl + SOM + GE + NC + ME*
Mastoid process (MP)	73	-	73	71	71	69	66	64
Mandibular shape (MS)	72	73	-	71	71	69	66	64
Glabella (Gl)	69	71	71	-	71	69	66	64
Supra-orbital margin (SOM)	68	71	71	71	-	69	66	64
Gonial eversion/flaring (GE)	63	68	69	69	69	-	66	64
Nuchal crest (NC)	53	63	66	67	67	66	-	64
Mental eminence (ME)	53	63	66	67	67	66	64	-

Trait additions are added in descending order of classification accuracy:

- Female sample = NC > ME > MP > Gl > SOM > MS > GE.
- Male sample = GE > MS > SOM > MP > Gl > ME > NC.
- Pooled sample = MP > MS > Gl > SOM > GE > NC > ME.

Of all pairwise and stepwise combinations in the pooled sample, the mastoid process and mandibular shape combination produced the highest accuracy rate (73%, 152/210) (Table 4.9 and 4.10). Any further trait additions caused a decline in accuracy (Table 4.10). It was observed that as more traits were added (irrespective of which trait was the starting trait), accuracy tended to converge at 66% (Figure 4.3C). Traits that had the same starting classification accuracy rates in the pooled sample, *i.e.*, nuchal crest and mental eminence, followed the same trajectory in the stepwise combination to the 64% endpoint accuracy.

When assessed by sex, the stepwise combination with the highest accuracy rates in females, was again the nuchal crest and mental eminence (97%, 92/95), before further additions caused accuracies to decline (Table 4.10). The same is observed in the male sample, where the combination with the highest accuracy was gonial eversion and mandibular shape (81%, 104/129).

Stepwise combinations in both male and female samples followed similar patterns to the pooled sample trajectory (Figure 4.3), with the female trend converging at 77% and male trend at 53%. The difference in accuracies was attributed to the differing individual classification accuracies obtained when traits were assessed by sex (female trait accuracies being generally higher than males – see Table 4.7).

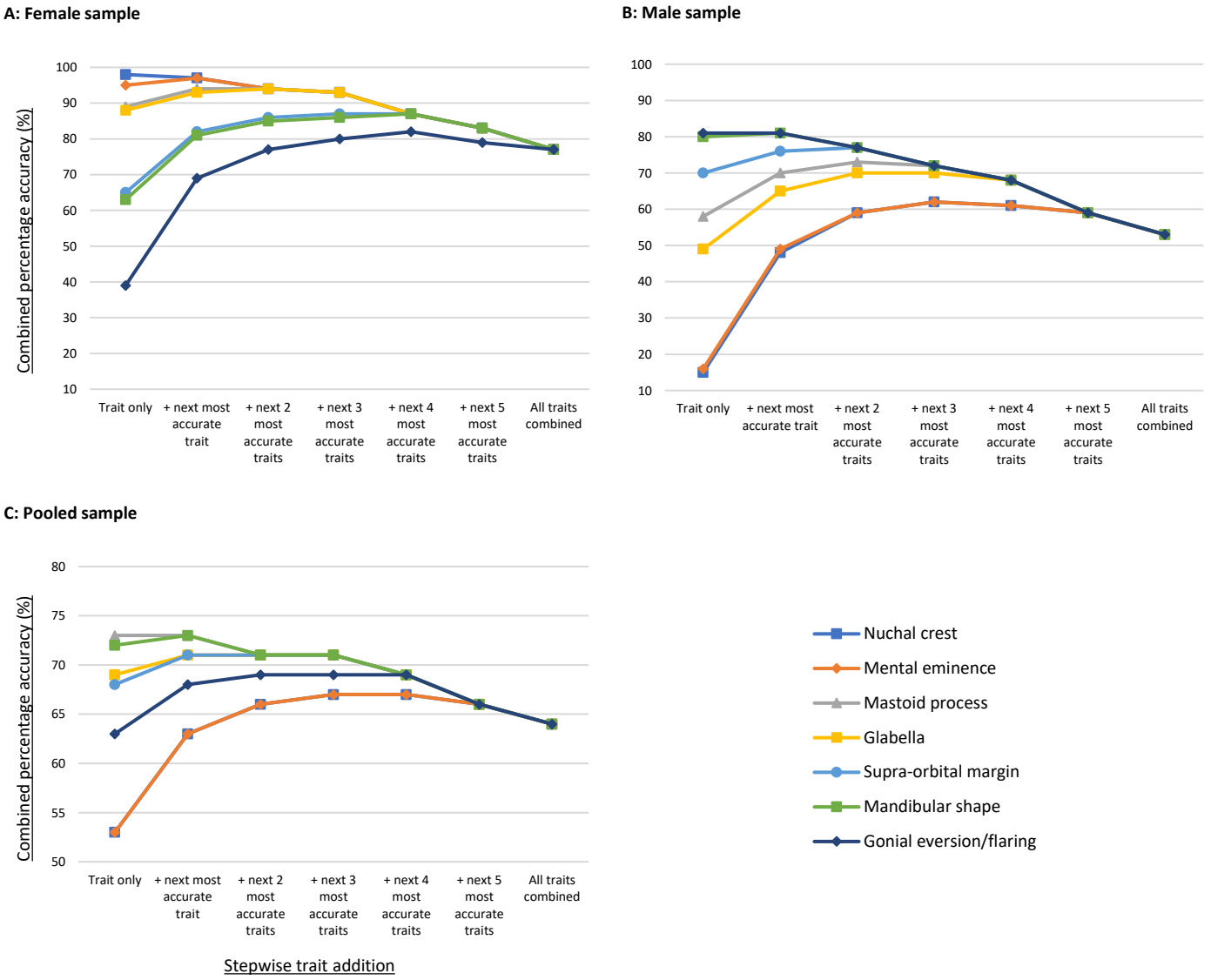

Figure 4.3: Cumulatively combined percentage accuracy rates by stepwise addition of assessed morphological traits. A: Female sample trajectory; B: Male sample trajectory; C: Pooled sample trajectory (Traits with the same starting classification accuracies are superimposed upon each other as they follow the same trajectory to the endpoint).

4.6. Metrical sex estimation

Of the total sample (n = 175), 99% (174/175) of individuals had the skeletal elements required for metrical sex estimation, *i.e.*, mandibles, humeral and/or femoral heads (in addition to pelves used in pelvic sex estimation) (Appendix B: Skeletal element survey). All metrical sex estimation results listed below were obtained using this 174 individual sample. Of these individuals, 44% (77/174) were female and 56% (97/174) were male.

4.6.1. How accurate are the assessed HS-K metrical parameters when compared to pelvic sex estimates?

a. Metrical descriptive statistics

Table 4.11 summarises the descriptive statistics for both sexes, including the average mean values for each parameter assessed and it associated standard deviation. Table 4.12 shows Mann-Whitney U statistics obtained for male and female samples, calculated sexual dimorphism ratios and demarking points. The Mann-Whitney U statistic shows that males, on average were larger than females for all measurements assessed and presented statistically significant (p-value ≤ 0.05) higher mean values for all measurements, when compared with females (*i.e.*, confirming that the assessed variables exhibit sexual dimorphism). Sexual dimorphism ratios for all variables were greater than 100, once again indicating that male measurements were generally larger than females.

Table 4.11: Descriptive statistics of assessed metrical variables.

Variables		Female			Male		
		N	Mean (mm)	SD	N	Mean (mm)	SD
Mandibular	BB	36	107.04	5.23	40	111.1	4.79
	BCB	43	90.15	5.15	46	94.18	4.47
	CH	60	47.22	4.03	67	50.74	4.87
	MML	49	109.32	3.82	53	113.24	4.8
Humeral	HVHD	60	34.44	2.19	79	37.69	3.18
Femoral	FVHD	69	37.06	2.22	85	40.16	2.53

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter.

Table 4.12: Mann-Whitney U statistics, sexual dimorphism ratios and calculated demarking points (in mm) of assessed metrical variables.

Variables		Mann-Whitney U-statistic	Sexual dimorphism ratio	Demarking point
Mandibular	BB	3.142.*	103.8	F < 109.07 < M
	BCB	3.580*	104.47	F < 92.17 < M
	CH	4.049*	107.52	F < 48.99 < M
	MML	3.942*	103.58	F < 111.28 < M
Humeral	HVHD	6.064*	109.43	F < 36.07 < M
Femoral	FVHD	6.760*	108.35	F < 38.61 < M

Sexual dimorphism ratios = male mean/female mean × 100.
Demarking point = average of the mean values for each sex (measured values higher than the demarking point = male, values lower than demarking point = female).
Values that meet statistical significance (p-value≤0.05) are denoted by *.

Female and male measurement distribution of parameters assessed were graphically represented in Figure 4.4 (where measurements were grouped into intervals and counts of individuals within each interval were represented as frequencies).

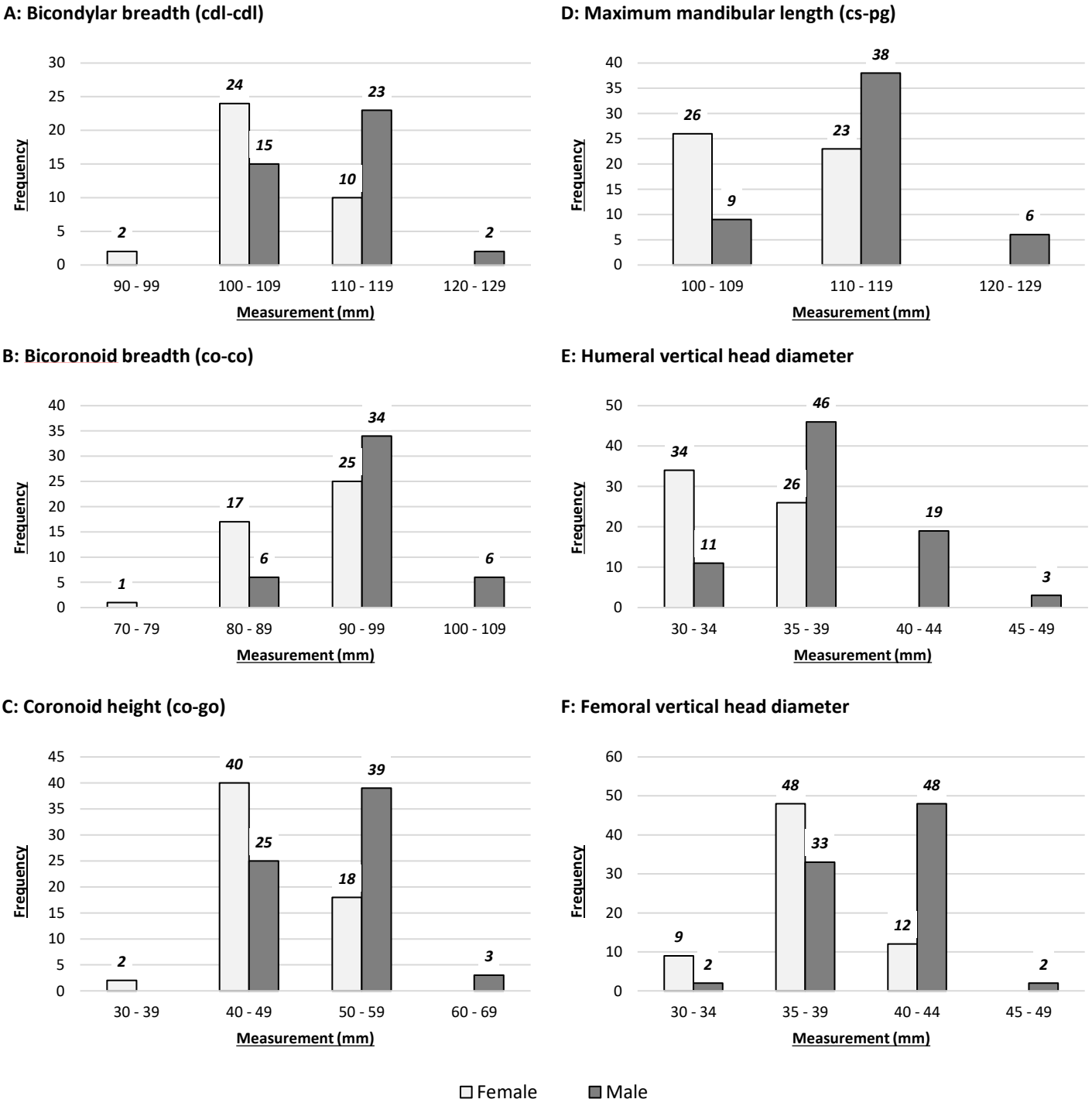

Figure 4.4: Female and male measurement distribution of assessed mandibular, humeral, and femoral metrical parameters (in millimetres (mm)). A = bicondylar breadth (cdl-cdl), B = bicoronoid breadth (co-co), C = coronoid height (co-go), D = maximum mandible length (cs-pg), E= humeral vertical head diameter (maximum head diameter), F = femoral vertical head diameter. Sex of data points within figures are based on pelvic sex estimates. Measurements grouped into intervals, counts of individuals within each interval represented as frequencies.

Table 4.13 summarises average accuracies obtained when using demarking points to estimate sex. Parameters with the highest accuracy rates in the pooled sample were FVHD (74%, 114/154), and HVHD (71%, 98/139). The parameters with the lowest accuracies were BCB (63%, 56/89) and BB (66%, 50/76). It should be noted these lower performing parameters were bilateral measurements that would not have been recorded in the case of broken/half-mandibles.

Table 4.13: Calculated average accuracies using demarking points (in mm) for sex estimation.

Variables		Pelvic sex	Total assessed		Concordant		Discordant	
			n	%	n	%	n	%
Mandibular	BB	Female	36	47	**24**	**67***	12	33
		Male	40	41	**26**	**65***	14	35
		Total	76	44	**50**	**66***	26	34
	BCB	Female	43	56	**27**	**63***	16	37
		Male	46	47	**29**	**63***	17	37
		Total	89	51	**56**	**63***	33	37
	CH	Female	60	78	**40**	**67***	20	33
		Male	67	69	**46**	**69***	21	31
		Total	127	73	**86**	**68***	41	32
	MML	Female	49	64	**30**	**61***	19	39
		Male	53	55	**38**	**72***	15	28
		Total	102	59	**68**	**67***	34	33
Humeral	HVHD	Female	60	78	**47**	**78***	13	22
		Male	79	81	**51**	**65***	28	35
		Total	139	80	**98**	**71***	41	29
Femoral	FVHD	Female	69	90	**51**	**74***	18	26
		Male	85	88	**63**	**74***	22	26
		Total	154	89	**114**	**74***	40	26

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter.
Demarking point = average of the mean values for each sex (measured values higher than the demarking point = male, value lower than demarking point = female).
Values that meet statistical significance (p-value≤0.05) are denoted by *.

In females, parameters with the highest accuracies were also HVHD and FVHD (78%, 47/60 and 74%, 51/69 respectively), whilst the lowest was MML (61%, 30/49). In males, parameters with the highest accuracies were FVHD (74%, 63/85) and MML (72%, 38/53) (Table 4.13). Similar accuracy rates were observed between sexes for most parameters, apart from HVHD and MML which showed accuracy differences of 13% (female = 78%, male = 65%) and 11% (female = 61%, male = 72%), respectively. Hypothesis-testing using a one-sample chi-squared test confirmed all parameters met statistical significance (p-value ≤ 0.05).

4.6.2. Discriminant function analysis

a. Univariate discriminant function analysis

The measured variables and their corresponding coefficients, constants and female and male group centroids can be found in Table 4.14. Each variable's mean value, coefficient and constant are used to formulate the corresponding DFS equations, into which independent measured variables from unknown mandibles and humeral and femoral heads may be substituted for sex estimation. Overall, the post-cranial parameters (*i.e.*, HVHD and FVHD) performed better than the mandibular parameters. The percentage sex estimation accuracy for this sample is highest for the FVHD (75%), followed by HVHD (71%). To obtain a DFS from each of the variables, the coefficient was multiplied by the parameter measurement (in mm), and the corresponding constant was added, *e.g.*, DFS (BB) = (0.2 x BB (in mm)) - 21.817. The measured bone was classified as male if the DFS is greater than -0.0215 (sectioning point) and as female if the score was less than -0.0215 (All derived equations are summarised in Table 4.17).

Table 4.14: Univariate discriminant function analysis of mandibular, humeral, and femoral metrical parameters.

Variables		Unstandardised coefficient	Constant	Male and Female Centroids (mean)	Sectioning point	Accuracy (%)
Mandibular	BB	0.2	-21.817	F = -0.428 M = 0.385	-0.0215	68.4
	BCB	0.208	-19.179	F = -0.433 M = 0.405	-0.014	62.9 (61.8)*
	CH	0.223	-10.924	F = -0.417 M =0.373	-0.022	65.4
	MML	0.23	-25.56	F = -0.467 M = 0.432	-0.0175	66.7
Humeral	HVHD	0.357	-12.968	F = -0.66 M = 0.501	-0.0795	71.2
Femoral	FVHD	0.417	-16.185	F = -0.713 M = 0.579	-0.067	75.3

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter.
Sectioning point = Means of male and female centroids.
Discriminant function score equation (DFS) = (unstandardized coefficient x variable (in mm)) + constant. DFS greater than sectioning point is male and less than is female.
*Accuracy and cross-validated accuracies were the same for all parameters except bicoronoid breadth that had a lower cross-validated accuracy of 61.8%

b. Direct (multivariate) discriminant function analysis

Four functions derived from direct DFA are summarised in Table 4.15: function 1 using mandibular predictor variables, function 2 using post-cranial (humeral and femoral) predictor variables, function 3 using all variables and function 4 using the three best performing variables, *i.e.*, BB, HVHD and FVHD (determined during univariate analysis – Table 4.14).

Table 4.15: Direct discriminant function analysis of mandibular, humeral, and femoral metrical parameters.

Functions	Parameters	Unstandardised coefficient	Standardised coefficient	Wilk's lambda	Structure point	Centroids	Sectioning point	Average accuracy (%)	Cross-validated accuracy (%)
1 (mandible)	BB BCB CH MML Constant	0.071 0.074 0.074 0.12 -31.519	0.326 0.313 0.331 0.523	0.691	0.762 0.684 0.63 0.549	F = -0.669 M = 0.648	**-0.0105**	**71.4**	**68.3**
2 (post-cranial)	HVHD FVHD Constant	0.149 0.285 -16.455	0.414 0.678	0.683	0.95 0.86	F =-0.747 M = 0.612	**-0.0675**	**72.5**	**72.5**
3 (all variables)	BB BCB CH MML HVHD FVHD Constant	0.029 0.011 0.077 -0.024 0.107 0.308 -21.049	0.138 0.05 0.338 -0.106 0.273 0.671	0.54	0.9 0.794 0.546 0.475 0.457 0.446	F = -0.888 M = 0.923	**0.0175**	**78.4**	**72.5**
4 (best performing variables)	BB HVHD FVHD Constant	0.019 0.133 0.306 -18.745	0.094 0.359 0.679	0.572	0.958 0.847 0.479	F = -0.852 M = 0.852	**0.000**	**80.6**	**77.4**

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter.
Discriminant function score equation (DFS) = (parameter measurement x corresponding unstandardised coefficient) (for all parameters) + constant. DFS greater than sectioning point is male and less than is female.

Direct functions 4 and 3 provided the highest average accuracies (80.6% and 78.4% respectively). A slight decrease in accuracy was observed for both these functions when cross-validated, but this predictive accuracy was considerably larger than what was likely to be obtained by chance (50% in the case of two categories, *i.e.*, male and female). Direct discriminant function equations were derived from Table 4.15 using the standard equation form of DFS (All derived equations are summarised in Table 4.17).

c. Stepwise (multivariate) discriminant function analysis

Four functions derived from stepwise DFA are summarised in Table 4.16. The same four combinations of predictor variables used in direct DFA were entered for each stepwise function (*i.e.*, function 1 = mandibular variables, function 2 = post-cranial variables, function 3 = all variables, function 4 = best performing variables). The stepwise functions summarised in Table 15 shows the SPSS-selected best variable/s for each function. Function 1 selected two of the four mandibular variables (BCB and MML), function 2 selected both post-cranial variables (HVHD and FVHD), function 3 selected one of all seven variables (FVHD), and function 4 selected one of the three best performing variables entered (FVHD) (Table 4.16).

Stepwise functions 2, 3 and 4 provided the highest average accuracies (72.5% and 72.1% (both function 3 and 4), respectively). No decrease in accuracy was observed for all three functions. Multivariate stepwise discriminant function equations were derived from Table 4.16 using the standard equation form of DFS (All derived equations are summarised in Table 4.17).

Table 4.16: Stepwise discriminant function analysis of mandibular, humeral, and femoral metrical parameters.

Functions	Parameters	Unstandardised coefficient	Standardised coefficient	Wilk's lambda	Structure point	Centroids	Sectioning point	Average accuracy (%)	Cross-validated accuracy (%)
1 (mandible)	BCB	0.142	0.598	0.794	0.809	F = -0.63 M = 0.611	**-0.0095**	**71.1**	**69.7**
	MML	0.16	0.699	0.827	0.726				
	Constant	-31.018							
2 (post-cranial)	HVHD	0.149	0.414	0.744	0.95	F = -0.747 M = 0.612	**-0.0675**	**72.5**	**72.5**
	FVHD	0.285	0.678	0.704	0.86				
	Constant	-16.455							
3 (all variables)	FVHD	0.458	1	0.591	1	F = -0.799 M = 0.831	**0.016**	**72.1**	**72.1**
	Constant	-17.792							
4 (best performing variables)	FVHD	0.45	1	0.592	1	F = -0.816 M = 0.816	**0.000**	**72.1**	**72.1**
	Constant	-17.521							

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter.
Discriminant function score equation (DFS) = (parameter measurement x corresponding unstandardised coefficient) (for all parameters) + constant. DFS greater than sectioning point is male and less than is female.
Variables included in each function above represent those that produced the highest accuracy when assessed using stepwise discriminant function analysis. Variables were removed from the function by the statistical program if their inclusion reduced the function's accuracy.

Table 4.17: Summary of derived discriminant function score equations.

Discriminant function analysis	Function	DFS Equation	Sectioning point	Average accuracy (%)	Cross-validated accuracy (%)
Univariate	**BB**	(BB x 0.2) – 21.817	-0.0215	68.4	68.4
	BCB	(BCB x 0.208) – 19.179	-0.014	62.9	61.8
	CH	(CH x 0.223) – 10.924	-0.022	65.4	65.4
	MML	(MML x 0.23) – 25.56	-0.0175	66.7	66.7
	HVHD	(HVHD x 0.357) – 12.968	-0.0795	71.2	71.2
	FVHD	(FVHD x 0.417) – 16.185	-0.067	75.3	75.3
Direct (multivariate)	**1**	(BB x 0.071) + (BCB x 0.074) + (CH x 0.074) + (MML x 0.120) – 31.519	-0.0105	71.4	68.3
	2	(HVHD x 0.149) + (FVHD x 0.285) - 16.455	-0.0675	72.5	72.5
	3	(BB x 0.029) +(BCB x 0.011) + (CH x 0.077) + (MML x -0.024) + (HVHD x 0.107) + (FVHD x 0.308) – 21.049	0.0175	78.4	72.5
	4	(BB x 0.019) + (HVHD x 0.133) + (FVHD x 0.306) - 18.745	0.000	80.6	77.4
Stepwise (multivariate)	**1**	(BCB x 0.142) + (MML x 0.160) – 31.018	-0.0095	71.1	69.7
	2	(HVHD x 0.149) + (FVHD x 0.285) – 16.455	-0.0675	72.5	72.5
	3	(FVHD x 0.458) – 17.792	0.016	72.1	72.1
	4	(FVHD x 0.450) – 17.521	0.000	72.1	72.1

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter. Discriminant function score equation (DFS) = (parameter measurement x corresponding unstandardised coefficient) (for all parameters) + constant. DFS greater than sectioning point is male and less than is female.

CHAPTER 5
DISCUSSION

Sex estimation is only useful in forensic and bioarchaeological cases if it is carried out accurately. The population-specific nature of sexing traits must be accounted for during the development of sex estimation techniques (Steyn *et al.*, 1997; Pfeiffer & Harrington, 2011; Kurki *et al.*, 2012; Pfeiffer *et al.*, 2019, Gibbon & Davies, 2020), yet in HS-K populations, sex estimation methods for non-pelvic regions of the skeleton has not been developed. The aim of this study was to assess the accuracies of commonly established internationally recognised sex estimation methods when applied to HS-K individuals. Combinations of metrical and morphological assessments were employed, and it was hypothesised that these would produce low accuracy rates in the given population. Thus, the secondary aim of the study was to use the obtained accuracy results to optimise the sex estimation methods being assessed for HS-K population-specific application. This was done by identifying the skeletal elements most accurate for morphological assessment and by developing the first HS-K-specific discriminant equations from the obtained metrical data. The interpretations of the study's findings are explained in greater detail below.

5.1. Which traits/parameters are best preserved for sex estimation in this sample?

Due to its potential to reduce our ability to assess sex and age (Jackes, 2000), preservation must be recorded and discussed in any archaeological/forensic study (Waldron, 1987). Skeletal elements in this study were selected whilst keeping likelihood of bone preservation in mind. The pelvis, as previously mentioned, is the preferred skeletal element for sex estimation due to its high degree of sexual dimorphism (Phenice, 1969; Tague, 1992; Bruzek, 2002; Kurki, 2007; Steyn & Patriquin, 2009; Betti, 2014; Best *et al*., 2018; Klales, 2020), however Waldron (1987) reports that pelves are only recovered in 66% of archaeological excavations. Additionally, irregular bones, such as the pelvis, are more susceptible to breakage, crushing, and warping, than other shapes (Henderson, 1987), and lack of access to pelves can limit sex estimation efforts.

The cranium is the most frequently recovered skeletal element in South Africa (2012 Annual Report, Forensic Anthropology Research Centre, University of Pretoria, South Africa), whilst the mandible, as the largest of the facial bones, is well-resistant to post-mortem changes due to its dense bone composition (Steyn & İşcan, 1998; Hu *et al.*, 2006; Franklin *et al.*, 2008; Sikka & Jain, 2016). Long bones of adults have a dense outer cortical layer that aids in preservation. The epiphyses of these bones, whilst more fragile than the shaft of long bones, have better sex estimation power and are easily identifiable if present (Henderson, 1987; Waldron, 1987). These features make these bones ideal for sex estimation, but little information is available regarding the preservation of the individual traits/parameters found on these bones.

5.1.1. Morphological trait preservation

Preservation of cranial and mandibular morphological traits assessed ranged from 75% to 90% with the supra-orbital margin and glabella being the best preserved, observable in 90% (139/155) and 88% (136/155) of individuals, respectively. As bone-dense regions of the cranium, this was not a surprising result. However, when extrapolating from existing research, the mastoid process (which lies adjacent to the thickest and most dense of the cranial bones: the petrous pyramid (Knipe & Hacking, 2021)) may be expected to preserve better than other traits. However, due to pneumatisation during development, the mastoid process contains small internal air pockets (Cinamon, 2009), potentially making it more susceptible to taphonomic processes (Child, 1995; Henderson, 1987), which could explain the observed preservation rates for this feature.

Mandibular shape exhibiting the lowest preservation rate at 71% (110/155) is counter-intuitive when one considers its dense bone composition and resistance to post-mortem alterations (Steyn & İşcan, 1998; Hu *et al.*, 2006; Franklin *et al.*, 2008; Sikka & Jain, 2016). However, it should be noted that many fragmented/half-mandibles encountered during the data collection process were excluded from analysis, as they compromised assessment of other traits. Half-mandibles were often split through the mental eminence (which also exhibited lower preservation rates at 75% (117/155)) and missing their counterpart, affecting both mandibular shape and mental eminence assessment. This does not mean the traits assessed were poorly preserved, simply that a smaller number of mandibular traits were assessed as compared to crania (as a half mandible would affect assessment of multiple traits, whereas a fragmented cranium usually only affects the traits in the area of fragmentation). Additionally, preservation

and expression of mandibular flaring/gonial eversion has been known to be affected by tooth loss (Oettle´ *et al.*, 2009). The mandibular angle has been shown to change throughout life as teeth are added and lost, with changes being more pronounced in males. Loth and Henneberg (1996) suggest that the loss of even one molar might result in a change of mandibular shape. Correlating the effect of tooth loss on mandibular trait preservation in this sample was beyond the scope of this study, however it is acknowledged that tooth loss may have contributed to the preservation rates of mandibular traits observed here.

When assessed by sex, similar preservation rates were observed for all traits for both females and males. This supports previous research suggesting no correlation between sex and preservation (Henderson, 1987; Nawrocki, 1995). The same is not true for age-at-death and preservation. This study's sample consisted of unequal numbers of individuals present in each age group, with most of the sample falling under the middle-aged category (MA = 35-49 years old). Bone density increases in the first few years of life, throughout childhood and adolescence, and then begins to decrease. This correlation between bone density and age are a possible explanation for the lack of very young and very old individuals often encountered in archaeological assemblages (Stojanowski *et al.*, 2002). This could impact rates of preservation observed for skeletal elements/parameters. Additionally, males who die young may still appear feminine as the development of 'masculine' features is dependent on an extended growth period and increased muscularity. Conversely, skeletal traits (specifically cranial traits) can become more robust as females age (Buikstra & Ubelaker, 1994). Additionally, in older individuals there may be more antemortem tooth loss and resorption of bone as a result of this may influence mandibular morphology. Whilst possible, it should be noted that older individuals (OA) only made up 5% (9/175) of this sample, with an additional 13% (23/175) of individuals spanning both middle and older age ranges (MA/OA = 35-50+ years). However, the effect of age-at-death on preservation was beyond the scope of this study, thus, may be a potential further research option in preservation of HS-K remains.

5.1.2. Metrical parameter preservation

Preservation of mandibular, femoral, and humeral parameters ranged from 44% to 89% with the FVHD and HVHD being the best preserved, observable in 89% (155/174) and 80% (140/174) of individuals, respectively. This was an unexpected result as epiphyses of long bones are more fragile than the mandible due to the porous, cancellous bone they contain

(Henderson, 1987; Dall'Oca *et al.*, 2014). Femoral and humeral head parameters were expected to have lower preservation rates as they were included in the study primarily due to their noted sex discriminating capabilities (Steyn & İşcan, 1997, 1999; Vance *et al.*, 2011). Previous research has also confirmed that long bone shafts survive better than proximal or distal ends in archaeological assemblages due to higher bone mineral density (Henderson, 1987, Willey *et al.*, 1997). Additionally, in archaeological assemblages, diaphyses were found to survive better than epiphyses (Gonzalez *et al.*, 2012). For the same reasons, higher preservation rates of mandibular parameters were expected. However, the assessed mandibular parameters in this study were only a select few of many existing metrical measurements and was not reflective of general mandibular preservation, which could explain the observed preservation rates for these parameters.

The lowest preservation rates were observed for BB (44%, 76/174), BCB (53%, 91/174) and MML (61%, 106/174). This was likely due to the excluded large counts of fragmented/half-mandibles. The bilateral nature of these measurements meant they could not be recorded in less than complete mandibles, limiting the number of individuals that could be assessed. Conversely, the unilateral CH parameter exhibited higher preservation rates (73%, 128/174), likely due to parameter landmarks being present in duplicates (on both left and right sides of the mandible), and thus, could still be assessed in fragmented mandibles. Further research into metrical sex estimation of the HS-K may benefit from including more unilateral mandibular measurements to circumvent the issue of fragmented/half-mandibles.

When assessed by sex, similar preservation rates were observed for all parameters for both females and males. Once again, this supports previous research suggesting no correlation between sex and preservation (Henderson, 1987; Nawrocki, 1995).

5.2. Morphological sex estimation

5.2.1. How accurate are the assessed HS-K morphological cranial and mandibular traits when compared to pelvic sex estimates?

Comparison of morphological traits and pelvic sex estimates demonstrate that current methods of sex estimation are not accurate when applied to the HS-K. Two features emerged from this study. Firstly, some traits had an obvious sex bias where one sex (*i.e.*, female) was more accurately identified than the other, and secondly, some traits produced high quantities of

indeterminate/ambiguous scores (highlighted by large differences in concordance and classification accuracy rates). Both issues can be attributed to sexual dimorphic differences between this study's HS-K sample and the samples used to create the sex estimation methods applied here (Đuric *et al.*, 2005; Inskip *et al.*, 2018). By presenting the individual traits' score distribution (Table 4.5), the degree of sexual dimorphism exhibited by each trait in an HS-K sample is visible, as well as how it relates to the cut-offs used to discriminate between sexes for the methods applied.

Considering individual mandibular traits first, no ambiguous scores were recorded, due to the lack of a multi-score system, forcing one to categorise traits as either masculine or feminine. This approach produced trait accuracies of 72% (79/110) for mandibular shape and 63% (78/124) for gonial eversion/flaring. Mandibular shape can be considered a relatively reliable sex indicator in this sample. The square mandibular shape of males was quite pronounced in male HS-K individuals whilst female mandibular rami were visibly angled further back than male's shorter and broader rami. Unlike mandibular shape, a notably large proportion of females (61%, 33/54) were classified as male when assessing gonial eversion, along with most of the males assessed (81%, 57/70). This indicates that gonial eversion may not be a good sex indicator as it presents robustly in both females and males (eversion observed in 73% (90/124) of all assessed individuals). Loth and Henneberg (2000) suggested gonial eversion being more characteristic of hereditary factors than sexual dimorphism. Additionally, this area shows marked adaptive and functional responses to external stress (Kemkes-Grottenthaler *et al.*, 2002), largely due to the masticatory muscles that insert there.

Tooth loss can be considered as one such external stressor, as it modifies mandibular morphology as well as the direction and density of masticatory muscles (as they adapt by re-distributing masticatory pressure across the remaining teeth) (Oettle´ *et al.*, 2009). Eversion occurs due to dominance of the masseter muscle, whilst the medial pterygoid muscle inverts the region (Loth & Henneberg, 2000). Thus, the large proportion of everted mandibles observed in the HS-K may be more indicative of diet and food processing than sexual dimorphism, as the masseter muscle is primarily responsible for elevation and limited protraction of the jaw. Further research would be required to confirm whether the sexual dimorphism in this region of the mandible in the HS-K is influenced by interaction of other such biological, environmental, and cultural factors.

Cranial sexual dimorphism is influenced by external factors such as environment, physical activity, dietary practices, disease, and sexual selection (Carlson & van Gerven, 1977; Larsen, 1981; Relethford, 1994; Sparks & Jantz, 2002; van Vark *et al.*, 2003). As such, cranial sexual dimorphism tends to be more population-specific, as it has a greater potential to vary between groups (Carlson, 1976; Krogman & İşcan, 1986; Novotny *et al.*, 1993; Walrath *et al.*, 2004; Garvin *et al.*, 2014). Of the individual cranial traits, all traits had very low proportions of masculine scores, with distribution being skewed towards the lower scoring range. This was unsurprising as extreme gracility has been well documented in the HS-K and is known to complicate sex estimation in this population.

Certain cranial traits did perform better than others. The mastoid process, glabella and supra-orbital margin presented score distributions that fit closer, but not exactly, to contemporary standards than others, resulting in higher classification accuracies. The most accurate trait for estimating sex morphologically in this HS-K sample was the mastoid process (73%, 73/100). Sexual dimorphic differences of the mastoid process are particularly prominent, as it serves as the attachment site for multiple muscles (Cinamon, 2009; Bhagya *et al.*, 2013). Thus, the mastoid process should be relied upon more heavily when other traits are absent, if remains are too fragmented, or if other traits fall in the ambiguous range. It should be noted that the mastoid process, along with the supra-orbital margin, has a considerable amount of overlap between sexes in the Score 3 category. This was present to some extent in all traits except the glabella. This highlights the importance of assessing accuracy rates separately for females and males, as relying on pooled sex accuracy rates alone can be misleading (Inskip *et al.*, 2018).

High ambiguity scoring rates and/or skewing in score distributions potentially suggest that biological sex and robusticity/development may relate differently in this sample than in contemporary populations (Đuric *et al.*, 2005; Inskip *et al.*, 2018). The results obtained here are explained by the lack of HS-K-specific sexing standards. Most notably as males in the sample frequently score lower than contemporary males would, they are significantly more gracile than males used to create the standards. This likely results from the genetic component of ‘smallness’ associated with S-K populations and their ancestors (Sealy & Pfeiffer, 2000; Pfeiffer, 2009).

The supraorbital margin, glabella, and mental eminence can all be considered of equal weight when estimating sex. They were reliable enough to confirm sex estimates but should

not be considered definitive above other traits. However, due to the large proportions of male individuals being assigned Score 3 or 4 (and lack of males in the Score 5 category in these three traits), it may be useful to reconsider Score 3 as male and Score 2 as ambiguous. The skewed scoring distribution may be indicative of a reduced range of sexual dimorphism. Adjustment to the scoring scale to accommodate this may provide a better picture of the sex-discriminating power of these traits. This adjusted method may also potentially reduce the concern of large proportions of ambiguous results.

Adjustment of scoring scales are not a new approach. Following the use of Buikstra and Ubelaker (1994) 5-point scoring scale to assess the greater sciatic notch of the pelvis, Walker (2005) reconsidered the range of variation, particularly with respect to males. He recorded 74% to 76% of males were scored as either female or ambiguous for the sciatic notch when a standard scoring protocol was followed. As a result, he suggested Score 2 may be more indicative of ambiguous morphology than Score 3. Reassignment of Score 2 as ambiguous and Score 3 to 5 as male resulted in higher classification accuracy rates for males (62% to 63% versus 19% to 21% for traditional scores), but lower classification accuracy rates for females (72% for each side of the pelvis, versus 96% to 100%). Following this, Kjellström (2004) assessed a 'weighted' scoring approach on the pelvis, cranium and femur of a medieval Swedish sample and concluded that the adjusted scoring method clearly affected sex assessments. This study supports this approach of an adjusted scoring scale to improve sex estimates in this population. Additionally, it may prove valuable to test whether other populations with similar lifestyles or unique morphologies exhibit similar score distribution patterns to those identified in this HS-K sample.

The nuchal crest and mental eminence score distribution differed greatly from other traits assessed. The mental eminence located at the midline of the mandibular body, is usually more pronounced in males than females (Walker, 2008). Of the fragmented mandibles encountered, many seemed to break along this area, dividing mandibles in half. Mental eminence may also benefit from an adjusted scoring scale as large proportions of male individuals were assigned Score 2 (44%, 28/63) and 3 (30%, 19/63).

The nuchal crest serves as the attachment site for several muscles and is usually flat or nearly flat on female crania (Walker, 2008). However, in the assessed sample, males presented similar morphologies to females. Nearly all females were correctly identified (98% female accuracy for nuchal crest and 95% for mental eminence) but the majority of the males assessed

also scored in the female range resulting in lower male accuracies (15% and 16% respectively). Differences between female and male nuchal crest expression were imperceptible, with 48% (35/73) of males being assigned a Score 1 and 30% (22/73) a Score 2. Most individuals presented with gracile nuchal crest morphology (83%, 112/135) with no distinguishable difference between sexes. Thus, it is advised that use of the nuchal crest as a sex indicator be avoided in the HS-K population.

Sex estimates derived from individual traits overall ranged from 38% to 72% (concordance accuracy). Although some individual trait estimates lack a high level of agreement with pelvic estimates, a substantial accuracy increase was observed when ambiguous estimates were excluded, raising accuracy to 53% to 73% (classification accuracy). However, the use of individual traits for sex estimation without the pelves could have resulted in up to 29% of individuals remaining unsexed if corresponding pelvic estimates were not available (ambiguous estimates made up 29% of all assessed supra-orbital margin and mental eminence traits – see Table 4.6). Similar results were observed by Inskip *et al.* (2018) and Đuric *et al.* (2005) in medieval English and contemporary Balkan populations, where 13% and 15% of individuals respectively, could not be given an estimate without a pelvic or molecular estimate. This shows that whilst individual trait estimates are valuable (in the absence of pelves), their sole application may result in more individuals remaining unsexed.

5.2.2. Which combination of morphological traits produces the highest classification accuracy rates in this sample?

Accuracies obtained from combined cranial traits slightly outperform individual morphological traits. Combined cranial sex estimates yielded a classification accuracy of 74% (111/150), slightly higher than the mastoid process at 73% (73/100), the best performing individual trait. The same is not true for the combined mandibular sex estimates, as mandibular shape alone (72%, 79/110) was slightly more accurate than the combined mandibular sex estimate (71%, 78/110). However, both combined cranial and mandibular estimates resulted in lower levels of ambiguous/indeterminate cases: a benefit of assessing sex with multiple traits.

Pairwise-combinations of individual traits did not surpass that of the combined cranial sex estimate. The highest pairwise-combined accuracy was between the mastoid process and mandibular shape combination (73%, 152/210), unsurprising as these were the two most

accurate individual traits. Following sex-specific assessment, the most accurate pairwise combinations were also obtained by combining the two most accurate traits in each sample. For males, this was the gonial eversion and mandibular shape combination (81%, 104/129), and for females, the nuchal crest and mental eminence combination (97%, 92/95). However, it should be noted that the traits with the highest accuracy in the female sample have the lowest classification accuracies in the pooled sample, once again highlighting the obvious sex biases present in the scoring distribution of these traits. Further research options may include assessing trait pairs as a whole and assigning a single sex estimate based on the overall robusticity/gracility of the pair, to determine if this approach helps increase sex estimation accuracies.

Individual traits were also combined in a stepwise fashion, to assess the effect each trait had on total cumulative accuracy. Once again, the combinations with the highest recorded accuracies were mastoid process and mandibular shape in the pooled sample (73%). Further trait additions caused declines in accuracy, with total cumulative accuracy of all traits together reaching a cumulative endpoint accuracy of 64%. Similar trajectories were obtained for each individual sex, however the ranges spanned by each sex differed greatly. In the females, stepwise-combined accuracy started at 98% and dropped to 77% following addition of remaining traits. In males, this trend started at 81% and dropped to 53%. This is a result of the low male classification accuracies observed for individual traits.

5.3. Metrical sex estimation

5.3.1. How accurate are the assessed HS-K metrical parameters when compared to pelvic sex estimates?

The metrical analyses of this study initially intended on investigating nine metrical parameters, however, following inter-observer error analysis, low agreement levels were found specifically in connection with the gonion or pogonion landmarks. Metrical assessments are adversely impacted if skeletal landmarks used for measurements are subject to error (Krishan *et al.*, 2016; Oikonomopoulou *et al.*, 2017). As a result, three metrical parameters were excluded from further use during the study. A well-documented limitation of metrical analyses are the difficulties observers may experience locating skeletal landmarks if they are not well-defined

(DiGangi & Moore, 2013; Klales, 2020). This subjectivity in skeletal landmark location limits the development, testing, and application of metrical sex estimation methods.

All remaining metrical parameters assessed displayed significant sexual dimorphism with HVHD and FVHD being the most diagnostic. Statistical analysis confirmed that males, on average, were larger than females for all measurements, however, it should be noted that the greatest difference in means amounts to little over 4 mm. These 'differences' should be approached with caution as such small variations may simply be the result of statistical analysis categorising measurements into discrete groups. Whilst statistically significant, these differences may not necessarily mean practical relevance (Hojat & Xu, 2004) and the possibility of overlap between male and female dimensions should be noted when using these parameters in practice.

Measurement distribution of traits differed greatly from each other, and variable average accuracies were obtained when using demarking points to classify sex. Parameters with the highest accuracy rates (using demarking points) were FVHD (74%, 114/154), and HVHD (71%, 98/139). The lowest accuracies were obtained for bilateral measurements of the mandible, specifically BCB (63%, 56/89) and BB (66%, 50/76). When assessed by sex, similar accuracy rates were observed between sexes for all parameters except HVHD and MML which showed accuracy differences of 13% (female = 78%, male = 65%) and 11% (female = 61%, male = 72%), respectively. Estimating sex using demarking points should not be used in isolation in the HS-K population, as average accuracies obtained are not high enough to render them individually useful in sex estimation.

5.3.2. Discriminant function analysis

DFS equations have been provided for individual (univariate), directly combined (direct - multivariate) and selected variables (stepwise - multivariate) of the mandible, humerus and femur. By substituting measured variables into appropriately selected equations and comparing results with the calculated sectioning points, the sex of unknown of mandibles, humeri and femora of HS-K individuals were classified. Since the mean values of all parameters examined were greater in males than in the females, DFS greater than sectioning points classify skeletal elements as male, whilst lower scores as female sex.

Obtained discriminant function equations using the assessed metrical parameters produced accuracies ranging from 62% to 77%. FVHD yielded the most accurate discriminant function for a single measurement (univariate) at 75%. This supports previous findings in other populations that showed femoral head was the most important sex discriminator in white and black American populations (İşcan *et al.*, 1994) and in Black South African populations (Asala *et al.*, 2004), but is contrary to the findings of Steyn and İşcan (1998) in white South African populations. Although the individual variables did not perform well in the univariate analysis, when used in conjunction with others, they may be of benefit.

Of the multivariate assessments, the direct combination of BB, FVHD and HVHD yielded the highest cross-validated accuracy of all generated equations at 77% (average accuracy = 81%), outperforming the stepwise DFA. This function was derived by combining the three best-performing variables identified during the univariate analysis. For the stepwise analysis, the statistical program selected for the best performing variables to include in the function. The highest accuracy obtained was 73% for the combination of FVHD and HVHD, after which additional inclusion of other parameters in the function decreased its accuracy. Minimal decreases in accuracy were observed for equations when cross-validated, confirming the predictive accuracy of the equations generated.

Humeral and femoral head parameters were found to be more successful in sex estimation than mandibular parameters. This once again potentially indicates that the HS-K mandible is more reflective of adaptive and functional responses to biological, environmental, and cultural factors, rather than sexual dimorphism (Loth & Henneberg, 2000; Kemkes-Grottenthaler *et al.*, 2002). The success of the femoral head in estimating sex may be attributed to the important role it plays in body weight transmission from the axial skeleton to the lower limb, and to the greater range of hip joint movement: features expected to be influenced by sex (Purkait, 2003; Murphy, 2005; Milner & Boldsen, 2012).

Overall, the accuracies obtained through DFA are lower than those obtained in other populations using the same skeletal traits. Thieme and Schull (1957) found femoral head metrics produced accuracies of up to 98% in the American Terry Collection. Loth and Henneberg's (1996) study of black South African mandibles yielded close to 92% accuracy. Steyn and İşcan (1997) found an accuracy of 82% for white South African mandibles and 93% for humeral head diameter in black South African populations (Steyn and İşcan, 1999). Purkait (2003) found a 92% accuracy assessing femoral head diameter in an Indian sample. Kranioti and Michalodimitrakis (2009) obtained accuracies of 85 to 92% for HVHD in a modern Crete

sample. Saini *et al.* (2011) found CH produced an accuracy of 80% in modern Indian mandibles. Kranioti *et al.* (2014) found mandibular metrics in a modern Greek sample produced accuracies of up to 80%. However, all accuracy rates obtained in this study were consistently lower accuracies than those of other populations, owing to the lower levels of sexual dimorphism present in the HS-K population.

Notably, the equations produced in this study are the first for an HS-K population. Due to the population-specific nature of discriminant equations, it is advised to assess remains using standards developed for their population. Application of the equations generated in this study would allow one to assess sex of remains with considerable accuracy and a known error rate, previously not possible in this population.

5.4. Study limitations

This study forms the first systematic investigation into the complexities of estimating sex with current methods in the HS-K population. As a result, a large limitation of this research is the lack of similar research in the HS-K against which the study's findings can be compared. Where possible, results were compared to other populations and cross-validation of methods used were incorporated into the study (*e.g.*, 'leave-one-out' approach for generated discriminant functions). Whilst some methods/techniques used in this study are considered subjective, observer error analyses ensured that methodological error was minimised. However, conclusions are based almost entirely on the results of this study, thus, additional research would be required to confirm the results of the study.

An additional limitation to this study was the unknown impact of tooth loss on mandibular morphology. As previously mentioned, the loss of just a single molar can cause large changes to the overall mandibular shape (Loth & Henneberg, 1996), mostly through resorption of alveolar bone and compensatory modification of the masticatory mechanism (and the muscles involved there) (Oettle´ *et al.*, 2009). This could impact mandibular preservation as well as expression of mandibular traits, and thus, should be taken into account.

The archaeological nature of the sample also limits the analyses that can be conducted, as assessments depended on availability and preservation of bones. A major study limitation was that the 'true' sex of individuals was unknown and had to be estimated before any further analyses could be conducted. Whilst characteristic of an archaeological assemblage, this may

have introduced error in the sample being studied. Additionally, the osteological paradox (Wood *et al.*, 1992) of assessing skeletal remains should be noted: results obtained may not be representative of the entire past HS-K population. It should also be noted that this study is limited to HS-K remains of a specific time-period and results of this study would not be suited for S-K remains of different temporal settings, *i.e.*, post-colonial S-K remains would likely contain varying levels of admixture (Morris 1984, 1992; Cavalli-Sforza *et al.*, 1994; Cruciani *et al.*, 2002; Franklin *et al.* 2007, Franklin *et al.* 2010), whilst pre-LSA and early Holocene communities would have occupied different regions and experienced different evolutionary pressures (Stynder *et al.*, 2007b; Wright & Weintroub, 2014). The limited amounts of accessible skeletal material from the Holocene period capped the study sample. Whilst all efforts were taken to include as many individuals in the study as possible, the smaller study sample may also be considered a study limitation.

5.5. Recommendations for implementation and future research

Throughout the course of this study, additional questions were raised which may provide promising avenues for future research. As previously stated, this study's sample consisted of unequal numbers of individuals present in each age group. The effect of age on preservation and skeletal sexual dimorphic expression was beyond the scope of the study, but it is acknowledged that age affects the structural integrity of bone (Stojanowski *et al.*, 2002). These effects have not been investigated in this study as some age groups were not large enough to be certain of these effects.

An interesting result of the study was regarding mandibular preservation and sexual dimorphic expression. Whilst fragmented/half-mandibles limited analyses in this study, the commonly noted occurrence of mandibular breakage in the same area may be a potential investigation avenue for mandibular preservation and the mechanical effects of taphonomic processes on mandibles. The effect of tooth loss on mandibular morphology, and it's correlation with age, is also a potential avenue for future research. The results of this study suggested that the mandible of HS-K individuals seemed to be more indicative of adaptive and functional responses rather than sexual dimorphism. Additional research would be required to see if this is true, and if so, sexual dimorphism expression in HS-K mandibles should be revisited whilst considering the influences of other biological, environmental, and cultural

factors. This may provide opportunities to further optimise sex estimation methods on the HS-K mandible using the adjusted scale approach.

It is acknowledged that the metrical assessment of long bones in this study was limited to only vertical head diameters of humeri and femora. These metrical dimensions are correlated with body mass but given the significantly reduced stature and mass of HS-K population, it was unknown if these metrical parameters would exhibit sexual dimorphism. Assessment of these parameters proved that sexual dimorphism is present in long bone measurements. This opens additional research avenues into the testing the sex estimation power of alternate long bone measurements, such as epiphyseal circumferences and distal widths. This could be used to produce more multivariate analyses to improve sex estimation accuracies of metrical parameters.

The generally gracile morphological scoring distribution of males were an interesting finding that should be noted. Adjustment to the scoring scale of morphological traits identified previously also provides future research options. Further investigation is required to assess whether scale adjustments will reduce the number of ambiguous observations as proposed and whether it really does provide a better picture of the sex-discriminating power of traits. Additional morphological research options may also include assessing trait pair accuracies (as a whole and assigning a single sex estimate based on the overall robusticity/gracility of the pair), to determine if this approach helps increase sex estimation accuracies.

As previously mentioned, no other study examines the difficulties associated with sex estimation methods in the HS-K population. Similar studies would provide good comparative data to validate and confirm the results of this study. It should be noted that the sample assessed here represents individuals from varied spatial/temporal settings, which may result in some biases. As sexual dimorphism is greatly affected by various environmental and socio-cultural factors (Ubelaker & DeGaglia, 2017), comparison between HS-K individuals of different time periods and geographical locations could be useful in understanding patterns of sexual dimorphism in traits and their usefulness in assessing sex. This could also be informative in determining whether different sex estimation methods are required for different historical contexts.

Overall, investigating other populations with similar lifestyles or morphologies (or similar sex estimation complexities) may provide additional insights into the best methods of

optimising sex estimation approaches for population-specific application. Following population-specific sexing standards, it may be useful to investigate the accuracies of other osteobiographical analyses in a similar manner (*e.g.*, age estimation, stature estimation, *etc.*), as these too may not be appropriate for the unique morphology exhibited by the HS-K population.

Use of the population-specific sex standards developed in this study may greatly improve identification rates in archaeological scenarios, provided they are applied to the correct population in the correct context. This study provides insights into the skeletal elements that are likely to have preserved sexing features, as well as identifies optimal and problematic sexing regions of the skeleton. The purpose of this is to hopefully facilitate targeted sex estimation attempts. The study also provides the first known-accuracy methods of estimating sex in HS-K populations, to serve as a stepping-stone to further improving methods of sex estimation for application in the HS-K population.

These outputs may help scientists better understand the dynamics of ancient societies that were previously out of reach due to unreliable sexing standards. This study's results could potentially contribute to a deeper understanding of HS-K past histories, population practices, gender ratios, reproductive and gender-based problems, as well as division of labour, gender roles and burial practices, amongst others (Wadley, 1993, 1996, 1997). The creation of such standards also sets a precedent for other populations exhibiting morphologically unique features that do not conform to existing sex estimation standards.

CHAPTER 6

CONCLUSION

Sex estimation is an integral tool in bioarchaeology and forensic contexts and serves many purposes, however, this process requires accuracy to be useful. The population-specific nature of methods and sexual dimorphic differences are well-documented, with misclassifications known to occur when techniques derived from one population are applied to remains from another (L'Abbé *et al.,* 2011; Oikonomopoulou *et al.,* 2017). The adverse downstream effects of inaccuracies in sex estimation are well-documented and range from individual to population-level.

This study assessed the accuracy of commonly used morphological and metrical methods of sex estimation in an HS-K skeletal assemblage, and through a comparison of trait/parameter outcomes to pelvic sex estimates, confirmed that methods assessed were not accurate. The main findings of the study were as follows:

- Differential preservation of both morphological traits and metrical parameters were observed. The morphological trait with the highest preservation rate was the supra-orbital margin, whilst the lowest was mandibular shape. Of the metrical parameters, FVHD and HVHD exhibited the highest preservation rates, whilst bilateral mandibular parameters exhibited the lowest (specifically BB and BCB).
- Of the morphological traits assessed, mastoid process and mandibular shape were the most accurate, and mental eminence and nuchal crest were the least. However, these patterns observed in the pooled sample, were not retained when sexes were assessed separately, illustrating sex biases in the scoring distribution of certain traits.
- All six metrical parameters were sexually dimorphic, with the dimensions of FVHD and HVHD being the most discriminatory. FVHD yielded the most accurate discriminant function for a single measurement (univariate). For combined measurements (multivariate) the direct combination of BB, FVHD and HVHD, and the stepwise combination of FVHD and HVHD yielded the highest accuracies.

The results of the study confirmed that the HS-K population exhibits a reduced range of sexual dimorphism than other populations. It is suggested that researcher's lack of

familiarity with the nuanced range of sexual dimorphism exhibited by the HS-K is the reason why sex estimation can be difficult in this population. As such, caution is advised when pelvic traits are unobservable.

Morphologically, cranial, and mandibular traits exhibited skewed scoring toward the gracile end of the scoring spectrum for both male and female individuals. Individually, traits showed differences in the scaling and degree of sexual dimorphism between the HS-K sample and the original samples used to create the standards. Here, greater gracility in males and reduced ranges of sexual dimorphism resulted in low accuracy rates. Certain traits performed better than others, with the mastoid process, mandibular shape and glabella yielding the highest accuracies and nuchal crest yielding the lowest. This was not the same for sexes when assessed individually, indicating that some traits had an apparent sex bias. This knowledge may improve sex estimation accuracies for the HS-K through reanalysis of scores associated with 'female' and 'male'.

Traits where males were relatively gracile (mastoid process, supra-orbital margin, glabella, mental eminence) imply there is potential to acknowledge that Score 2 could be considered ambiguous (due to the large proportions of male and female overlap), and Score 3 likely represents male. This does not mean that all HS-K individuals present with gracile skeletal traits. There is a distinction between sexes for most traits, with males exhibiting more robusticity than females. The complication is that male robusticity exhibited by the HS-K falls within the gracility ranges of most contemporary populations, where these methods are usually applied.

It is recommended that greater consideration be given to higher-accuracy traits, *i.e.*, the mastoid process, mandibular shape, and glabella, whilst the nuchal crest should be avoided. Additionally, caution is advised when basing sex estimates on individual cranial traits, especially if a population's range of sexual dimorphism is unknown. It is recommended that more than one method is used when estimating sex in the HS-K to minimise error. In the absence of dependable sexing traits, one must consider the necessity of a sex estimate versus the error it may introduce.

Metrically, all parameters assessed were sexually dimorphic, with femoral and humeral parameters outperforming mandibular parameters. Assessed parameters were used to create the first HS-K-specific discriminant function equations with FVHD yielding the most accurate discriminant function for a single measurement (univariate). For combined measurements

(multivariate) the direct combination of BB, FVHD and HVHD, and the stepwise combination of FVHD and HVHD yielded the highest accuracies. Whilst the accuracies obtained through DFA are lower than those of contemporary populations, its use is still encouraged due to the population-specific nature of discriminant equations. Application of the equations generated in this study would allow one to assess sex of remains with a known accuracy and only through its use will we be able to refine these methods further. These equations should only be applied to the HS-K population group due to the population-specific nature of discriminant functions.

This study identified the most useful skeletal sexing regions in the HS-K population. The existence of population-specific standards, combined with knowledge of optimal sex estimation regions of the skeleton will improve sex estimation accuracy rates in this population. This, in turn, will improve identification rates in archaeological scenarios, leading to a deeper understanding of the HS-K. Future research should test whether the proposed adjusted standards yield higher accuracies. The creation of these population-specific standards also hopes to set a precedent for other populations exhibiting morphologically unique features that do not conform to existing sex estimation standards.

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A P P E N D I C E S

Appendix A: Ethics approvals and permissions

UNIVERSITY OF CAPE TOWN
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Human Research Ethics Committee

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20 November 2018

HREC REF: 448/2020

A/Prof V Gibbon
Division of Clinical Anthropology
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Room 5.06.1 Anatomy Building-FHS
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Dear A/Prof Gibbon

PROJECT TITLE: ASSESSMENT OF CURRENT SEX ESTIMATION STANDARDS FOR APPLICATION IN HOLOCENE KHOESAN POPULATIONS (MMED CANDIDATE: MS S MALEK)

Thank you for your response to the HREC comments.

The HREC has granted conditional approval to begin assessments.
If the SAN Council has any objections the HREC must be alerted and that finalisation of the project should not be completed without the Councils documented input.

This approval is subject to strict adherence to the HREC recommendations regarding research involving human participants during COVID -19, dated 17 March 2020 & 06 July 2020.

Approval is granted for one year until the 30 November 2021.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

The HREC acknowledge that the student: Ms Sadiyah Malek will also be involved in this study.

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

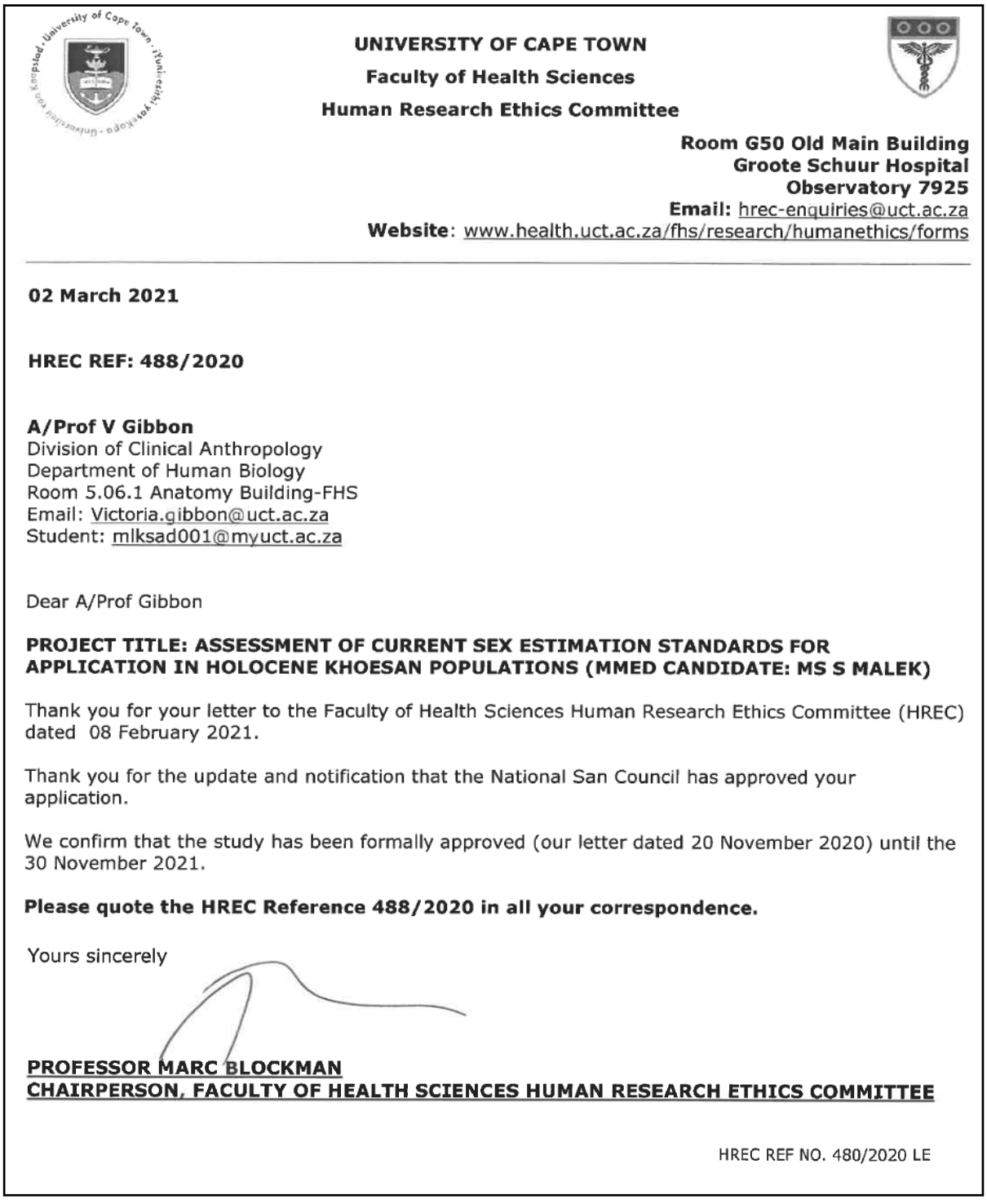
Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

Figure A1: Conditional ethical clearance granted by the Human Research Ethics Committee, University of Cape Town, for the present study (2020) (HREC ref: 488/2020).



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room G50 Old Main Building
Groote Schuur Hospital
Observatory 7925
Email: hrec-enquiries@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

02 March 2021

HREC REF: 488/2020

A/Prof V Gibbon
Division of Clinical Anthropology
Department of Human Biology
Room 5.06.1 Anatomy Building-FHS
Email: Victoria.gibbon@uct.ac.za
Student: mlksad001@myuct.ac.za

Dear A/Prof Gibbon

PROJECT TITLE: ASSESSMENT OF CURRENT SEX ESTIMATION STANDARDS FOR APPLICATION IN HOLOCENE KHOESAN POPULATIONS (MMED CANDIDATE: MS S MALEK)

Thank you for your letter to the Faculty of Health Sciences Human Research Ethics Committee (HREC) dated 08 February 2021.

Thank you for the update and notification that the National San Council has approved your application.

We confirm that the study has been formally approved (our letter dated 20 November 2020) until the 30 November 2021.

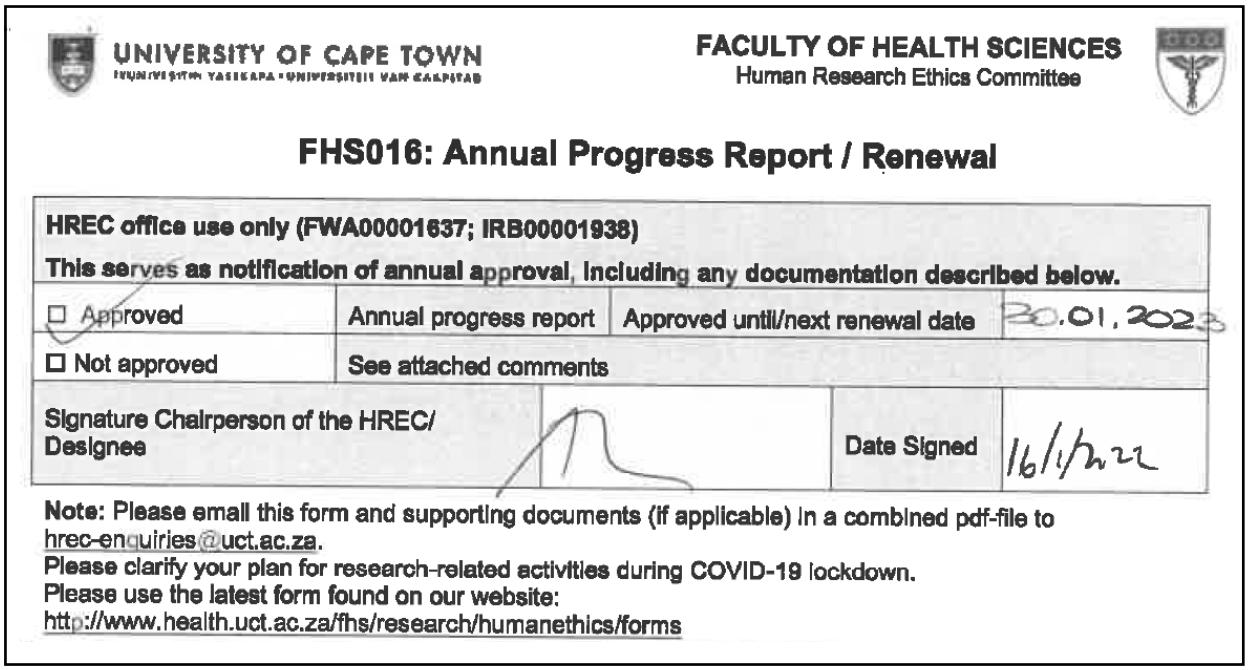
Please quote the HREC Reference 488/2020 in all your correspondence.

Yours sincerely

PROFESSOR MARC BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE

HREC REF NO. 480/2020 LE

Figure A2: Final ethical clearance granted by the Human Research Ethics Committee, University of Cape Town, for the present study (2021) (HREC ref: 488/2020).



UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

FHS016: Annual Progress Report / Renewal

HREC office use only (FWA00001637; IRB00001938)			
This serves as notification of annual approval, including any documentation described below.			
☐ Approved	Annual progress report	Approved until/next renewal date	30.01.2023
☐ Not approved	See attached comments		
Signature Chairperson of the HREC/ Designee		Date Signed	16/1/2022

Note: Please email this form and supporting documents (if applicable) in a combined pdf-file to hrec-enquiries@uct.ac.za.
Please clarify your plan for research-related activities during COVID-19 lockdown.
Please use the latest form found on our website:
http://www.health.uct.ac.za/fhs/research/humanethics/forms

Figure A3: Ethical clearance renewal granted by the Human Research Ethics Committee, University of Cape Town, for the present study (2022) (HREC ref: 488/2020).

From: Leana Snyders
Sent: Thursday, 04 February 2021 9:57 AM
To: Sadiyah Malek
Cc: wclouw@yahoo.co.uk; chrisjant6@gmail.com
Subject: Re: Student Research Application to San National Council

CAUTION: This email originated outside the UCT network. Do not click any links or open attachments unless you know and trust the source.

Dear Sadiyah

I do hope my email find you well.

Please be advised that the San Council have approved your application based on the following.

1. You need to at all times give feedback to the Council before you publish any documentation.
2. You may not give data to any thirds party without discussing it with the Council.
3. Should you change the research methodology as per your application you need to inform the Council prior.

Kind Regards

Leana Snyders

On Wednesday, February 3, 2021, 05:11:49 PM GMT+2, Sadiyah Malek <mlksad001@myuct.ac.za> wrote:

Dear National San Council

I hope this email finds you well. My name is Sadiyah Malek and I am a Master's student from the University of Cape Town under the supervision of Associate professor Victoria Gibbon and Professor Judith Sealy.

I submitted a research application to the San Council in August 2020 regarding my Master's research and have followed up on it in September and November 2020 but am yet to hear back on its status. I would just like to confirm if application has been received and if it being processed as I am uncertain if my emails have been going through successfully.

I am currently in a very critical phase of my research and am rather desperate to hear back from the council as I cannot proceed any further. I am more than happy to set up a meeting on any platform you prefer to discuss the application should you have any questions.

I look forward to hearing from you soon. Any assistance regarding this matter would be greatly appreciated.

Kind regards,
Sadiyah Malek

MSc (Med) Biological Anthropology

Figure A4: San National Council communication and research clearance.

Appendix B: Sample information and raw data

Table B1: Skeletal element survey of total sample.

Repository	ID	Skeletal element					Molecular sex
		Cranium	*Mandible*	*Femoral head*	*Humeral head*	*Pelvis*	
UCT Skeletal Repository	UCT 1	Present	Present	Present	Present	Present	Absent
	UCT 2	Present	Present	Present	Present	Present	Absent
	UCT 3	Present	Absent	Present	Present	Present	Absent
	UCT 5	Present	Present	Present	Present	Present	Absent
	UCT 29	Present	Absent	Present	Present	Present	Present
	UCT 31	Present	Absent	Present	Present	Absent	Present
	UCT 36	Present	Present	Present	Present	Present	Absent
	UCT 43	Present	Present	Present	Present	Present	Present
	UCT 44	Present	Present	Present	Present	Present	Present
	UCT 45	Absent	Absent	Present	Present	Present	Present
	UCT 50	Present	Absent	Present	Present	Present	Present
	UCT 54	Present	Present	Present	Present	Present	Present
	UCT 60	Present	Present	Present	Present	Present	Absent
	UCT 67b	Present	Present	Present	Present	Present	Absent
	UCT 88	Present	Present	Present	Present	Present	Absent
	UCT 97	Present	Present	Present	Present	Present	Absent
	UCT 106	Present	Present	Present	Present	Present	Absent
	UCT 107	Present	Present	Present	Present	Present	Absent
	UCT 112	Present	Present	Absent	Present	Present	Absent
	UCT 113	Present	Present	Present	Present	Present	Absent
	UCT 120	Present	Present	Present	Present	Present	Absent
	UCT 130	Present	Present	Present	Present	Present	Absent
	UCT 131	Present	Present	Present	Present	Present	Absent
	UCT 158	Present	Present	Present	Present	Present	Absent
	UCT 162	Present	Present	Present	Present	Present	Absent
	UCT 164	Present	Present	Absent	Present	Present	Absent
	UCT 168	Present	Present	Absent	Present	Present	Absent
	UCT 169	Present	Present	Absent	Absent	Present	Absent
	UCT 172	Present	Present	Absent	Absent	Present	Absent
	UCT 181/206	Present	Present	Present	Present	Absent	Present
	UCT 182/200	Present	Present	Present	Present	Present	Present
	UCT 183/201	Present	Present	Present	Present	Present	Present
	UCT 185/202	Present	Present	Absent	Present	Present	Present
	UCT 192/213	Present	Present	Present	Present	Present	Present
	UCT 212	Absent	Absent	Absent	Present	Present	Absent
	UCT 226	Present	Present	Present	Present	Present	Absent
	UCT 230	Present	Present	Present	Present	Present	Absent
	UCT 232	Present	Present	Present	Present	Present	Absent
	UCT 246	Present	Present	Present	Present	Present	Absent
	UCT 248a	Present	Present	Absent	Present	Present	Absent
	UCT 250	Present	Present	Present	Present	Present	Absent
	UCT 254	Present	Present	Present	Present	Present	Absent
	UCT 283	Absent	Absent	Present	Present	Present	Absent
	UCT 318	Present	Present	Present	Present	Present	Absent
	UCT 319c	Present	Absent	Present	Absent	Present	Absent
	UCT 323	Present	Present	Absent	Present	Present	Absent
	UCT 324	Absent	Absent	Absent	Present	Present	Absent
	UCT 331	Present	Absent	Present	Present	Present	Absent
	UCT 347	Present	Present	Present	Absent	Present	Absent
	UCT 373	Absent	Present	Present	Present	Present	Absent
	UCT 382	Present	Present	Absent	Present	Present	Absent
	UCT 383	Present	Present	Absent	Present	Present	Absent

	UCT 385	Absent	Absent	Present	Present	Absent	Present
	UCT 386	Present	Present	Present	Present	Present	Present
	UCT 390	Absent	Absent	Present	Present	Present	Present
	UCT 391	Present	Present	Present	Present	Present	Present
	UCT 392 + 387	Present	Absent	Present	Absent	Present	Present
	UCT 394	Absent	Absent	Present	Present	Present	Present
	UCT 395	Absent	Absent	Absent	Present	Present	Present
	UCT 396	Absent	Absent	Present	Present	Present	Present
	UCT 398	Absent	Absent	Present	Absent	Absent	Present
	UCT 399	Present	Present	Present	Present	Present	Absent
	UCT 412	Present	Present	Present	Present	Present	Absent
	UCT 427	Present	Present	Present	Present	Present	Absent
	UCT 428	Present	Present	Present	Present	Present	Absent
	UCT 436	Present	Present	Present	Present	Present	Absent
	UCT 450	Present	Present	Present	Present	Present	Absent
	UCT 451	Present	Present	Present	Present	Present	Absent
	UCT 531	Present	Present	Present	Present	Present	Absent
	UCT 539	Present	Present	Present	Present	Present	Absent
	UCT 565	Present	Present	Present	Present	Present	Absent
	UCT 566	Present	Present	Present	Present	Present	Absent
	UCT 578	Present	Present	Present	Present	Present	Absent
	UCT 579	Present	Present	Present	Present	Present	Absent
	UCT 584	Present	Present	Present	Present	Present	Absent
	UCT 587	Present	Present	Present	Present	Present	Absent
	UCT 591	Present	Present	Present	Present	Present	Absent
	UCT 593	Present	Present	Present	Present	Present	Absent
	UCT 594	Present	Present	Present	Present	Present	Absent
	UCT 605	Present	Present	Present	Present	Present	Absent
	UCT 609	Present	Present	Present	Present	Present	Absent
	UCT 620	Present	Present	Present	Present	Present	Absent
	UCT 622	Present	Present	Present	Present	Present	Absent
	UCT 655	Present	Absent	Present	Present	Present	Absent
	UCT 659	Present	Absent	Present	Present	Present	Absent
	UCT 661	Present	Absent	Present	Present	Present	Absent
	UCT 676	Present	Absent	Present	Present	Present	Absent
	UCT 683	Present	Present	Present	Absent	Present	Absent
	UCT 684	Present	Present	Absent	Present	Present	Absent
	UCT 686/ERF 839	Present	Present	Absent	Present	Present	Absent
	UCR AR2	Present	Absent	Absent	Absent	Present	Absent
	UCT AR4	Present	Present	Absent	Absent	Present	Absent
	UCT AR5	Present	Present	Present	Present	Present	Absent
	UCT AR6	Present	Present	Present	Present	Present	Absent
	UCT AR8	Present	Present	Absent	Absent	Present	Absent
	UCT AR9	Present	Present	Present	Present	Present	Absent
	UCT AR12	Present	Present	Absent	Present	Present	Absent
	UCT AR13	Absent	Present	Present	Present	Present	Absent
	5MAGSTR	Absent	Present	Absent	Present	Present	Absent
	ERF 16015	Present	Present	Absent	Absent	Present	Absent
	MR 211	Absent	Present	Present	Present	Present	Absent
	P 1205	Absent	Absent	Present	Present	Present	Absent
	P 1207	Present	Present	Absent	Present	Present	Absent
	P 1271	Present	Present	Absent	Present	Present	Absent
National Museum (Bloemfontein)	P 1273	Present	Present	Present	Absent	Present	Absent
	P 1275	Present	Present	Absent	Absent	Present	Absent
	P 1451	Present	Absent	Present	Present	Present	Absent
	P 1639	Present	Present	Present	Present	Present	Absent
	P 1640	Present	Present	Present	Present	Present	Absent
	P 1704	Present	Absent	Present	Present	Present	Absent
	P 1705 A	Present	Absent	Absent	Absent	Present	Absent

Iziko Museum Human Skeletal Repository (Cape Town)	SS1	Absent	Absent	Present	Present	Present	Absent
	SS2	Present	Absent	Present	Present	Present	Absent
	SS3	Present	Absent	Present	Present	Present	Absent
	SAM 32	Present	Present	Present	Present	Present	Absent
	SAM 34	Present	Present	Present	Present	Present	Absent
	SAM 1131	Present	Absent	Present	Present	Present	Absent
	SAM 1145	Present	Present	Present	Present	Present	Absent
	SAM 1146	Present	Present	Present	Present	Present	Absent
	SAM 1157	Present	Present	Absent	Present	Present	Absent
	SAM 1247a	Present	Present	Present	Present	Present	Absent
	SAM 1443	Present	Present	Present	Present	Present	Absent
	SAM 1444	Present	Present	Present	Absent	Present	Absent
	SAM 1446	Present	Present	Absent	Present	Present	Absent
	SAM 1449	Present	Present	Present	Present	Present	Absent
	SAM 1457	Present	Absent	Present	Present	Present	Absent
	SAM 1473	Present	Present	Absent	Absent	Present	Absent
	SAM 1871	Present	Present	Present	Present	Present	Absent
	SAM 1878a	Present	Present	Present	Present	Present	Absent
	SAM 1878b	Absent	Absent	Present	Present	Present	Absent
	SAM 1879	Present	Present	Present	Present	Present	Absent
	SAM 1889	Absent	Absent	Present	Present	Present	Absent
	SAM 1893	Present	Absent	Present	Present	Present	Absent
	SAM 3026	Present	Absent	Present	Present	Present	Absent
	SAM 4305	Absent	Absent	Present	Present	Present	Absent
	SAM 4637	Present	Present	Present	Absent	Present	Absent
	SAM 4720	Present	Present	Absent	Present	Present	Absent
	SAM 4790	Present	Present	Present	Present	Present	Absent
	SAM 4800	Present	Present	Present	Present	Present	Absent
	SAM 4838a	Present	Present	Present	Present	Present	Absent
	SAM 4838b	Present	Present	Present	Present	Present	Absent
	SAM 4840	Present	Present	Present	Present	Present	Absent
	SAM 4901	Present	Present	Absent	Present	Present	Absent
	SAM 4905	Absent	Absent	Present	Present	Present	Absent
	SAM 4930	Absent	Absent	Absent	Absent	Present	Absent
	SAM 4931	Present	Present	Present	Present	Present	Absent
	SAM 4934	Present	Absent	Absent	Present	Present	Absent
	SAM 4943	Present	Present	Present	Present	Present	Absent
	SAM 4964	Present	Present	Present	Present	Present	Absent
	SAM 5035a	Present	Present	Present	Present	Present	Absent
	SAM 5036	Absent	Absent	Present	Absent	Present	Absent
	SAM 5041	Present	Present	Present	Present	Present	Absent
	SAM 5048	Present	Present	Absent	Present	Present	Absent
	SAM 5050	Present	Present	Absent	Absent	Present	Absent
	SAM 5075	Present	Present	Present	Present	Present	Absent
	SAM 5077 IV/D	Present	Present	Absent	Present	Present	Absent
	SAM 5083	Present	Present	Present	Present	Present	Absent
	SAM 5095	Present	Present	Present	Present	Present	Absent
	SAM 6020	Present	Present	Present	Present	Present	Absent
	SAM 6023	Present	Present	Present	Present	Present	Absent
	SAM 6041a	Present	Present	Present	Present	Present	Absent
	SAM 6041b	Present	Present	Present	Present	Present	Absent
	SAM 6049	Present	Present	Present	Present	Present	Absent
	SAM 6050	Present	Present	Present	Present	Present	Absent
	SAM 6051	Absent	Absent	Present	Present	Present	Absent
	SAM 6072	Present	Present	Present	Present	Present	Absent
	SAM 6075	Present	Present	Present	Present	Present	Absent
	SAM 6147	Present	Present	Present	Present	Present	Absent
	SAM 6149	Present	Present	Present	Present	Present	Absent
	SAM 6264	Absent	Absent	Present	Present	Present	Absent

SAM 6317	Present	Present	Present	Present	Present	Absent
SAM 6318	Present	Present	Present	Present	Present	Absent
SAM 6331	Present	Present	Present	Present	Present	Absent
SAM 6332	Present	Present	Present	Present	Present	Absent
SAM 6348b	Present	Present	Present	Present	Present	Absent

UCT = University of Cape Town; SAM refers to 'South African Museum', Iziko Museum's former name. The acronym 'SAM' is still used in archival records to categorise and identify remains and is thus retained here for consistency.
Of the 100 individuals from UCT, 92 were derived from the UCT Skeletal Repository in the Faculty of Health Sciences and 8 were unaccessioned individuals temporarily curated UCT's Department of Archaeology (individuals labelled using the UCT AR# convention).

Table B2: Pelvic sex estimation data.

ID	Phenice Method		Supplementary pelvic traits			Molecular sex	Final pelvic sex estimate
	Subpubic Concavity	*Ventral Arc*	*Ischiopubic Ramus*	*Greater Sciatic Notch*	*Pre-auricular Sulcus*		
UCT 1	2	X	2	2	2	-	F
UCT 2	1	1	2	1	3	-	F
UCT 3	1	1	1	2	3	-	F
UCT 5	1	2	2	1	3	-	F
UCT 29	4	5	5	5	5	M	M
UCT 31	X	X	X	X	X	M	M
UCT 36	X	X	X	4	5	-	M
UCT 43	2	2	1	2	3	F	F
UCT 44	4	5	4	4	4	M	M
UCT 45	4	4	4	3	X	M	M
UCT 50	4	5	4	4	X	M	M
UCT 54	1	1	1	1	2	F	F
UCT 60	X	X	X	4	3	-	M
UCT 67b	X	X	X	4	5	-	M
UCT 88	1	2	1	1	2	-	F
UCT 97	4	5	5	4	X	-	M
UCT 106	X	X	X	1	3	-	F
UCT 107	4	4	3	4	5	-	M
UCT 112	4	4	5	4	5	-	M
UCT 113	2	X	1	1	3	-	F
UCT 120	2	X	X	1	3	-	F
UCT 130	4	5	4	4	5	-	M
UCT 131	X	X	X	1	2	-	F
UCT 158	2	1	1	3	3	-	F
UCT 162	4	X	X	3	3	-	M
UCT 164	X	X	X	1	X	-	F
UCT 168	4	5	4	3	X	-	M
UCT 169	X	X	X	1	2	-	F
UCT 172	X	X	X	3	2	-	F
UCT 181/206	1	2	1	4	4	M	M
UCT 182/200	X	X	X	1	2	N/A	F
UCT 183/201	2	X	4	1	X	N/A	F
UCT 185/202	X	X	X	1	2	F	F
UCT 192/213	2	1	2	1	2	N/A	F
UCT 212	4	5	5	4	5	-	M
UCT 226	4	4	3	4	5	-	M
UCT 230	4	4	4	4	5	-	M
UCT 232	3	4	3	4	5	-	M
UCT 246	X	X	X	4	5	-	M
UCT 248a	X	X	X	1	2	-	F
UCT 250	X	X	X	3	4	-	M

UCT 254	4	4	3	4	3	-	M
UCT 283	4	4	5	3	3	-	M
UCT 318	2	X	2	1	2	-	F
UCT 319c	4	X	4	2	3	-	M
UCT 323	2	2	2	X	X	-	F
UCT 324	2	1	2	1	2	-	F
UCT 331	X	X	X	4	3	-	M
UCT 347	X	X	X	5	5	-	M
UCT 373	1	1	1	1	2	-	F
UCT 382	3	5	4	2	X	-	M
UCT 383	X	X	X	4	5	-	M
UCT 385	X	X	X	X	X	M	M
UCT 386	4	5	3	3	5	M	M
UCT 390	3	4	4	3	4	?	M
UCT 391	1	1	1	1	2	N/A	F
UCT 392 + 387	5	5	4	2	5	M	M
UCT 394	4	4	4	4	3	M	M
UCT 395	2	1	2	1	2	F	F
UCT 396	1	1	1	1	X	F	F
UCT 398	X	X	X	X	X	M	M
UCT 399	2	X	X	1	2	-	F
UCT 412	1	X	1	1	2	-	F
UCT 427	1	1	2	1	2	-	F
UCT 428	3	3	2	4	5	-	M
UCT 436	X	X	X	1	3	-	F
UCT 450	4	5	4	4	X	-	M
UCT 451	2	2	3	1	2	-	F
UCT 531	X	2	2	1	X	-	F
UCT 539	4	5	4	3	3	-	M
UCT 565	3	3	4	4	3	-	M
UCT 566	2	X	2	1	2	-	F
UCT 578	2	X	3	1	2	-	F
UCT 579	1	3	2	1	3	-	F
UCT 584	X	X	X	1	2	-	F
UCT 587	X	X	X	3	4	-	M
UCT 591	3	3	3	4	4	-	M
UCT 593	X	X	X	2	2	-	F
UCT 594	X	X	X	5	X	-	M
UCT 605	1	2	2	1	3	-	F
UCT 609	X	X	X	4	5	-	M
UCT 620	X	X	X	1	3	-	F
UCT 622	5	5	4	4	X	-	M
UCT 655	X	X	X	4	3	-	M
UCT 659	X	X	X	1	2	-	F
UCT 661	X	X	X	5	X	-	M
UCT 676	2	1	2	2	3	-	F
UCT 683	X	X	X	4	5	-	M
UCT 684	4	4	3	2	3	-	M
UCT 686/ERF 839	4	X	4	3	5	-	M
UCR AR2	2	3	1	2	3	-	F
UCT AR4	3	4	4	3	X	-	M
UCT AR5	2	2	1	2	2	-	F
UCT AR6	4	4	3	3	3	-	M
UCT AR8	3	4	3	2	3	-	M
UCT AR9	2	1	2	2	X	-	F
UCT AR12	5	4	3?	4	3	-	M
UCT AR13	2	1	1	1	2	-	F
5MAGSTR	X	X	X	2	X	-	F

ERF 16015	X	X	X	5	4	-	M
MR 211	4	3	4	5	5	-	M
P 1205	1	1	1	1	3	-	F
P 1207	4	4	3	4	4	-	M
P 1271	1	2	2	2	X	-	F
P 1273	4	3	4	3	4	-	M
P 1275	4	4	4	4	5	-	M
P 1451	4	3	3	3	4	-	M
P 1639	2	2	1	1	X	-	F
P 1640	1	2	2	2	3	-	F
P 1704	2	2	1	1	3	-	F
P 1705 A	2	2	2?	2	3	-	F
SS1	4	4	4	4	3	-	M
SS2	2	1	2	3	3	-	F
SS3	4	3	4	4	4	-	M
SAM 32	2	2	1	1	3	-	F
SAM 34	4	4	3	3	4	-	M
SAM 1131	2	1	1	2	2	-	F
SAM 1145	4	5	5	4	X	-	M
SAM 1146	5	5	4	5	5	-	M
SAM 1157	1	1	2	1	2	-	F
SAM 1247a	1	1	2	1	2	-	F
SAM 1443	4	4	3	3	4	-	M
SAM 1444	4	X	4	5	4	-	M
SAM 1446	X	X	2	1	2	-	F
SAM 1449	4	4	4	4	3	-	M
SAM 1457	2	1	2	1	2	-	F
SAM 1473	1	1	2	1	2	-	F
SAM 1871	2	1	3	3	2	-	F
SAM 1878a	5	5	4	5	5	-	M
SAM 1878b	1	1	1	1	2	-	F
SAM 1879	5	5	5	3	3	-	M
SAM 1889	5	5	5	5	5	-	M
SAM 1893	5	4	4	3	4	-	M
SAM 3026	1	2	2	1	2	-	F
SAM 4305	3	4	4	5	4	-	M
SAM 4637	1	1	1	1	2	-	F
SAM 4720	5	4	5	4	4	-	M
SAM 4790	5	4	5	3	4	-	M
SAM 4800	1	1	1	1	2	-	F
SAM 4838a	4	4	5	3	X	-	M
SAM 4838b	2	1	1	1	2	-	F
SAM 4840	2	3	2	3	3	-	F
SAM 4901	5	5	5	5	5?	-	M
SAM 4905	3	4	4	4	X	-	M
SAM 4930	2	X	2	1	2	-	F
SAM 4931	5	5	4	5	5	-	M
SAM 4934	5	3	4	5	3	-	M
SAM 4943	1	3	1	2	2	-	F
SAM 4964	4	5	4	3	3	-	M
SAM 5035a	4	4	4	4	3	-	M
SAM 5036	5	5	5	4	5	-	M
SAM 5041	3	3	4	2	3	-	M
SAM 5048	5	5	3	5	4	-	M
SAM 5050	2	2	1	2	2	-	F
SAM 5075	4	4	3	4	5	-	M
SAM 5077 IV/D	4	X	3	3	4	-	M
SAM 5083	2	2	2	3	3	-	F
SAM 5095	2	2	2	1	2	-	F

SAM 6020	3	3	3	2	2	-	M
SAM 6023	4	3	3	5	5	-	M
SAM 6041a	3	4	3	4	5	-	M
SAM 6041b	5	5	5	4	3	-	M
SAM 6049	5	5	3	5	5	-	M
SAM 6050	2	1	3	1	2	-	F
SAM 6051	2	3	2	1	2	-	F
SAM 6072	5	5	5	4	X	-	M
SAM 6075	1	1	1	1	2	-	F
SAM 6147	4	4	3	3	3	-	M
SAM 6149	5	5	5	5	5	-	M
SAM 6264	4	5	4	3	3	-	M
SAM 6317	4	5	4	5	5	-	M
SAM 6318	4	5	4	3	5	-	M
SAM 6331	1	1	1	1	2	-	F
SAM 6332	4	4	3	3	4	-	M
SAM 6348b	2	1	1	1	2	-	F

Pelvic sex estimate determined using Phenice method (1969) and molecular sex results. Molecular sex results were available for 17 individuals from UCT Skeletal Repository (12 males, 5 females), 12 of which had corresponding pelvic sex estimates and the remaining 5 having only molecular sex results.

Table B3: Age estimation data.

ID	Cranial suture closure					Pelvic assessment					Sternal rib ends		Age estimate				
	Vault sutures		*Antero-lateral sutures*		*Cranial age range*	*Pubis symphysis*		*Auricular surface*		*Pelvic age range*	*Phase*	*Rib-end age range*	*Cranial estimate*	*Pelvic estimate*	*Rib-end estimate*	*Total age estimate*	*Age category*
	Score	*"S"*	*Score*	*"S"*		*Phase*	*Age range*	*Phase*	*Age range*								
UCT 1	4,0	S2 (22 - 45)	2,0	S2 (28 - 43)	30 - 40	-	-	4	35 - 39	35 - 39	3	30 - 39	30 - 40	35 - 39	30 - 39	30 - 40	MA
UCT 2	8,0	S3 (27 - 44)	7,0	S5 (35 - 57)	35 - 50	4	26 - 70	5?	40 - 44	26 - 35		20 - 32	35 - 50	26 - 35	20 - 32	25 - 35	YA
UCT 3	-	-	-	-	-	3	21 - 53	4	35 - 39	25 - 40	-	-	-	25 - 40	-	25 - 40	YA/MA
UCT 5	2,0	S1 (19 - 44)	2,0	S2 (28 - 43)	25 - 40	2	19 - 40	3	30 - 34	25 - 35	3	30 - 39	25 - 40	25 - 35	30 - 39	25 - 35	YA
UCT 29	13,0	S4 (30 - 60)	9,0	S6 (40 - 60+)	35 - 55	4	23 - 59	5	40 - 44	30 - 45	3	30 - 39	35 - 55	30 - 45	30 - 39	45+	MA/OA
UCT 31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30 - 50	MA
UCT 36	10,0	S3 (27 - 42)	2,0	S2 (28 - 43)	35 - 50	-	-	7	50 - 60	50 - 60	6	60 - 69	35 - 50	50 - 60	60 - 69	40 - 65	MA = MA/OA
UCT 43	3,0	S2 (23 - 45)	3,0	S3 (28 - 51)	25 - 45	3	21 - 53	4	35 - 39	25 - 45	3	30 - 39	25 - 45	25 - 45	30 - 39	30 - 45	MA
UCT 44	6,0	S2 (23 - 45)	2,0	S2 (28 - 45)	25 - 40	2	19 - 40	3	30 - 34	25 - 40	2	20 - 29	25 - 40	25 - 40	20 - 29	30 - 40	YA/MA
UCT 45	-	-	-	-	-	3	22 - 45	3	30 - 34	20 - 35	2	20 - 29	-	20 - 35	20 - 29	25 - 30	YA
UCT 50	21,0	S6 (34 - 60)	9,0	S6 (39 - 60+)	50+	4	23 - 59	6	45 - 49	30 - 55	4 TO 5	40 - 59	50+	30 - 55	40 - 59	40 - 60	MA/OA
UCT 54	-	-	-	-	-	5	25 - 83	6	45 - 49	35 - 50	5	50 - 59	-	35 - 50	50 - 59	45 - 60	OA
UCT 60	7,0	S3 (27 - 44)	5,0	S3 (27 - 51)	30 - 45	-	-	4	35 - 39	35 - 39	-	-	30 - 45	35 - 39	-	30 - 45	MA
UCT 67b	8,0	S3 (27 - 44)	3,0	S3 (27 - 51)	35 - 45	-	-	6	45 - 49	45 - 49	-	-	35 - 45	45 - 49	-	35 - 50	MA
UCT 88	9,0	S3 (27 - 44)	8,0	S5 (35 - 57)	35 - 50	3	21 - 53	6	45 - 49	25 - 40	-	-	35 - 50	25 - 40	-	27 - 40	YA/MA
UCT 97	-	-	-	-	-	3	22 - 45	3	30 - 34	25 - 40	-	-	-	25 - 40	-	25 - 40	YA/MA
UCT 106	5,0	S2 (22 - 45)	6,0	S4 (28 - 54)	35 - 45	-	-	6	45 - 49	45 - 49	-	-	35 - 45	45 - 49	-	35 - 50	MA
UCT 107	8,0	S3 (27 - 42)	6,0	S4 (28 - 54)	35 - 50	4	23 - 59	6	45 - 49	30 - 50	-	-	35 - 50	30 - 50	-	30 - 50	MA
UCT 112	18,0	S5 (35 - 59)	6,0	S4 (30 - 60)	40 - 55	4	23 - 59	7	50 - 60	35 - 55	-	-	40 - 55	35 - 55	-	35 - 50	MA
UCT 113	14,0	S4 (30 - 60)	6,0	S4 (28 - 54)	40 - 50	-	-	6	45 - 49	45 - 49	-	-	40 - 50	45 - 49	-	40 - 50	MA
UCT 120	2,0	S1 (19 - 44)	5,0	S3 (26 - 51)	30 - 45	-	-	5	40 - 44	40 - 44	-	-	30 - 45	40 - 44	-	35 - 45	MA
UCT 130	1,0	S1 (19 - 44)	3,0	S3 (26 - 51)	25 - 45	2	19 - 35	6	45 - 49	30 - 50	3	30 - 39	25 - 45	30 - 50	30 - 39	25 - 45	YA = YA/MA
UCT 131	18,0	S5 (35 - 60)	9,0	S6 (40 - 60)	45 - 60	-	-	5	40 - 44	30 - 45	2	20 - 29	45 - 60	30 - 45	20 - 29	25 - 50	YA/MA
UCT 158	-	-	-	-	-	-	-	5	40 - 44	40 - 44	-	-	-	40 - 44	-	40 - 44	MA
UCT 162	1,0	S1 (19 - 44)	5,0	S3 (26 - 51)	30 - 45	-	-	5	40 - 44	40 - 44	-	-	30 - 45	40 - 44	-	30 - 45	MA
UCT 164	9,0	S3 (27 - 44)	3,0	S3 (27 - 51)	35 - 45	-	-	5	40 - 44	40 - 44	-	-	35 - 45	40 - 44	-	35 - 45	MA
UCT 168	18,0	S5 (35 - 60)	10,0	S6 (40 - 60+)	45 - 60	-	-	-	-	-	-	-	45 - 60	-	-	45 - 60	OA
UCT 169	12,0	S4 (30 - 60)	9,0	S6 (40 - 60+)	40 - 60	-	-	4	35 - 39	35 - 39	-	-	40 - 60	35 - 39	-	30 - 50	MA
UCT 172	15,0	S4 (30 - 60)	4,0	S3 (27 - 51)	35 - 50	-	-	-	-	-	-	-	35 - 50	-	-	35 - 50	MA
UCT 181/206	-	-	-	-	-	3 to 4	21 - 70	6	45 - 49	40 - 65	-	-	-	40 - 65	-	35 - 50	YA/MA
UCT 182/200	-	-	-	-	-	2	19 - 40	-	-	19 - 40	-	-	-	19 - 40	-	19 - 40	YA/MA
UCT 183/201	-	-	-	-	-	5	26 - 70	-	-	26 - 70	-	-	-	26 - 70	-	26 - 70	-
UCT 185/202	10,0	S3 (27 - 44)	2,0	S2 (28 - 44)	30 - 45	-	-	5 TO 6	40 - 49	40- 49	-	-	30 - 45	40- 49	-	35 - 50	MA
UCT 192/213	5,0	S2 (23 - 45)	10,0	S6 (40 - 60)	30 - 55	2	19 - 40	-	-	19 - 40	-	-	30 - 55	19 - 40	-	30 - 50	MA
UCT 212	-	-	-	-	-	3	22 - 45	3	30 - 34	25 - 40	-	-	-	25 - 40	-	25 - 40	YA/MA
UCT 226	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UCT 230	3,0	S2 (23 - 45)	-	-	-	3	22 - 43	6	45 - 49	30 - 50	3	30 - 39	-	30 - 50	30 - 39	30 - 45	MA
UCT 232	11,0	S3 (27 - 42)	8,0	S5 (35 - 56)	35 - 50	3	22 - 43	4	35 - 39	30 - 45	-	-	35 - 50	30 - 45	-	30 - 45	MA
UCT 246	10,0	S3 (27 - 44)	1,0	S1 (20 - 41)	25 - 40	-	-	4	35 - 39	35 - 39	3	30 - 39	25 - 40	35 - 39	30 - 39	30 - 40	MA
UCT 248a	11,0	S3 (27 - 44)	9,0	S6 (40 - 60+)	35 - 55	-	-	-	-	-	-	-	35 - 55	-	-	35 - 55	MA
UCT 250	14,0	S4 (30 - 60)	10,0	S6 (40 - 60+)	45 - 55	-	-	6	45 - 49	45 - 49	-	-	45 - 55	45 - 49	-	45 - 55	MA/OA
UCT 254	8,0	S3 (27 - 42)	2,0	S2 (28 - 43)	30 - 40	4	23 - 59	6	45 - 49	30 - 45	4	40 - 49	30 - 40	30 - 45	40 - 49	30 - 50	MA

UCT 283	-	-	-	-	-	2	19 - 35	3	30 -34	25 - 35	2	20 - 29	-	25 - 35	20 - 29	20 - 35	YA
UCT 318	2,0	S1 (19 - 44)	4,0	S3 (26 - 51)	25 - 40	-	-	6	45 - 49	45 - 49	-	-	25 - 40	45 - 49	-	30 - 50	MA
UCT 319c	12,0	S4 (30 - 60)	4,0	S3 (27 - 51)	35 - 50	4	23 - 59	4 TO 5	35 - 44	25 - 50	-	-	35 - 50	25 - 50	-	25 - 45	YA
UCT 323	-	-	3,0	S3 (27 - 51)	35 - 45	3	21 - 53	4	35 - 39	35 - 39	-	-	35 - 45	35 - 39	-	35 - 45	MA
UCT 324	-	-	-	-	-	3	21 - 53	4	35 - 39	25 - 45	3	30 - 39	-	25 - 45	30 - 39	25 - 40	YA/MA
UCT 331	5,0	S2 (23 - 45)	2,0	S2 (28 - 44)	30 - 40	-	-	3	30 - 34	30 - 34	-	-	30 - 40	30 - 34	-	30 - 40	YA/MA
UCT 347	-	-	-	-	-	-	-	6	45 - 49	45 - 49	-	-	-	45 - 49	-	45 - 49	MA
UCT 373	-	-	-	-	-	5	25 - 83	5	40 - 44	35 - 45	3	30 - 39	-	35 - 45	30 - 39	30 - 45	MA
UCT 382	-	-	-	-	-	4	23 - 59	4	35 - 39	35 - 39	3	30 - 39	-	35 - 39	30 - 39	30 - 40	YA/MA
UCT 383	10,0	S3 (27 - 44)	10,0	S6 (40 - 60+)	35 - 60	-	-	3	30 - 34	30 - 34	2 TO 3	20 - 39	35 - 60	30 - 34	20 - 39	30 - 50	MA
UCT 385	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UCT 386	11,0	S3 (27 - 44)	8,0	S5 (35 - 55)	35 - 50	4	23 - 59	6	45 - 49	30 - 55	-	-	35 - 50	30 - 55	-	30 - 55	MA
UCT 390	-	-	-	-	-	4	23 - 59	5	40 - 44	25 - 45	-	-	-	25 - 45	-	25 - 45	YA/MA
UCT 391	-	-	-	-	-	3 TO 4	21 - 70	4	35 - 39	25 - 45	-	-	-	25 - 45	-	25 - 45	YA
UCT 392 + 387	5,0	S2 (23 - 45)	9,0	S6 (40 - 60+)	30 - 55	4	23 - 59	5	40 - 44	25 - 35	-	-	30 - 55	25 - 35	-	27 - 35	YA
UCT 394	-	-	-	-	-	4	23 - 59	5 TO 6	40 - 49	30 - 50	-	-	-	30 - 50	-	30 - 50	MA
UCT 395	-	-	-	-	-	4	26 - 70	5	40 - 44	30 - 50	-	-	-	30 - 50	-	30 - 50	MA
UCT 396	-	-	-	-	-	4	26 - 70	5	40 - 44	30 - 50	-	-	-	30 - 50	-	30 - 50	MA
UCT 398	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UCT 399	18,0	S5 (35 - 60)	7,0	S5 (35 - 56)	45 - 55	-	-	7	50 - 60	50 - 60	5	50 - 59	45 - 55	50 - 60	50 - 59	50 - 60	OA
UCT 412	13,0	S4 (30 - 60)	11,0	S7 (49 - 60+)	40 - 60	-	-	5	40 - 44	40 - 44	3 TO 4	30 - 49	40 - 60	40 - 44	30 - 49	30 - 45	MA
UCT 427	9,0	S3 (27 - 44)	5,0	S3 (27 - 51)	35 - 45	-	-	3	30 - 34	30 - 34	-	-	35 - 45	30 - 34	-	30 - 40	YA/MA
UCT 428	15,0	S4 (30 - 60)	2,0	S2 (28 - 44)	30 - 50	5	28 - 78	4	35 - 39	35 - 39	-	-	30 - 50	35 - 39	-	30 - 45	MA
UCT 436	13,0	S4 (30 - 60)	10,0	S6 (40 - 60+)	40 - 55	-	-	5 TO 6	40 - 49	40 - 49	3	30 - 39	40 - 55	40 - 49	30 - 39	35 - 50	MA
UCT 450	10,0	S3 (27 - 44)	7,0	S5 (35 - 55)	35 - 50	5	28 - 78	5	40 - 44	30 - 50	3	30 - 39	35 - 50	30 - 50	30 - 39	30 - 45	MA
UCT 451	7,0	S3 (27 - 44)	10,0	S6 (40 - 60+)	35 - 55	4	26 - 70	4	35 - 39	25 - 35	2 TO 3	20 - 39	35 - 55	25 - 35	20 - 39	27 - 40	YA/MA
UCT 531	5,0	S2 (23 - 45)	5,0	S3 (27 - 51)	30 - 45	3	21 - 53	5	40 - 44	40 - 44	-	-	30 - 45	40 - 44	-	30 - 45	MA
UCT 539	9,0	S3 (27 - 44)	5,0	S3 (27 - 51)	30 - 45	4	23 - 59	-	-	-	3	30 - 39	30 - 45	-	30 - 39	30 - 45	MA
UCT 565	12,0	S4 (30 - 60)	4,0	S3 (27 - 51)	35 - 50	4	23 - 59	5	40 - 44	30 - 45	3	30 - 39	35 - 50	30 - 45	30 - 39	30 - 45	MA
UCT 566	-	-	-	-	-	-	-	4	35 - 39	35 - 39	3 TO 4	30 - 49	-	35 - 39	30 - 49	30 - 45	MA
UCT 578	8,0	S3 (27 - 42)	9,0	S6 (40 - 60+)	35 - 55	-	-	6	45 - 49	45 - 49	-	-	35 - 55	45 - 49	-	35 - 50	MA
UCT 579	12,0	S4 (30 - 60)	5,0	S3 (27 - 51)	35 - 50	4	23 - 59	5	40 - 44	30 - 45	3	30 - 39	35 - 50	30 - 45	30 - 39	30 - 45	MA
UCT 584	15,0	S4 (30 - 60)	8,0	S5 (35 - 57)	40 - 55	-	-	6	45 - 49	35 - 50	-	-	40 - 55	35 - 50	-	30 - 50	MA
UCT 587	12,0	S4 (30 - 60)	11,0	S7 (49 - 60+)	40 - 60	-	-	4	35 - 39	35 - 39	4	40 - 49	40 - 60	35 - 39	40 - 49	35 - 50	MA
UCT 591	7,0	S3 (27 - 42)	6,0	S4 (28 - 54)	35 - 50	3	22 - 43	5 to 6	40 - 49	30 - 49	4	40 - 49	35 - 50	30 - 49	40 - 49	35 - 50	MA
UCT 593	17,0	S5 (35 - 59)	10,0	S6 (40 - 60+)	45 - 60	-	-	6	45 - 49	45 - 49	3	30 - 39	45 - 60	45 - 49	30 - 39	35 - 50	MA
UCT 594	17,0	S5 (35 - 60)	9,0	S6 (40 - 60+)	50 - 60	-	-	-	-	-	5	50 - 59	50 - 60	-	50 - 59	50 - 60	OA
UCT 605	16,0	S5 (35 - 60)	6,0	S4 (28 - 54)	45 - 60	6	42 - 87	8	60+	50 - 65	6	60 - 69	45 - 60	50 - 65	60 - 69	60 +	MA
UCT 609	-	-	-	-	-	-	-	4	35 - 39	35 - 39	-	-	-	35 - 39	-	35 - 39	MA
UCT 620	10,0	S3 (27 - 44)	9,0	S6 (40 - 60)	35 - 55	-	-	4	35 - 39	25 - 40	2	20 - 29	35 - 55	25 - 40	20 - 29	25 - 35	YA
UCT 622	9,0	S3 (27 - 44)	10,0	S6 (40 - 60+)	40 - 55	3	22 - 43	4	35 - 39	25 - 35	2 TO 3	20 - 39	40 - 55	25 - 35	20 - 39	27 - 40	YA/MA
UCT 655	8,0	S3 (27 - 44)	9,0	S6 (40 - 60)	35 - 60	-	-	4	35 - 39	30 - 40	2	20 - 29	35 - 60	30 - 40	20 - 29	30 - 50	MA
UCT 659	2,0	S1 (19 - 44)	5,0	S3 (27 - 51)	25 - 45	-	-	4	35 - 39	35 - 39	3	30 - 39	25 - 45	35 - 39	30 - 39	30 - 45	MA
UCT 661	2,0	S1 (19 - 44)	2,0	S2 (28 - 44)	25 - 40	-	-	-	-	-	-	-	25 - 40	-	-	25 - 40	YA/MA
UCT 676	4,0	S2 (22 - 45)	7,0	S5 (35 - 56)	35 - 50	-	-	6	45 - 49	45 - 49	-	-	35 - 50	45 - 49	-	40 - 50	MA
UCT 683	4,0	S2 (23 - 45)	6,0	S4 (30 - 55)	30 - 50	-	-	-	-	-	-	-	30 - 50	-	-	30 - 50	MA
UCT 684	17,0	S5 (35 - 60)	9,0	S6 (40 - 60)	45 - 55	-	-	4 TO 5	35 - 44	35 - 44	3	30 - 39	45 - 55	35 - 44	30 - 39	30 - 50	MA

UCT 686/ERF 839	18,0	S5 (35 - 60)	11,0	S7 (49 - 60+)	45 - 60	-	-	-	-	-	-	-	45 - 60	-	-	45 - 60	OA
UCR AR2	14,0	S4 (30 - 60)	9,0	S6 (39 - 60+)	35 - 55	-	-	5 TO 6?	40 - 49	40 - 49	-	-	35 - 55	40 - 49	-	35 - 55	MA/OA
UCT AR4	-	-	-	-	-	3	22 - 45	4	35 - 39	25 - 40	-	-	-	25 - 40	-	30 - 40	YA/MA
UCT AR5	-	-	-	-	-	4	26 - 70	4	35 - 39	30 - 45	-	-	-	30 - 45	-	30 - 45	MA
UCT AR6	11,0	S3 (27 - 42)	8,0	S5 (35 - 57)	35 - 50	2	19 - 35	3	30 - 34	25 - 35	3	30 - 39	35 - 50	25 - 35	30 - 39	30 - 45	MA
UCT AR8	-	-	-	-	-	2	19 - 40	-	-	19 - 40	-	-	-	19 - 40	-	19 - 40	YA/MA
UCT AR9	1,0	S1(19 -44)	4,0	S3 (27 - 51)	25 - 45	3	21 - 53	-	-	21 - 53	3	30 - 39	25 - 45	21 - 53	30 - 39	30 - 45	MA
UCT AR12	-	-	-	-	-	4	23 - 59	5	40 - 44	35 - 55	4	40 - 49	-	35 - 55	40 - 49	35 - 50	MA
UCT AR13	-	-	-	-	-	5	25 - 83	5	40 - 44	30 - 45	-	-	-	30 - 45	-	30 - 45	MA
5MAGSTR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ERF 16015	9,0	S3 (27 - 44)	6,0	S4 (30 - 55)	35 - 50	-	-	-	-	-	-	-	35 - 50	-	-	35 - 50	MA
MR 211	-	-	-	-	-	4	23 - 59	4	35 - 39	30 - 55	5 TO 6	50 - 60	-	30 - 55	50 - 60	45 - 60	OA
P 1205	-	-	-	-	-	-	-	6 TO 7	45 - 60	45 - 60	-	-	-	45 - 60	-	45 - 60	OA
P 1207	21,0	S6 (34 - 60)	11,0	S7 (49 - 60+)	45 - 60	4	23 - 59	6	45 - 49	30 - 50	-	-	45 - 60	30 - 50	-	35 - 55	MA/OA
P 1271	1,0	S1 (19 - 44)	5,0	S3 (27 - 51)	25 - 45	3	21 - 53	3	30 - 34	25 - 35	2	20 - 29	25 - 45	25 - 35	20 - 29	25 - 35	YA
P 1273	2,0	S1 (19 - 44)	4,0	S3 (27 - 51)	25 - 45	4	23 - 59	3	30 - 34	25 - 35	3	30 - 39	25 - 45	25 - 35	30 - 39	25 - 40	YA/MA
P 1275	3,0	S2 (22 - 45)	4,0	S3 (27 - 51)	30 - 45	4	23 - 59	4 TO 5	35 - 44	30 - 50	-	-	30 - 45	30 - 50	-	30 - 45	MA
P 1451	1,0	S1 (19 - 44)	4,0	S3 (27 - 51)	25 - 45	2	19-35	2 TO 3	25 - 34	25 - 35	2	20 - 29	25 - 45	25 - 35	20 - 29	25 - 40	YA/MA
P 1639	14,0	S4 (30 - 60)	11,0	S7 (49 - 60+)	40 - 60	6	42 - 87	8	60+	40 - 60	5	50 - 59	40 - 60	40 - 60	50 - 59	45 - 60	OA
P 1640	1,0	S1 (19 - 44)	4,0	S3 (27 - 51)	25 - 45	1	15 - 24	2	25 - 29	20 - 30	2	20 - 29	25 - 45	20 - 30	20 - 29	25 - 35	YA
P 1704	-	-	-	-	-	3	21 - 53	4 TO 5	35 - 44	25 - 35	-	-	-	25 - 35	-	25 - 35	YA
P 1705 A	-	-	-	-	-	-	-	4 TO 5	35 - 44	35 - 44	-	-	-	35 - 44	-	35 - 44	MA
SS1	-	-	-	-	-	2	22 - 45	3	30 - 34	25 - 40	3	30 - 39	-	25 - 40	30 - 39	25 - 40	YA/MA
SS2	-	-	-	-	-	3	21 - 53	4	35 - 39	25 - 40	3	30 - 39	-	25 - 40	30 - 39	25 - 40	YA/MA
SS3	12,0	S4 (30 - 60)	1,0	S1 (20 - 41)	35 - 50	4	23 - 59	6	45 - 49	25 - 45	-	-	35 - 50	25 - 45	-	30 - 50	MA
SAM 32	9,0	S3 (27 - 44)	7,0	S5 (35 - 57)	30 - 50	4	26 - 70	4	35 - 39	30 - 45	2	20 - 29	30 - 50	30 - 45	20 - 29	25 - 45	YA/MA
SAM 34	5,0	S2 (23 - 45)	9,0	S6 (39 - 60+)	35 - 55	5	28 - 78	6	45 - 49	30 - 55	4 TO 5	40 - 59	35 - 55	30 - 55	40 - 59	35 - 60	MA/OA
SAM 1131	12,0	S4 (30 - 60)	11,0	S7 (49 - 60+)	40 - 60	6	42 - 87	7	50 - 60	40 - 60	4	40 - 49	40 - 60	40 - 60	40 - 49	40 - 60	MA/OA
SAM 1145	18,0	S5 (35 - 59)	10,0	S6 (40 - 60+)	40 - 60	5	28 - 78	6	45 - 49	30 - 55			40 - 60	30 - 55		35 - 55	MA/OA
SAM 1146	12,0	S4 (30 - 60)	9,0	S6 (39 - 60+)	40 - 60	3	22 - 45	5 TO 6	40 - 49	35 - 50	4	40 - 49	40 - 60	35 - 50	40 - 49	35 - 50	MA
SAM 1157	17,0	S5 (35 - 59)	9,0	S6 (39 - 60+)	45 - 60	4	26 - 70	4	35 - 39	30 - 50	3	30 - 39	45 - 60	30 - 50	30 - 39	30 - 55	MA/OA
SAM 1247a	9,0	S3 (27 - 44)	8,0	S5 (35 - 57)	35 - 50	-	-	4	35 - 39	35 - 39	3	30 - 39	35 - 50	35 - 39	30 - 39	30 - 45	MA
SAM 1443	13,0	S4 (30 - 60)	8,0	S5 (35 - 57)	40 - 55	3	22 - 43	4	35 - 39	30 - 45	4	40 - 49	40 - 55	30 - 45	40 - 49	40 - 60	MA/OA
SAM 1444	15,0	S4 (30 - 60)	11,0	S7 (49 - 60+)	40 - 60	-	-	6	45 - 49	45 - 49	4 TO 5	40 - 59	40 - 60	45 - 49	40 - 59	40 - 60	MA/OA
SAM 1446	9,0	S3 (27 - 44)	6,0	S4 (30 - 60)	35 - 50	-	-	4 TO 5	35 - 44	35 - 44	-	-	35 - 50	35 - 44	-	35 - 50	MA
SAM 1449	-	-	-	-	-	3	22 - 45	4 TO 5	35 - 44	25 - 40	-	-	-	25 - 40	-	25 - 40	YA/MA
SAM 1457	9,0	S3 (27 - 44)	6,0	S4 (30 - 60)	30 - 50	4	26 - 70	5	40 - 44	35 - 50	-	-	30 - 50	35 - 50	-	30 - 50	MA
SAM 1473	10,0	S3 (27 - 44)	6,0	S4 (30 - 60)	30 - 50	3	21 - 53	3 TO 4	30 - 39	30 - 45	3	30 - 39	30 - 50	30 - 45	30 - 39	30 - 45	MA
SAM 1871	14,0	S4 (30 - 60)	8,0	S5 (35 - 57)	40 - 50	-	-	4	35 - 39	35 - 39	-	-	40 - 50	35 - 39	-	35 - 50	MA
SAM 1878a	18,0	S5 (35 - 59)	11,0	S7 (49 - 60+)	45 - 60+	5	28 - 78	6	45 - 49	30 - 50	4	40 - 49	45 - 60+	30 - 50	40 - 49	45 - 60	OA
SAM 1878b	-	-	-	-	-	6	42 - 87	6	45 - 49	40 - 60	-	-	-	40 - 60	-	40 - 60	MA/OA
SAM 1879	11,0	S3 (27 - 44)	8,0	S5 (35 - 57)	35 - 50	2	19 - 35	3	30 - 34	25 - 40	2 TO 3	20 - 39	35 - 50	25 - 40	20 - 39	25 - 40	YA/MA
SAM 1889	-	-	-	-	-	4	23 - 59	5	40 - 44	30 - 50	3	30 - 39	-	30 - 50	30 - 39	30 - 45	MA
SAM 1893	10,0	S3 (27 - 44)	7,0	S5 (35 - 57)	35 - 50	3	22 - 45	5	40 - 44	30 - 45	4	40 - 49	35 - 50	30 - 45	40 - 49	30 - 50	MA
SAM 3026	-	-	-	-	-	1	15 - 24	1 TO 2	20 - 29	20- 30	-	-	-	20- 30	-	20 - 30	YA
SAM 4305	-	-	-	-	-	4	23 - 59	5	40 - 44	35 - 55	4	40 - 49	-	35 - 55	40 - 49	35 - 55	MA/OA
SAM 4637	6,0	S2 (23 - 45)	2,0	S2 (28 - 45)	30 - 40	4	26 - 70	5	40 - 44	35 - 55	-	-	30 - 40	35 - 55	-	35 - 55	MA/OA

SAM 4720	-	-	-	-	-	3	22 - 45	4	35 - 39	25 - 45	-	-	-	25 - 45	-	25 - 45	YA/MA
SAM 4790	4,0	S2 (22 - 45)	5,0	S3 (27 - 51)	30 - 45	4	23 - 59	6	45 - 49	35 - 55	4	40 - 49	30 - 45	35 - 55	40 - 49	30 - 45	MA
SAM 4800	10,0	S3 (27 - 44)	-	-	-	4	26 - 70	4 TO 5	35 - 44	30 - 50	-	-	-	30 - 50	-	30 - 50	MA
SAM 4838a	-	-	-	-	-	3	22 - 45	-	-	22 - 45	3	30 - 39	-	22 - 45	30 - 39	25 - 45	YA/MA
SAM 4838b	-	-	-	-	-	4	26 - 70	5	40 - 44	25 - 45	4	40 - 49	-	25 - 45	40 - 49	30 - 45	MA
SAM 4840	4,0	S2 (22 - 45)	5,0	S3 (27 - 51)	30 - 50	1	15 - 24	1	20 - 24	20 - 30	2	20 -29	30 - 50	20 - 30	20 -29	20 - 30	YA
SAM 4901	19,0	S6 (34 - 60)	3,0	S3 (27 - 51)	40 - 60	5	28 - 78	7 TO 8	50 - 60+	40 - 60	-	-	40 - 60	40 - 60	-	40 - 60	MA/OA
SAM 4905	4,0	S2 (22 - 45)	8,0	S5 (35 - 57)	30 - 50	3	22 - 45	5	40 - 44	30 - 50	-	-	30 - 50	30 - 50	-	30 - 50	MA
SAM 4930	-	-	-	-	-	-	-	4	35 - 39	35 - 39	-	-	-	35 - 39	-	35 - 39	MA
SAM 4931	13,0	S4 (30 - 60)	8,0	S5 (35 - 57)	35 - 60	3	22 - 45	4	35 - 39	25 - 40	2	20 - 29	35 - 60	25 - 40	20 - 29	25 - 35	YA
SAM 4934	-	-	-	-	-	3	22 - 45	4 TO 5	35 - 44	25 - 45	-	-	-	25 - 45	-	25 - 45	YA/MA
SAM 4943	9,0	S3 (27 - 44)	2,0	S2 (28 - 45)	30 - 45	3	21 - 53	4	35 - 39	25 - 45	-	-	30 - 45	25 - 45	-	25 - 45	YA/MA
SAM 4964	2,0	S1 (19 - 44)	5,0	S3 (27 - 51)	30 - 45	2	19 - 35	4	35 - 39	20 - 40	-	-	30 - 45	20 - 40	-	20 - 35	YA
SAM 5035a	12,0	S4 (30 - 60)	9,0	S6 (39 - 60+)	40 - 60	3	22 - 45	4	35 - 39	25 - 45	-	-	40 - 60	25 - 45	-	25 - 45	YA/MA
SAM 5036	-	-	-	-	-	3	22 - 45	3	30 - 34	25 - 35	3	30 - 39	-	25 - 35	30 - 39	25 - 40	YA/MA
SAM 5041	8,0	S3 (27 - 44)	8,0	S5 (35 - 57)	35 - 55	3	22 - 45	4 TO 5	35 - 44	25 - 50	2	20 - 29	35 - 55	25 - 50	20 - 29	25 - 40	YA/MA
SAM 5048	6,0	S2 (23 - 45)	9,0	S6 (39 - 60+)	35 - 55	2	19 - 35	3	30 - 34	25 - 35	-	-	35 - 55	25 - 35	-	25 - 40	YA/MA
SAM 5050	10,0	S3 (27 - 44)	7,0	S5 (35 - 57)	35 - 55	-	-	4	35 - 39	35 - 39	-	-	35 - 55	35 - 39	-	35 - 50	MA
SAM 5075	-	-	-	-	-	3	22 - 45	5	40 - 44	30 - 50	3	30 - 39	-	30 - 50	30 - 39	30 - 45	MA
SAM 5077 IV or D	-	-	-	-	-	-	-	5	40 - 44	40 - 44	-	-	-	40 - 44	-	40 - 44	MA
SAM 5083	17,0	S5 (35 - 59)	11,0	S7 (49 - 60+)	40 - 60	4	26 - 70	4	35 - 39	30 - 50	-	-	40 - 60	30 - 50	-	35 - 60	MA/OA
SAM 5095	12,0	S4 (30 - 60)	7,0	S5 (35 - 57)	35 - 60	4	26 - 70	4	35 - 39	30 - 50	-	-	35 - 60	30 - 50	-	35 - 60	MA/OA
SAM 6020	9,0	S3 (27 - 44)	8,0	S5 (35 - 57)	35 - 50	SE-?	?	3 TO 4	30 - 39	30 - 39	-	-	35 - 50	30 - 39	-	35 - 50	MA
SAM 6023	-	-	-	-	-	-	-	4	35 - 39	35 - 39	-	-	-	35 - 39	-	35 - 39	MA
SAM 6041a	-	-	-	-	-	2	19 - 35	4	35 - 39	25 - 40	-	-	-	25 - 40	-	25 - 40	YA/MA
SAM 6041b	-	-	-	-	-	3	22 - 45	3 TO 4	30 - 39	25 - 45	-	-	-	25 - 45	-	25 - 45	YA/MA
SAM 6049	16,0	S5 (35 - 60)	10,0	S6 (40 - 60+)	45 - 60	4	23 - 59	5	40 - 44	30 - 50	4	40 - 49	45 - 60	30 - 50	40 - 49	40 - 55	MA/OA
SAM 6050	-	-	-	-	-	3	21 - 53	3 TO 4	30 - 39	30 - 50	-	-	-	30 - 50	-	30 - 50	MA
SAM 6051	12,0	S4 (30 - 60)	7,0	S5 (35 - 57)	40 - 60	2	19 - 40	-	-	19 - 40	2 TO 3	20 - 39	40 - 60	19 - 40	20 - 39	25 - 40	YA/MA
SAM 6072	2,0	S1 (19 - 44)	8,0	S5 (35 - 57)	30 - 50	3	22 - 45	4	35 -39	25 - 40	2	20 - 29	30 - 50	25 - 40	20 - 29	25 - 35	YA
SAM 6075	11,0	S3 (27 - 44)	8,0	S5 (35 - 57)	40 - 55	3	21 - 53	4	35 - 39	25 - 50	3	30 - 39	40 - 55	25 - 50	30 - 39	30 - 50	MA
SAM 6147	13,0	S4 (30 - 60)	8,0	S5 (35 - 57)	40 - 60	3	22 - 45	4	35 - 39	25 - 45	-	-	40 - 60	25 - 45	-	30 - 50	MA
SAM 6149	15,0	S4 (30 - 60)	11,0	S7 (49 - 60+)	40 - 60	4	23 - 59	5	40 - 44	35 - 60	4	40 - 49	40 - 60	35 - 60	40 - 49	40 - 60	MA/OA
SAM 6264	18,0	S5 (35 - 59)	11,0	S7 (49 - 60+)	45 - 60	3	22 - 45	4	35 - 39	25 - 45	3	30 - 39	45 - 60	25 - 45	30 - 39	25 - 35	YA
SAM 6317	13,0	S4 (30 - 60)	7,0	S5 (35 - 57)	40 - 60	4	23 - 59	-	-	23 - 59	4	40 - 49	40 - 60	23 - 59	40 - 49	35 - 60	MA/OA
SAM 6318	17,0	S5 (35 - 59)	7,0	S5 (35 - 57)	40 - 60	-	-	-	-	-	3 TO 4	30 - 49	40 - 60	-	30 - 49	35 - 55	MA/OA
SAM 6331	10,0	S3 (27 - 44)	8,0	S5 (35 - 57)	30 - 55	4	26 - 70	5	40 - 44	30 - 50	3	30 - 39	30 - 55	30 - 50	30 - 39	30 - 50	MA
SAM 6332	3,0	S2 (22 - 45)	5,0	S3 (27 - 51)	30 - 50	-	-	4 TO 5	35 - 44	25 - 40	2 TO 3	20 - 39	30 - 50	25 - 40	20 - 39	25 - 35	YA
SAM 6348b	9,0	S3 (27 - 44)	10,0	S6 (40 - 60+)	35 - 60	4	26 - 70	5	40 - 44	35 - 60	4 TO 5	40 - 59	35 - 60	35 - 60	40 - 59	40 - 60	MA/OA

Cranial suture sites assessed included midlambdoid, lambda, obelion, anterior sagittal suture, bregma, midcoronal suture, pterion, sphenofrontal suture and inferior- and superior- sphenotemporal sutures (using the ectocranial site analysis technique) (Meindl & Lovejoy, 1985). Suture sites were grouped into lateral-anterior and vault groups, composite scores calculated for each group are listed above.
Rib end modifications and pubic symphyseal surface degeneration assessed by Brooks & Suchey (1990) scale, and auricular surface by Lovejoy *et al.* (1985).
YA = Young adult (20-34 years old); MA = Middle-aged adult (35-49 years old); OA = Older-aged adult (50+ years old) (Buikstra & Ubelaker, 1994). YA/MA and MA/OA categories refer to individuals with age-at-death estimates extending across more than one of the Buikstra & Ubelaker (1994)-defined age categories.

Table B4: Morphological (cranial and mandibular) sex estimation data.

ID	Morphological cranial assessment						Morphological mandibular assessment		
	NC	*MP*	*SOM*	*Gl*	*ME*	*Cranial sex estimate*	*MS*	*GF*	*Mandibular sex estimate*
UCT 1	3	2	2	1	2	F	M	F	?
UCT 2	2	2	1	1	2	F	F	F	F
UCT 3	4	X	5	5	X	M	X	X	X
UCT 5	1	1	2	2	3	F	F	M	?
UCT 29	4	3	3	4	X	M	X	X	X
UCT 31	1	1	3	2	X	F	X	X	X
UCT 36	2	2	3	4	4	M	M	M	M
UCT 43	1	3	3	2	1	F	F	M	?
UCT 44	4	4	4	2	2	M	M	M	M
UCT 45	X	X	X	X	X	X	X	X	X
UCT 50	1	3	3	3	X	M	X	X	X
UCT 54	1	1	2	X	1	F	F	M	?
UCT 60	1	3	1	1	2	F	F	F	F
UCT 67b	X	3	5	4	3	M	M	F	?
UCT 88	1	2	3	2	1	F	M	M	M
UCT 97	X	X	X	X	1	F	M	F	M
UCT 106	2	2	2	1	1	F	M	M	M
UCT 107	1	3	2	2	1	F	F	F	F
UCT 112	3	3	2	4	2	M	M	M	M
UCT 113	2	1	3	2	X	F	F	F	F
UCT 120	1	3	3	1	2	F	M	F	?
UCT 130	2	4	5	2	X	M	X	M	M
UCT 131	2	3	1	X	2	F	M	M	M
UCT 158	1	X	2	1	1	F	F	F	F
UCT 162	1	5	3	4	2	M	F	F	F
UCT 164	1	1	2	1	1	F	M	M	M
UCT 168	4	3	4	5	3	M	M	M	M
UCT 169	3	4	4	X	2	M	X	M	M
UCT 172	3	3	4	2	2	F	F	F	F
UCT 181/206	X	X	3	3	2	M	M	M	M
UCT 182/200	1	1	2	2	3	F	F	F	F
UCT 183/201	1	1	1	2	2	F	F	F	F
UCT 185/202	2	2	2	2	X	F	F	M	?
UCT 192/213	1	4	2	2	1	F	F	M	?
UCT 212	X	X	X	X	X	X	X	X	X
UCT 226	2	4	4	4	X	M	M	M	M
UCT 230	1	X	3	1	2	F	M	M	M
UCT 232	1	4	4	4	2	M	X	M	M
UCT 246	1	2	4	1	X	F	X	M	M
UCT 248a	1	2	1	1	1	F	F	F	F
UCT 250	1	4	5	3	3	M	M	M	M
UCT 254	1	3	4	3	2	M	M	M	M
UCT 283	X	X	X	X	X	X	X	X	X
UCT 318	2	1	3	1	1	F	F	M	?
UCT 319c	X	5	4	2	X	M	X	X	X
UCT 323	X	1	4	4	3	M	F	F	F
UCT 324	X	X	X	X	X	X	X	X	X
UCT 331	1	1	3	2	X	F	X	X	X
UCT 347	X	4	3	3	2	M	M	M	M
UCT 373	X	X	X	X	X	X	F	M	?
UCT 382	2	X	X	X	X	F	M	M	M
UCT 383	2	5	3	5	X	M	X	M	M
UCT 385	X	X	X	X	X	X	X	X	X
UCT 386	4	2	4	3	2	M	M	M	M

UCT 390	X	X	X	X	X	X	X	X	X
UCT 391	X	X	1	1	2	F	F	F	F
UCT 392 + 387	2	2	2	3	X	F	X	X	X
UCT 394	X	X	X	X	X	X	X	X	X
UCT 395	X	X	X	X	X	X	X	X	X
UCT 396	X	X	X	X	X	X	X	X	X
UCT 398	X	X	X	X	X	X	X	X	X
UCT 399	1	2	1	1	2	F	M	M	M
UCT 412	1	1	2	1	2	F	F	F	F
UCT 427	1	3	3	2	1	F	F	F	F
UCT 428	1	2	4	1	2	F	X	F	F
UCT 436	1	2	1	1	2	F	M	M	M
UCT 450	2	3	4	5	3	M	M	M	M
UCT 451	2	3	4	2	2	F	X	M	M
UCT 531	1	1	1	1	1	F	M	M	M
UCT 539	1	3	4	4	2	M	M	M	M
UCT 565	2	1	2	1	2	F	M	M	M
UCT 566	1	1	3	1	1	F	F	F	F
UCT 578	2	1	1	2	1	F	F	F	F
UCT 579	2	1	4	2	2	F	M	F	?
UCT 584	1	1	1	1	1	F	F	F	F
UCT 587	1	2	2	4	1	F	F	M	?
UCT 591	1	5	4	4	2	M	M	M	M
UCT 593	2	2	2	1	4	F	M	F	M
UCT 594	4	4	4	4	4	M	M	M	M
UCT 605	1	2	1	1	2	F	F	F	F
UCT 609	1	2	4	4	X	M	X	M	M
UCT 620	1	1	2	2	2	F	F	F	F
UCT 622	2	4	2	4	2	M	M	M	M
UCT 655	3	2	2	2	X	F	X	X	X
UCT 659	2	3	X	X	X	F	X	X	X
UCT 661	2	1	X	2	X	F	X	X	X
UCT 676	3	2	4	2	X	F	X	X	X
UCT 683	1	3	3	2	2	?	M	M	M
UCT 684	2	2	1	1	4	F	F	M	?
UCT 686/ERF 839	4	4	4	4	X	M	X	M	M
UCR AR2	1	1	3	2	X	F	X	X	X
UCT AR4	4	5	3	2	3	M	M	M	M
UCT AR5	X	X	3	2	2	F	M	M	M
UCT AR6	1	4	3	3	3	M	F	F	F
UCT AR8	1	2	2	1	1	F	X	M?	M?
UCT AR9	1	4	3	2	X	M	M	M	M
UCT AR12	X	X	X	X	1	F	M	M	M
UCT AR13	X	X	X	X	X	X	M	M	M
5MAGSTR	X	X	X	X	X	X	F	F	F
ERF 16015	5	5	3	4	4	M	M	M	M
MR 211	X	X	X	X	X	X	M	M	M
P 1205	X	X	X	X	X	X	X	X	X
P 1207	2	4	4	4	3	M	M	F	M
P 1271	1	1	2	1	1	F	F	F	F
P 1273	1	1	2	2	1	F	F	M	?
P 1275	2	3	2	1	2	F	M	M	M
P 1451	1	2	3	2	X	F	X	X	X
P 1639	1	1	3	1	2	F	F	M	?
P 1640	1	1	2	1	2	F	M	M	M
P 1704	1	1	X	X	X	F	X	X	X
P 1705 A	1	1	3	1	X	F	X	X	X
SS1	X	X	X	X	X	X	X	X	X

SS2	X	X	4	4	X	M	X	X	X
SS3	1	X	4	3	X	M	X	X	X
SAM 32	1	1	3	4	2	F	F	M	F
SAM 34	4	1	4	4	3	M	M	M	M
SAM 1131	1	1	2	1	X	F	X	X	X
SAM 1145	1	3	4	2	3	M	M	M	M
SAM 1146	1	2	4	3	3	M	M	M	M
SAM 1157	2	2	3	2	3	F	F	M	M
SAM 1247a	1	3	3	1	3	M	M	M	M
SAM 1443	3	5	4	5	2	M	M	M	M
SAM 1444	1	4	3	3	2	F	F	F	F
SAM 1446	1	2	4	4	3	M	M	M	M
SAM 1449	1	3	2	1	2	F	F	M	F
SAM 1457	1	2	3	4	X	F	X	X	X
SAM 1473	2	3	4	4	3	M	M	M	M
SAM 1871	3	5	3	1	3	M	M	M	M
SAM 1878a	1	5	4	3	4	M	M	M	M
SAM 1878b	X	X	X	X	X	X	X	X	X
SAM 1879	1	4	3	2	2	M	M	M	M
SAM 1889	X	X	X	X	X	X	X	X	X
SAM 1893	2	3	2	4	X	M	X	X	X
SAM 3026	X	1	X	X	X	F	X	X	X
SAM 4305	X	X	X	X	X	X	X	X	X
SAM 4637	3	2	4	2	3	M	X	M	M
SAM 4720	X	X	X	X	1	F	M	M	M
SAM 4790	2	3	4	3	2	M	M	F	M
SAM 4800	X	X	X	X	1	F	F	F	F
SAM 4838a	X	X	X	X	X	X	X	X	X
SAM 4838b	X	X	X	X	X	X	X	X	X
SAM 4840	1	3	4	1	1	M	M	M	M
SAM 4901	2	4	3	5	X	M	X	X	X
SAM 4905	1	2	2	1	2	F	F	F	F
SAM 4930	1	X	3	1	3	F	F	M	F
SAM 4931	2	3	3	1	3	M	X	M	M
SAM 4934	X	X	X	X	X	X	X	X	X
SAM 4943	1	3	4	1	3	F	X	M	M
SAM 4964	1	4	4	2	2	M	M	M	M
SAM 5035a	3	3	3	5	2	M	M	F	M
SAM 5036	X	X	X	X	1	F	M	M	M
SAM 5041	1	4	4	5	3	M	M	M	M
SAM 5048	1	1	4	1	3	F	F	M	M
SAM 5050	1	1	4	1	2	F	F	M	M
SAM 5075	X	X	X	X	4	M	M	M	M
SAM 5077 IV/D	X	2	X	X	2	F	M	M	M
SAM 5083	2	3	2	2	3	F	M	M	M
SAM 5095	2	4	2	2	1	F	F	M	F
SAM 6020	2	4	4	3	3	M	M	M	M
SAM 6023	X	X	X	X	X	X	X	X	X
SAM 6041a	4	5	3	4	4	M	M	M	M
SAM 6041b	2	3	4	3	3	M	M	M	M
SAM 6049	2	2	4	5	3	M	M	M	M
SAM 6050	X	X	X	X	X	X	X	X	X
SAM 6051	2	3	2	2	3	F	F	M	M
SAM 6072	2	5	3	3	3	M	M	M	M
SAM 6075	2	3	4	2	4	M	M	M	M
SAM 6147	2	4	4	2	X	M	X	M	M
SAM 6149	3	4	5	3	3	M	M	M	M
SAM 6264	3	3	4	5	2	M	M	M	M
SAM 6317	1	4	4	3	2	M	F	F	F

SAM 6318	1	3	4	2	1	M	X	M	M
SAM 6331	1	2	4	1	1	F	F	M	M
SAM 6332	1	4	5	2	2	M	M	M	M
SAM 6348b	1	1	2	2	3	F	F	F	F

NC = Nuchal crest, MP = Mastoid process, SOM = supra-orbital margin, Gl = Glabella, ME = Mental eminence, MS = Mandibular shape, GE = Gonial eversion/flaring.

Table B5: Metrical (mandibular, humeral, and femoral) sex estimation data (in mm).

ID	Mandibular parameters												Humeral parameters						Femoral parameters					
	BB			*BCB*			*MML*			*CH*			*R. HVHD*			*L. HVHD*			*R. FVHD*			*L. FVHD*		
	1	*2*	*x̄*	*1*	*2*	*x̄*	*1*	*2*	*x̄*	*1*	*2*	*x̄*	*1*	*2*	*x̄*	*1*	*2*	*x̄*	*1*	*2*	*x̄*	*1*	*2*	*x̄*
UCT 1	108,2	108,2	108,2	86,4	84,9	85,7	105,3	105,0	105,2	48,3	49,4	48,8	35,5	37,6	36,6	37,1	37,5	37,3	36,6	36,8	36,7	36,1	37,3	36,7
UCT 2	-	-	-	-	-	-	107,1	106,7	106,9	57,2	57,4	57,3	35,5	37,0	36,3	33,2	32,8	33,0	36.72	37,6	37,6	37,9	37,7	37,8
UCT 3	-	-	-	-	-	-	-	-	-	-	-	-	37,8	38,0	37,9	39,2	38,7	39,0	40,7	40,7	40,7	40,2	39,3	39,8
UCT 5	102,0	102,0	102,0	85,4	84,2	84,8	110,5	110,0	110,3	56,0	55,9	55,9	33,9	33,8	33,8	33,3	34,0	33,6	37,4	37,3	37,3	36,5	36,7	36,6
UCT 29	-	-	-	-	-	-	-	-	-	-	-	-	39,7	39,5	39,6	36,7	36,8	36,8	42,1	42,5	42,3	40,9	41,3	41,1
UCT 31	-	-	-	-	-	-	-	-	-	-	-	-	41,8	41,4	41,6	-	-	-	42,5	41,7	42,1	-	-	-
UCT 36	115,7	115,8	115,7	-	-	-	115,8	113,7	114,8	44,4	46,3	45,4	42,8	43,0	42,9	41,4	40,9	41,1	44,4	43,2	43,8	-	-	-
UCT 43	97,6	97,6	97,6	86,7	86,6	86,6	105,0	105,2	105,1	53,0	52,2	52,6	31,8	31,8	31,8	32,0	31,9	31,9	31,9	32,7	32,3	33,1	33,6	33,3
UCT 44	-	-	-	89,5	89,7	89,6	117,1	116,7	116,9	52,0	52,0	52,0	41,6	41,9	41,7	39,4	40,0	39,7	40,0	41,1	40,6	39,6	38,6	39,1
UCT 45	-	-	-	-	-	-	-	-	-	-	-	-	39,1	39,3	39,2	39,8	41,1	40,4	41,0	40,9	41,0	-	-	-
UCT 50	-	-	-	-	-	-	-	-	-	-	-	-	35,5	35,0	35,2	34,7	34,3	34,5	38,4	38,4	38,4	-	-	-
UCT 54	102,1	102,4	102,2	84,9	85,1	85,0	-		-	-	-	-	33,0	33,6	33,3	35,8	35,9	35,8	35,5	35,6	35,5	35,5	35,3	35,4
UCT 60	106,6	106,7	106,6	96,2	96,0	96,1	108,8	107,5	108,1	50,5	50,0	50,2	44,4	44,6	44,5	43,4	42,9	43,2	42,3	42,6	42,5	40,6	41,4	41,0
UCT 67b	-	-	-	-	-	-	117,3	117,7	117,5	58,6	57,7	58,1	Path	-	-	43,3	43,0	43,1	40,4	39,8	40,1	42,6	42,7	42,7
UCT 88	104,9	104,8	104,9	91,6	91,7	91,6	-	-	-	54,2	54,1	54,2	37,3	37,5	37,4	38,4	38,5	38,5	37,4	37,9	37,6	37,4	37,6	37,5
UCT 97	111,7	111,9	61,8	93,9	94,1	94,0	113,4	113,5	113,5	47,0	46,7	46,8	35,6	35,7	35,6	36,7	37,4	37,1	38,7	39,3	39,0	40,3	40,0	40,1
UCT 106	-	-	-	81,0	80,1	80,5	114,6	114,0	114,3	53,5	54,5	54,0	38,0	38,0	38,0	37,1	37,6	37,4	40,1	39,8	40,0	40,1	40,3	40,2
UCT 107	104,5	104,5	104,5	90,9	90,7	90,8	111,3	111,6	111,4	44,9	46,4	45,6	35,4	35,4	35,4	34,3	34,5	34,4	38,8	39,0	38,9	36,8	36,5	36,6
UCT 112	114,2	114,4	114,3	94,3	94,3	94,3	120,1	120,3	120,2	55,4	55,6	55,5	-	-	-	-	-	-	43,7	42,2	43,0	43,2	43,3	43,2
UCT 113	-	-	-	-	-	-	-	-	-	50,0	50,3	50,2	32,7	33,8	33,3	-	-	-	36,8	37,0	36,9	36,1	35,1	35,6
UCT 120	102,3	102,2	102,3	90,3	90,1	90,2	106,3	106,6	106,5	48,4	47,7	48,0	33,4	33,1	33,3	32,3	32,0	32,1	36,8	36,9	36,9	37,0	37,2	37,1
UCT 130	-	-	-	-	-	-	-	-	-	62,2	62,7	62,5	40,3	41,5	40,9	-	-	-	41,2	41,0	41,1	41,5	41,8	41,6
UCT 131	-	-	-	-	-	-	113,8	113,7	113,8	58,2	58,6	58,4	-	-	-	36,3	36,2	36,2	39,1	38,7	38,9	38,9	38,5	38,7
UCT 158	-	-	-	-	-	-	-	-	-	-	-	-	34,3	33,4	33,9	-	-	-	37,1	37,5	37,3	37,8	38,0	37,9
UCT 162	-	-	-	82,1	81,1	81,6	-	-	-	-	-	-	35,8	35,4	35,6	35,2	35,4	35,3	37,7	36,4	37,0	39,2	38,9	39,1
UCT 164	104,6	104,6	104,6	90,6	90,7	90,6	100,9	100,3	100,6	49,5	49,3	49,4	-	-	-	-	-	-	36,0	35,8	35,9	36,2	35,9	36,0
UCT 168	-	-	-	91,6	91,3	91,5	113,9	115,2	114,6	56,0	56,9	56,5	-	-	-	-	-	-	37,7	39,1	38,4	38,9	38,4	38,7
UCT 169	-	-	-	-	-	-	113,7	114,4	114,0	56,0	55,7	55,9	-	-	-	-	-	-	-	-	-	-	-	-
UCT 172	-	-	-	89,5	87,6	88,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UCT 181/206	115,5	115,3	115,4	103,6	101,2	102,4	121,3	119,5	120,4	50,2	50,1	50,2	39,9	39,2	39,6	-	-	-	42,9	43,5	43,2	43,6	44,0	43,8
UCT 182/200	106,9	106,8	106,8	89,3	88,4	88,9	112,7	112,0	112,3	48,8	48,5	48,6	35,0	33,8	34,4	33,7	33,9	33,8	39,9	40,2	40,0	39,7	40,2	40,0
UCT 183/201	111,2	110,8	111,0	94,2	94,3	94,2	103,4	103,9	103,7	49,8	50,2	50,0	-	-	-	32,7	32,4	32,5	-	-	-	36,8	37,0	36,9
UCT 185/202	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40,8	40,1	40,5	40,9	40,3	40,6
UCT 192/213	-	-	-	87,1	87,0	87,1	105,8	105,0	105,4	43,7	43,8	43,7	32,4	32,1	32,2	34,0	34,1	34,1	35,1	35,3	35,2	34,6	34,8	34,7
UCT 212	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44,0	44,4	44,2
UCT 226	120,4	120,3	120,3	97,1	93,4	95,3	-	-	-	63,5	63,1	63,3	40,6	40,6	40,6	-	-	-	41,7	41,8	41,7	40,3	40,8	40,6
UCT 230	116,9	116,9	116,9	96,0	95,7	95,9	112,2	112,1	112,2	48,5	48,6	48,6	42,9	42,4	42,7	-	-	-	44,8	43,5	44,1	42,6	42,7	42,6
UCT 232	-	-	-	-	-	-	104,4	105,5	105,0	47,7	47,5	47,6	35,4	34,5	34,9	32,8	33,4	33,1	38,8	38,5	38,6	38,9	38,5	38,7
UCT 246	-	-	-	-	-	-	-	-	-	45,8	45,5	45,6	41,5	40,7	41,1	43,1	40,6	41,8	40,8	41,6	41,2	40,7	40,2	40,4
UCT 248a	-	-	-	-	-	-	109,9	110,4	110,1	54,1	52,1	53,1	-	-	-	-	-	-	36,9	37,8	37,4	36,9	37,2	37,0
UCT 250	-	-	-	94,9	94,8	94,8	116,5	116,0	116,2	50,6	50,0	50,3	38,8	39,3	39,1	37,9	38,3	38,1	40,8	40,4	40,6	41,2	41,0	41,1
UCT 254	109,9	109,7	109,8	96,7	94,8	95,7	112,7	111,9	112,3	45,3	44,9	45,1	39,2	39,0	39,1	37,6	38,8	38,2	39,7	39,0	39,3	39,1	38,8	39,0
UCT 283	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38,4	38,3	38,3	38,4	38,6	38,5	38,9	38,7	38,8

UCT 318	102,2	102,0	102,1	87,2	87,1	87,2	105,6	107,0	106,3	42,4	42,7	42,6	33,3	32,3	32,8	31,6	32,0	31,8	34,9	35,1	35,0	35,7	35,4	35,5
UCT 323	-	-	-	-	-	-	112,0	113,3	112,7	55,6	55,6	55,6	-	-	-	-	-	-	39,9	39,8	39,9	-	-	-
UCT 324	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37,6	37,5	37,5	36,8	36,7	36,8
UCT 331	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35,5	35,7	35,6	38,8	38,5	38,6	37,6	38,4	38,0
UCT 347	-	-	-	-	-	-	112,8	113,7	113,3	49,8	48,9	49,3	-	-	-	34,2	36,8	35,5	-	-	-	-	-	-
UCT 373	109,9	109,7	109,8	98,7	99,1	98,9	108,6	108,7	108,6	49,1	49,9	49,5	34,5	35,2	34,8	34,7	34,6	34,6	35,8	36,1	35,9	35,3	35,9	35,6
UCT 382	-	-	-	-	-	-	118,3	117,8	118,0	51,6	51,5	51,5	-	-	-	-	-	-	-	-	-	43,4	43,4	43,4
UCT 383	-	-	-	-	-	-	-	-	-	55,9	56,2	56,1	46,5	45,0	45,8	-	-	-	42,6	43,3	43,0	-	-	-
UCT 385	-	-	-	-	-	-	-	-	-	-	-	-	36,2	36,7	36,5	35,7	35,8	35,8	37,2	37,4	37,3	36,4	36,1	36,3
UCT 386	104,0	104,0	104,0	96,9	96,8	96,9	111,7	112,1	111,9	52,6	53,2	52,9	-	-	-	33,3	34,1	33,7	41,3	41,6	41,4	41,5	41,3	41,4
UCT 390	-	-	-	-	-	-	-	-	-	-	-	-	37,5	38,5	38,0	-	-	-	-	-	-	39,2	39,0	39,1
UCT 391	-	-	-	78,3	78,2	78,2	101,0	101,9	101,5	45,5	44,1	44,8	30,5	31,1	30,8	30,7	30,6	30,6	32,9	33,1	33,0	33,1	33,0	33,0
UCT 392 + 387	-	-	-	-	-	-	-	-	-	-	-	-		-	-	34,2	34,4	34,3	-	-	-	-	-	-
UCT 394	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34,9	34,8	34,8	38,4	38,6	38,5	-	-	-
UCT 395	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34,3	34,2	34,2	34,5	34,6	34,5
UCT 396	-	-	-	-	-	-	-	-	-	-	-	-	34,9	35,0	35,0	34,5	34,3	34,4	34,2	34,6	34,4	34,5	34,4	34,4
UCT 398	-	-	-	-	-	-	-	-	-	-	-	-	34,9	34,5	34,7	-	-	-	-	-	-	-	-	-
UCT 399	111,8	112,5	112,2	93,5	90,1	91,8	105,3	104,9	105,1	48,8	48,8	48,8	-	-	-	36,6	34,7	35,7	-	-	-	36,7	36,3	36,5
UCT 412	94,2	94,2	94,2	86,0	86,1	86,0	108,3	109,1	108,7	56,9	56,6	56,8	35,7	35,8	35,7	35,6	35,0	35,3	34,6	34,7	34,7	35,4	35,3	35,4
UCT 427	100,9	101,0	101,0	81,6	81,7	81,7	114,5	114,2	114,4	42,6	43,1	42,8	-	-	-	34,2	33,0	33,6	38,7	39,6	39,1	-	-	-
UCT 428	-	-	-	-	-	-	-	-	-	-	-	-	34,5	35,7	35,1	-	-	-	39,1	40,0	39,6	40,0	40,1	40,1
UCT 436	106,8	106,9	106,9	90,2	90,3	90,2	107,3	107,0	107,1	44,7	44,3	44,5	-	-	-	32,7	32,5	32,6	34,8	35,1	34,9	35,5	35,1	35,3
UCT 450	115,5	115,5	115,5	-	-	-	121,9	121,4	121,6	59,1	59,3	59,2	43,0	44,3	43,7	44,5	44,9	44,7	45,9	45,1	45,5	-	-	-
UCT 451	-	-	-	-	-	-	111,5	112,1	111,8	56,7	56,9	56,8	39,5	39,3	39,4	38,8	39,2	39,0	-	-	-	41,4	41,9	41,6
UCT 531	118,1	117,9	118,0	-	-	-	108,4	109,0	108,7	51,8	51,6	51,7	34,1	34,0	34,1	35,0	34,0	34,5	37,9	37,5	37,7	37,8	37,5	37,7
UCT 539	114,0	114,4	114,2	95,9	95,6	95,8	114,8	114,4	114,6	52,4	52,8	52,6	40,1	41,5	40,8	39,6	40,0	39,8	-	-	-	43,7	42,7	43,2
UCT 565	-	-	-	90,9	90,6	90,8	111,4	111,3	111,4	55,2	55,6	55,4	34,4	34,9	34,7	34,0	35,1	34,6	37,3	37,6	37,5	38,1	38,2	38,1
UCT 566	-	-	-	82,9	82,6	82,7	110,5	111,6	111,1	50,3	50,6	50,5	35,5	36,9	36,2	35,2	36,1	35,7	38,5	38,4	38,4	38,8	38,3	38,5
UCT 578	108,1	108,5	108,3	93,7	92,5	93,1	114,2	114,0	114,1	50,5	50,9	50,7	34,3	35,0	34,6	33,9	33,5	33,7	37,2	36,7	37,0	-	-	-
UCT 579	107,3	107,1	107,2	92,0	91,8	91,9	115,3	116,1	115,7	52,2	51,8	52,0	33,7	34,5	34,1	34,4	34,6	34,5	37,2	36,8	37,0	37,5	37,8	37,7
UCT 584	109,9	110,0	109,9	93,0	92,8	92,9	111,0	111,3	111,1	50,2	50,6	50,4	-	-	-	31,2	32,4	31,8	38,6	38,4	38,5	37,5	37,3	37,4
UCT 587	114,3	114,3	114,3	95,2	95,0	95,1	111,8	110,9	111,3	49,8	50,1	49,9	38,3	38,2	38,2	37,7	35,7	36,7	38,5	39,1	38,8	39,5	39,8	39,7
UCT 591	108,5	108,9	108,7	-	-	-	109,3	108,8	109,1	48,5	48,6	48,6	39,3	37,3	38,3	35,3	35,6	35,4	37,4	38,9	38,1	39,4	34,3	36,9
UCT 593	-	-	-	95,3	95,3	95,3	-	-	-	57,8	57,5	57,7	38,0	38,0	38,0	37,2	37,4	37,3	40,5	41,5	41,0	42,3	42,4	42,3
UCT 594	108,8	108,6	108,7	94,0	92,2	93,1	122,0	122,0	122,0	57,0	56,4	56,7	39,9	38,2	39,0	-	-	-	45,5	45,3	45,4	43,2	43,6	43,4
UCT 605	115,3	116,2	115,7	-	-	-	109,0	108,1	108,6	44,3	44,3	44,3	35,2	35,9	35,6	34,8	34,9	34,9	40,3	39,9	40,1	39,5	39,4	39,5
UCT 609	-	-	-	-	-	-	-	-	-	52,0	52,4	52,2	35,4	34,6	35,0	34,0	33,5	33,8	-	-	-	36,8	36,3	36,5
UCT 620	105,8	105,7	105,8	92,3	92,0	92,2	111,9	112,5	112,2	54,3	55,5	54,9	-	-	-	32,8	33,1	32,9	-	-	-	35,4	35,7	35,5
UCT 622	112,1	112,1	112,1	91,5	91,3	91,4	114,2	113,2	113,7	49,8	49,9	49,8	38,6	38,4	38,5	-	-	-	41,9	42,0	42,0	42,1	42,0	42,0
UCT 655	-	-	-	-	-	-	-	-	-	-	-	-	35,5	35,8	35,7	36,8	36,5	36,7	33,7	34,0	33,8	-	-	-
UCT 659	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38,8	38,7	38,7	-	-	-
UCT 661	-	-	-	-	-	-	-	-	-	-	-	-	31,3	31,3	31,3	-	-	-	34,3	34,6	34,5	34,2	33,2	33,7
UCT 676	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33,4	33,1	33,2	39,7	40,2	39,9	39,8	40,1	40,0
UCT 683	-	-	-	84,6	85,9	85,2	-	-	-	-	-	-	-	-	-	39,5	39,7	39,6	-	-	-	-	-	-
UCT 684	-	-	-	89,9	89,6	89,8	111,2	111,0	111,1	49,0	47,2	48,1	-	-	-	-	-	-	35,2	35,5	35,4	35,4	35,7	35,6
UCT 686/ERF 839	-	-	-	-	-	-	-	-	-	58,0	57,7	57,8	-	-	-	-	-	-	41,5	41,9	41,7	-	-	-
UCR AR2	?	?	-	?	?	-	?	?	-	?	?	-	YF	YF	-	YF	YF	-	YF	YF	-	YF	YF	-
UCT AR4	107,5	107,0	107,2	97,6	97,5	97,5	111,2	112,0	111,6	52,9	52,4	52,7	-	-	-	-	-	-	-	-	-	-	-	-

UCT AR5	-	-	-	89,5	89,4	89,5	105,5	105,3	105,4	47,0	46,6	46,8	34,6	34,7	34,6	35,2	35,1	35,1	38,2	38,0	38,1	36,9	37,8	37,4
UCT AR6	109,6	109,8	109,7	94,9	95,3	95,1	116,9	115,9	116,4	49,1	49,2	49,2	39,3	39,0	39,1	37,5	38,3	37,9	42,6	43,0	42,8	42,5	42,5	42,5
UCT AR8	-	-	-	-	-	-	-	-	-	48,9	49,3	49,1	-	-	-	-	-	-	-	-	-	-	-	-
UCT AR9	-	-	-	-	-	-	-	-	-	48,2	48,5	48,3	-	-	-	30,7	30,9	30,8	35,1	35,0	35,1	34,4	34,0	34,2
UCT AR12	108,8	108,8	108,8	92,1	92,2	92,1	113,1	112,7	112,9	51,7	51,4	51,6	-	-	-	-	-	-	39,4	39,5	39,4	40,2	40,2	40,2
UCT AR13	-	-	-	-	-	-	-	-	-	49,9	50,1	50,0	33,5	32,8	33,1	-	-	-	36,7	36,7	36,7	-	-	-
5MAGSTR	-	-	-	84,7	84,6	84,7	107,1	107,4	107,2	48,1	47,8	48,0	-	-	-	-	-	-	-	-	-	-	-	-
ERF 16015	122,6	122,3	122,4	-	-	-	120,9	120,2	120,5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MR 211	-	-	-	102,8	102,7	102,8	-	-	-	-	-	-	38,8	38,1	38,4	37,9	36,9	37,4	40,5	40,5	40,5	41,3	41,4	41,4
P 1205	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36,6	36,5	36,6	-	-	-	35,5	35,2	35,3
P 1207	-	-	-	97,8	98,3	98,1	-	-	-	-	-	-	-	-	-	-	-	-	43,0	42,7	42,8	42,2	41,4	41,8
P 1271	106,2	106,4	106,3	87,8	87,8	87,8	111,2	111,9	111,6	51,7	53,5	52,6	-	-	-	-	-	-	-	-	-	35,6	35,1	35,4
P 1273	105,2	105,3	105,3	-	-	-	104,7	105,2	105,0	41,7	42,5	42,1	36,0	37,2	36,6	-	-	-	-	-	-	-	-	-
P 1275	101,5	101,6	101,6	88,8	88,5	88,7	111,1	111,3	111,2	52,2	52,6	52,4	-	-	-	-	-	-	-	-	-	-	-	-
P 1451	-	-	-	-	-	-	-	-	-	-	-	-	37,8	37,3	37,5	36,0	34,6	35,3	37,7	37,9	37,8	38,0	37,9	37,9
P 1639	109,3	109,3	109,3	93,2	93,5	93,4	106,2	105,9	106,1	49,7	49,8	49,8	32,5	32,1	32,3	-	-	-	37,3	36,9	37,1	37,6	36,3	36,9
P 1640	104,0	104,1	104,0	86,6	87,0	86,8	105,6	105,3	105,4	46,7	47,1	46,9	34,5	35,1	34,8	34,6	34,5	34,5	35,4	36,2	35,8	35,1	35,8	35,5
P 1704	-	-	-	-	-	-	-	-	-	-	-	-	37,4	36,7	37,0	37,3	37,2	37,3	39,8	39,3	39,6	38,9	39,7	39,3
P 1705 A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37,6	37,3	37,4	42,1	42,2	42,2	-	-	-
SS2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33,1	32,7	32,9	34,6	34,5	34,5	34,0	33,8	33,9
SS3	-	-	-	-	-	-	-	-	-	-	-	-	39,6	39,4	39,5	37,3	37,3	37,3	39,5	40,4	39,9	40,0	40,2	40,1
SAM 32	-	-	-	-	-	-	109,2	109,1	109,2	47,5	46,8	47,1	Path.	-	-	38,4	38,7	38,6	34,3	34,3	34,3	34,5	34,3	34,4
SAM 34	104,2	104,2	104,2	88,4	88,3	88,3	112,7	112,7	112,7	51,5	51,8	51,6	37,9	37,3	37,6	34,9	34,9	34,9	37,6	37,5	37,6	37,6	37,6	37,6
SAM 1131	-	-	-	-	-	-	-	-	-	-	-	-	34,4	34,8	34,6	32,5	32,7	32,6	37,3	37,0	37,1	36,9	37,3	37,1
SAM 1145	115,7	115,5	115,6	88,9	89,3	89,1	109,9	110,1	110,0	44,9	43,6	44,2	37,0	36,5	36,8	36,9	36,7	36,8	38,7	38,6	38,7	38,7	38,7	38,7
SAM 1146	110,9	111,5	111,2	89,5	89,0	89,2	105,1	105,0	105,0	54,2	53,9	54,1	34,5	35,2	34,8	34,3	33,9	34,1	39,0	39,9	39,4	38,1	38,1	38,1
SAM 1157	-	-	-	93,7	93,9	93,8	108,6	108,6	108,6	44,6	44,7	44,7	-	-	-	-	-	-	33,8	33,8	33,8	-	-	-
SAM 1247a	116,0	116,1	116,1	98,9	98,4	98,6	113,2	113,5	113,3	55,8	55,9	55,8	34,7	35,1	34,9	35,0	34,9	34,9	39,0	39,6	39,3	40,5	39,8	40,1
SAM 1443	109,5	109,5	109,5	91,6	91,7	91,6	111,3	111,4	111,4	51,0	51,4	51,2	34,7	34,2	34,4	34,6	34,4	34,5	38,3	38,3	38,3	38,1	38,1	38,1
SAM 1444	114,6	114,8	114,7	97,0	97,2	97,1	112,9	112.89	112,9	53,6	54,3	53,9	39,0	39,4	39,2	-	-	-	-	-	-	-	-	-
SAM 1446	105,2	105,2	105,2	93,0	92,9	93,0	111,1	111,8	111,5	54,4	54,2	54,3	-	-	-	-	-	-	37,1	38,1	37,6	37,4	37,6	37,5
SAM 1449	-	-	-	-	-	-	109,0	108,4	108,7	56,1	56,0	56,1	34,4	35,3	34,9	35,8	36,0	35,9	37,7	36,9	37,3	38,1	38,0	38,1
SAM 1457	-	-	-	-	-	-	-	-	-	-	-	-	36,3	36,4	36,4	33,9	33,6	33,7	36,5	36,4	36,4	35,6	35,9	35,7
SAM 1473	107,0	107,0	107,0	89,3	90,0	89,7	113,3	113,5	113,4	52,9	53,4	53,1	-	-	-	-	-	-	-	-	-	-	-	-
SAM 1871	115,9	115,7	115,8	99,2	99,7	99,5	108,0	108,5	108,3	48,7	49,4	49,0	-	-	-	33,7	33,7	33,7	36,2	36,4	36,3	36,5	36,0	36,2
SAM 1878a	114,0	113,9	113,9	98,7	98,6	98,6	117,8	117,5	117,6	57,5	57,1	57,3	39,0	38,7	38,8	36,9	36,6	36,7	41,6	41,3	41,5	42,3	42,3	42,3
SAM 1878b	-	-	-	-	-	-	-	-	-	-	-	-	33,8	33,9	33,9	32,9	33,1	33,0	38,0	38,5	38,3	37,6	39,0	38,3
SAM 1879	-	-	-	90,0	90,0	90,0	110,6	110,2	110,4	52,6	52,3	52,5	35,9	36,7	36,3	35,0	35,1	35,1	40,0	40,0	40,0	40,2	40,1	40,2
SAM 1889	-	-	-	-	-	-	-	-	-	-	-	-	39,5	39,7	39,6	-	-	-	41,0	41,2	41,1	40,8	40,2	40,5
SAM 1893	-	-	-	-	-	-	-	-	-	-	-	-	36,7	36,4	36,6	36,6	36,8	36,7	39,2	39,4	39,3	39,3	39,7	39,5
SAM 3026	-	-	-	-	-	-	-	-	-	-	-	-	30,3	31,5	30,9	31,9	32,0	31,9	35,4	35,1	35,3	35,6	35,4	35,5
SAM 4305	-	-	-	-	-	-	-	-	-	60,8	60,6	60,7	40,1	40,2	40,1	38,3	38,4	38,3	-	-	-	42,6	42,0	42,3
SAM 4637	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35,1	34,7	34,9	-	-	-	-	-	-
SAM 4720	-	-	-	-	-	-	113,9	114,2	114,1	53,0	52,2	52,6	-	-	-	-	-	-	39,8	39,6	39,7	38,5	38,5	38,5
SAM 4790	118,1	117,8	117,9	100,4	100,5	100,5	118,3	118,2	118,2	62,2	62,3	62,2	44,9	45,0	44,9	46,3	46,3	46,3	46,1	46,1	46,1	45,3	45,6	45,5
SAM 4800	-	-	-	94,0	93,8	93,9	-	-	-	69,7	69,9	69,8	31,0	31,0	31,0	31,9	31,5	31,7	-	-	-	32,4	32,7	32,6
SAM 4838a	-	-	-	-	-	-	-	-	-	-	-	-	35,9	35,6	35,7	34,4	34,6	34,5	39,8	39,8	39,8	39,6	39,9	39,8

SAM 4838b	-	-	-	-	-	-	-	-	-	-	-	-	37,2	38,8	38,0	34,8	35,2	35,0	42,3	42,2	42,3	41,5	41,3	41,4
SAM 4840	102,0	102,2	102,1	89,6	89,7	89,6	105,2	105,0	105,1	41,1	40,4	40,8	34,0	34,0	34,0	34,4	34,3	34,4	40,9	40,8	40,9	40,8	40,8	40,8
SAM 4901	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40,5	40,7	40,6	40,7	41,3	41,0
SAM 4905	110,2	109,9	110,0	92,9	93,0	92,9	-	-	-	55,5	55,5	55,5	41,3	41,7	41,5	40,7	40,5	40,6	40,4	40,5	40,4	40,1	40,0	40,0
SAM 4930	-	-	-	-	-	-	113,5	113,6	113,5	57,7	57,8	57,7	-	-	-	-	-	-	-	-	-	-	-	-
SAM 4931	-	-	-	-	-	-	113,3	112,9	113,1	50,7	50,5	50,6	-	-	-	39,1	39,6	39,3	40,3	40,4	40,3	39,7	39,6	39,6
SAM 4934	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41,8	41,5	41,6	41,6	42,4	42,0
SAM 4943	-	-	-	-	-	-	-	-	-	-	-	-	33,1	33,5	33,3	33,0	33,0	33,0	34,2	34,1	34,2	34,2	34,3	34,2
SAM 4964	112,3	112,4	112,3	97,2	97,1	97,1	109,4	109,7	109,5	49,5	49,4	49,5	33,8	34,1	33,9	32,6	32,7	32,6	35,9	36,3	36,1	-	-	-
SAM 5035a	112,5	112,3	112,4	97,0	96,8	96,9	109,8	109,6	109,7	41,4	42,1	41,7	-	-	-	38,2	38,1	38,1	41,5	41,3	41,4	-	-	-
SAM 5036	111,2	111,2	111,2	91,6	92,0	91,8	118,5	118,3	118,4	51,9	51,6	51,7	40,0	40,4	40,2	44,2	44,1	44,1	-	-	-	-	-	-
SAM 5041	-	-	-	-	-	-	112,0	112,1	112,1	57,7	57,9	57,8	37,5	37,0	37,3	36,3	36,4	36,4	40,4	41,1	40,7	39,9	40,5	40,2
SAM 5048	106,1	105,8	105,9	93,8	93,6	93,7	106,7	106,3	106,5	45,7	46,0	45,9	-	-	-	-	-	-	34,9	35,3	35,1	-	-	-
SAM 5050	104,6	104,4	104,5	83,5	83,2	83,4	105,6	105,8	105,7	48,5	49,0	48,8	-	-	-	-	-	-	-	-	-	-	-	-
SAM 5075	105,1	105,2	105,1	101,7	101,5	101,6	101,1	100,8	100,9	47,3	47,9	47,6	35,3	35,4	35,4	34,5	34,8	34,6	37,0	36,7	36,8	36,5	36,5	36,5
SAM 5077 IV/D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38,3	38,5	38,4	-	-	-
SAM 5083	107,7	107,8	107,8	97,3	97,6	97,5	111,7	112,3	112,0	52,5	53,3	52,9	38,8	38,6	38,7	37,3	37,5	37,4	39,0	39,0	39,0	39,6	39,7	39,7
SAM 5095	102,2	102,4	102,3	94,5	94,4	94,4	104,9	104,1	104,5	46,1	46,7	46,4	32,3	31,5	31,9	33,0	32,8	32,9	35,5	35,3	35,4	-	-	-
SAM 6020	112,5	112,9	112,7	95,7	95,7	95,7	120,0	120,4	120,2	60,7	60,5	60,6	37,9	36,9	37,4	38,3	37,1	37,7	41,2	41,1	41,2	41,8	40,6	41,2
SAM 6023	-	-	-	-	-	-	-	-	-	-	-	-	37,9	37,7	37,8	36,6	37,2	36,9	39,2	39,3	39,3	39,2	39,5	39,3
SAM 6041a	107,2	107,5	107,4	96,1	96,1	96,1	116,6	116,5	116,5	58,1	58,0	58,0	38,2	38,0	38,1	38,1	37,1	37,6	40,3	40,1	40,2	40,3	41,0	40,6
SAM 6041b	-	-	-	100,7	100,8	100,7	-	-	-	-	-	-	40,6	40,8	40,7	-	-	-	42,4	42,2	42,3	43,1	42,6	42,9
SAM 6049	114,1	113,8	113,9	90,9	90,9	90,9	-	-	-	50,8	50,5	-	35,9	35,7	35,8	35,2	35,0	35,1	40,8	40,8	40,8	39,2	39,2	39,2
SAM 6050	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38,8	39,0	38,9	37,2	37,3	37,2	36,7	36,8	36,8
SAM 6051	109,3	109,4	109,4	-	-	-	115,2	115,1	115,1	53,2	53,8	53,5	30,3	30,4	30,4	30,2	30,2	30,2	-	-	-	35,3	35,4	35,3
SAM 6072	-	-	-	-	-	-	116,6	116,8	116,7	59,4	58,6	59,0	43,8	44,0	43,9	43,1	43,0	43,0	42,3	42,4	42,4	43,3	43,2	43,2
SAM 6075	108,8	108,5	108,7	98,9	98,9	98,9	113,9	113,7	113,8	51,6	51,7	51,7	36,4	36,8	36,6	36,2	36,0	36,1	37,9	38,2	38,0	37,8	37,7	37,7
SAM 6147	-	-	-	-	-	-	-	-	-	56,5	56,4	56,4	-	-	-	36,7	36,5	36,6	-	-	-	39,2	39,3	39,2
SAM 6149	113,6	113,9	113,7	100,5	100,4	100,5	119,3	119,0	119,2	50,8	50,5	50,6	40,2	40,6	40,4	40,0	40,0	40,0	43,2	43,2	43,2	42,7	42,7	42,7
SAM 6264	104,1	104,7	104,4	96,1	96,1	96,1	115,6	116,0	115,8	54,7	54,6	54,6	41,8	42,1	41,9	39,3	39,5	39,4	42,5	42,4	42,4	42,0	42,5	42,2
SAM 6317	-	-	-	-	-	-	-	-	-	52,3	52,2	52,3	38,7	38,8	38,7	38,6	38,0	38,3	42,7	42,6	42,6	44,5	44,3	44,4
SAM 6318	-	-	-	-	-	-	-	-	-	60,3	60,4	60,4	36,6	36,8	36,7	35,5	35,5	35,5	39,1	39,1	39,1	38,9	38,8	38,9
SAM 6331	114,4	114,4	114,4	95,4	95,4	95,4	112,8	112,6	112,8	51,6	51,7	51,6	36,9	36,9	36,9	-	-	-	38,2	39,0	38,6	39,2	39,2	39,2
SAM 6332	-	-	-	-	-	-	103,4	104,0	103,7	51,2	51,1	51,1	-	-	-	33,0	32,8	32,9	37,0	36,8	36,9	37,0	36,8	36,9
SAM 6348b	110,0	110,3	110,1	91,1	91,2	91,1	109,1	108,6	108,8	49,9	50,3	50,1	35,7	35,9	35,8	-	-	-	36,8	37,1	36,9	37,2	37,2	37,2

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter.

Table B6: Data collection summary.

ID	Demographic Assessment		Morphological sex assessment									Metrical sex assessment					
	Pelvic sex	*Age*	*NC*	*MP*	*SOM*	*Gl*	*ME*	*Cranial sex estimate*	*MS*	*GF*	*Mandibular sex estimate*	*BB*	*BCB*	*MML*	*CH*	*HVHD*	*FVHD*
UCT 1	F	MA	3	2	2	1	2	F	M	F	?	108,2	85,7	105,2	48,8	37,3	36,7
UCT 2	F	YA	2	2	1	1	2	F	F	F	F	X	X	106,9	57,3	33,6	36,6
UCT 3	F	YA/MA	4	X	5	5	X	M	X	X	X	X	X	X	X	37,4	40,2
UCT 5	F	YA	1	1	2	2	3	F	F	M	?	102,0	84,8	110,3	55,9	33,3	35,6
UCT 29	M	MA/OA	4	3	3	4	X	M	X	X	X	X	X	X	X	32,1	37,1
UCT 31	M	MA	1	1	3	2	X	F	X	X	X	X	X	X	X	33,8	40,0
UCT 36	M	MA = MA/OA	2	2	3	4	4	M	M	M	M	115,7	109,7	114,8	45,4	31,8	35,5
UCT 43	F	MA	1	3	3	2	1	F	F	M	?	97,6	86,6	105,1	52,6	35,7	36,5
UCT 44	M	YA/MA	4	4	4	2	2	M	M	M	M	X	89,6	116,9	52,0	33,7	37,0
UCT 45	M	YA	X	X	X	X	X	X	X	X	X	X	X	X	X	34,9	39,5
UCT 50	M	MA/OA	1	3	3	3	X	M	X	X	X	X	X	X	X	33,2	40,0
UCT 54	F	OA	1	1	2	X	1	F	F	M	?	102,2	85,0	X	X	34,5	37,7
UCT 60	M	MA	1	3	1	1	2	F	F	F	F	106,6	96,1	108,1	50,2	30,7	33,0
UCT 67b	M	MA	X	3	5	4	3	M	M	F	?	X	X	117,5	58,1	34,1	34,7
UCT 88	F	YA/MA	1	2	3	2	1	F	M	M	M	104,9	91,6	80,3	54,2	33,9	37,9
UCT 97	M	YA/MA	X	X	X	X	1	F	M	F	M	61,8	94,0	113,5	46,8	35,7	38,5
UCT 106	F	MA	2	2	2	1	1	F	M	M	M	X	80,5	114,3	54,0	32,5	37,0
UCT 107	M	MA	1	3	2	2	1	F	F	F	F	104,5	90,8	111,4	45,6	X	36,0
UCT 112	M	MA	3	3	2	4	2	M	M	M	M	114,3	94,3	120,2	55,5	X	X
UCT 113	F	MA	2	1	3	2	X	F	F	F	F	X	X	X	50,2	X	44,8
UCT 120	F	MA	1	3	3	1	2	F	M	F	?	102,3	90,2	106,5	48,0	X	38,7
UCT 130	M	YA = YA/MA	2	4	5	2	X	M	X	M	M	X	X	X	62,5	X	39,9
UCT 131	F	YA/MA	2	3	1	X	2	F	M	M	M	X	X	113,8	58,4	32,9	35,6
UCT 158	F	MA	1	X	2	1	1	F	F	F	F	X	X	X	X	34,5	37,7
UCT 162	M	MA	1	5	3	4	2	M	F	F	F	X	81,6	X	X	36,2	38,7
UCT 164	F	MA	1	1	2	1	1	F	M	M	M	104,6	90,6	100,6	49,4	31,8	37,4
UCT 168	M	OA	4	3	4	5	3	M	M	M	M	X	91,5	114,6	56,5	33,6	39,2
UCT 169	F	MA	3	4	4	X	2	M	X	M	M	X	X	114,0	55,9	X	X
UCT 172	F	MA	3	3	4	2	2	F	F	F	F	X	88,6	X	X	X	37,1
UCT 181/206	M	YA/MA	X	X	3	3	2	M	M	M	M	115,4	102,4	120,4	50,2	33,0	37,8
UCT 182/200	F	YA/MA	1	1	2	2	3	F	F	F	F	106,8	88,9	112,3	48,6	39,0	39,8
UCT 183/201	F	-	1	1	1	2	2	F	F	F	F	111,0	94,2	103,7	50,0	38,5	37,5
UCT 185/202	F	MA	2	2	2	2	X	F	F	M	?	X	X	X	X	X	40,6
UCT 192/213	F	MA	1	4	2	2	1	F	F	M	?	X	87,1	105,4	43,7	35,3	35,4
UCT 212	M	YA/MA	X	X	X	X	X	X	X	X	X	X	X	X	X	39,0	41,6
UCT 226	M	-	2	4	4	4	X	M	M	M	M	120,3	95,3	X	63,3	37,3	42,3
UCT 230	M	MA	1	X	3	1	2	F	M	M	M	116,9	95,9	112,2	48,6	32,6	35,3
UCT 232	M	MA	1	4	4	4	2	M	X	M	M	X	X	105,0	47,6	34,6	35,6
UCT 246	M	MA	1	2	4	1	X	F	X	M	M	X	X	X	45,6	X	36,8
UCT 248a	F	MA	1	2	1	1	1	F	F	F	F	X	X	110,1	53,1	X	34,5
UCT 250	M	MA/OA	1	4	5	3	3	M	M	M	M	X	94,8	116,2	50,3	34,4	34,4
UCT 254	M	MA	1	3	4	3	2	M	M	M	M	109,8	95,7	112,3	45,1	35,9	35,4

UCT 283	M	YA	X	X	X	X	X	X	X	X	X	X	X	X	X	31,9	33,3
UCT 318	F	MA	2	1	3	1	1	F	F	M	?	102,1	87,2	106,3	42,6	X	X
UCT 319c	M	YA	X	5	4	2	X	M	X	X	X	X	X	X	X	35,1	37,4
UCT 323	F	MA	X	1	4	4	3	M	F	F	F	X	X	112,7	55,6	30,8	34,2
UCT 324	F	YA/MA	X	X	X	X	X	X	X	X	X	X	X	X	X	33,1	36,7
UCT 331	M	YA/MA	1	1	3	2	X	F	X	X	X	X	X	X	X	X	35,4
UCT 347	M	MA	X	4	3	3	2	M	M	M	M	X	X	113,3	49,3	32,9	33,9
UCT 373	F	MA	X	X	X	X	X	X	F	M	?	109,8	98,9	108,6	49,5	36,6	35,3
UCT 382	M	YA/MA	2	X	X	X	X	F	M	M	M	X	X	118,0	51,5	32,3	37,0
UCT 383	M	MA	2	5	3	5	X	M	X	M	M	X	X	X	56,1	34,6	35,5
UCT 385	M	-	X	X	X	X	X	X	X	X	X	X	X	X	X	37,3	39,3
UCT 386	M	MA	4	2	4	3	2	M	M	M	M	104,0	96,9	111,9	52,9	X	X
UCT 390	M	YA/MA	X	X	X	X	X	X	X	X	X	X	X	X	X	38,6	34,4
UCT 391	F	YA	X	X	1	1	2	F	F	F	F	X	78,2	101,5	44,8	33,7	35,7
UCT 392 + 387	M	YA	2	2	2	3	X	F	X	X	X	X	X	X	X	35,0	40,1
UCT 394	M	MA	X	X	X	X	X	X	X	X	X	X	X	X	X	32,6	37,1
UCT 395	F	MA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	37,5
UCT 396	F	MA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	33,8
UCT 398	M	-	X	X	X	X	X	X	X	X	X	X	X	X	X	31,9	35,5
UCT 399	F	OA	1	2	1	1	2	F	M	M	M	112,2	91,8	105,1	48,8	33,0	38,3
UCT 412	F	MA	1	1	2	1	2	F	F	F	F	94,2	86,0	108,7	56,8	31,7	32,6
UCT 427	F	YA/MA	1	3	3	2	1	F	F	F	F	101,0	81,7	114,4	42,8	34,9	X
UCT 428	M	MA	1	2	4	1	2	F	X	F	F	X	X	X	X	X	X
UCT 436	F	MA	1	2	1	1	2	F	M	M	M	106,9	90,2	107,1	44,5	33,7	36,2
UCT 450	M	MA	2	3	4	5	3	M	M	M	M	115,5	X	121,6	59,2	38,9	36,8
UCT 451	F	YA/MA	2	3	4	2	2	F	X	M	M	X	X	111,8	56,8	30,2	35,3
UCT 531	F	MA	1	1	1	1	1	F	M	M	M	118,0	X	108,7	51,7	33,0	34,2
UCT 539	M	MA	1	3	4	4	2	M	M	M	M	114,2	95,8	114,6	52,6	32,9	35,4
UCT 565	M	MA	2	1	2	1	2	F	M	M	M	X	90,8	111,4	55,4	37,4	39,7
UCT 566	F	MA	1	1	3	1	1	F	F	F	F	X	82,7	111,1	50,5	35,8	37,2
UCT 578	F	MA	2	1	1	2	1	F	F	F	F	108,3	93,1	114,1	50,7	36,1	37,7
UCT 579	F	MA	2	1	4	2	2	F	M	F	?	107,2	91,9	115,7	52,0	36,9	39,2
UCT 584	F	MA	1	1	1	1	1	F	F	F	F	109,9	92,9	111,1	50,4	X	X
UCT 587	M	MA	1	2	2	4	1	F	F	M	?	114,3	95,1	111,3	49,9	34,4	40,8
UCT 591	M	MA	1	5	4	4	2	M	M	M	M	108,7	X	109,1	48,6	35,0	41,4
UCT 593	F	MA	2	2	2	1	4	F	M	F	M	X	95,3	77,4	57,7	41,1	43,8
UCT 594	M	OA	4	4	4	4	4	M	M	M	M	108,7	93,1	122,0	56,7	34,4	36,6
UCT 605	F	MA	1	2	1	1	2	F	F	F	F	115,7	X	108,6	44,3	40,9	41,6
UCT 609	M	MA	1	2	4	4	X	M	X	M	M	X	X	X	52,2	35,3	39,1
UCT 620	F	YA	1	1	2	2	2	F	F	F	F	105,8	92,2	112,2	54,9	39,6	43,8
UCT 622	M	YA/MA	2	4	2	4	2	M	M	M	M	112,1	91,4	113,7	49,8	33,1	38,7
UCT 655	M	MA	3	2	2	2	X	F	X	X	X	X	X	X	X	38,1	41,1
UCT 659	F	MA	2	3	X	X	X	F	X	X	X	X	X	X	X	38,2	39,0
UCT 661	M	YA/MA	2	1	X	2	X	F	X	X	X	X	X	X	X	35,5	36,9
UCT 676	F	MA	3	2	4	2	X	F	X	X	X	X	X	X	X	39,0	43,4
UCT 683	M	MA	1	3	3	2	2	?	M	M	M	X	85,2	X	X	39,6	X
UCT 684	M	MA	2	2	1	1	4	F	F	M	?	X	89,8	111,1	48,1	40,6	40,6
UCT 686/ERF 839	M	OA	4	4	4	4	X	M	X	M	M	X	X	X	57,8	50,5	X

UCR AR2	F	MA/OA	1	1	3	2	X	F	X	X	X	X	X	X	X	41,8	40,4
UCT AR4	M	YA/MA	4	5	3	2	3	M	M	M	M	107,2	97,5	111,6	52,7	42,7	42,6
UCT AR5	F	MA	X	X	3	2	2	F	M	M	M	X	89,5	105,4	46,8	43,1	42,7
UCT AR6	M	MA	1	4	3	3	3	M	F	F	F	109,7	95,1	116,4	49,2	34,6	38,1
UCT AR8	M	YA/MA	1	2	2	1	1	F	X	M?	M?	X	X	X	49,1	33,7	41,4
UCT AR9	F	MA	1	4	3	2	X	M	M	M	M	X	X	X	48,3	44,7	45,5
UCT AR12	M	MA	X	X	X	X	1	F	M	M	M	108,8	92,1	112,9	51,6	X	35,6
UCT AR13	F	MA	X	X	X	X	X	X	M	M	M	X	X	X	50,0	X	X
5MAGSTR	F	-	X	X	X	X	X	X	F	F	F	X	84,7	107,2	48,0	X	41,7
ERF 16015	M	MA	5	5	3	4	4	M	M	M	M	122,4	106,8	120,5	67,4	31,3	33,7
MR 211	M	OA	X	X	X	X	X	X	M	M	M	X	102,8	X	X	35,1	40,1
P 1205	F	OA	X	X	X	X	X	X	X	X	X	X	X	X	X	36,7	33,8
P 1207	M	MA/OA	2	4	4	4	3	M	M	F	M	X	98,1	X	X	35,6	38,0
P 1271	F	YA	1	1	2	1	1	F	F	F	F	106,3	87,8	111,6	52,6	36,7	39,7
P 1273	M	YA/MA	1	1	2	2	1	F	F	M	?	105,3	X	105,0	42,1	43,2	41,0
P 1275	M	MA	2	3	2	1	2	F	M	M	M	101,6	88,7	111,2	52,4	39,8	43,2
P 1451	M	YA/MA	1	2	3	2	X	F	X	X	X	X	X	X	X	33,8	36,6
P 1639	F	OA	1	1	3	1	2	F	F	M	?	109,3	93,4	106,1	49,8	45,8	43,0
P 1640	F	YA	1	1	2	1	2	F	M	M	M	104,0	86,8	105,4	46,9	X	43,4
P 1704	F	YA	1	1	X	X	X	F	X	X	X	X	X	X	X	X	38,7
P 1705 A	F	MA	1	1	3	1	X	F	X	X	X	X	X	X	X	35,5	X
SS1	M	YA/MA	X	X	X	X	X	X	X	X	X	X	X	X	X	37,1	40,1
SS2	F	YA/MA	X	X	4	4	X	M	X	X	X	X	X	X	X		43,2
SS3	M	MA	1	X	4	3	X	M	X	X	X	X	X	X	X	34,3	X
SAM 32	F	YA/MA	1	1	3	4	2	F	F	M	F	X	X	109,2	47,1	38,5	42,0
SAM 34	M	MA/OA	4	1	4	4	3	M	M	M	M	104,2	88,3	112,7	51,6	X	44,2
SAM 1131	F	MA/OA	1	1	2	1	X	F	X	X	X	X	X	X	X	38,3	38,8
SAM 1145	M	MA/OA	1	3	4	2	3	M	M	M	M	115,6	89,1	110,0	44,2	35,8	36,3
SAM 1146	M	MA	1	2	4	3	3	M	M	M	M	111,2	89,2	105,0	54,1	38,0	39,1
SAM 1157	F	MA/OA	2	2	3	2	3	F	F	M	M	X	93,8	108,6	44,7	34,8	38,5
SAM 1247a	F	MA	1	3	3	1	3	M	M	M	M	116,1	98,6	113,3	55,8	34,7	X
SAM 1443	M	MA/OA	3	5	4	5	2	M	M	M	M	109,5	91,6	111,4	51,2	36,8	41,1
SAM 1444	M	MA/OA	1	4	3	3	2	F	F	F	F	114,7	97,1	112,9	53,9	40,4	41,0
SAM 1446	F	MA	1	2	4	4	3	M	M	M	M	105,2	93,0	111,5	54,3	41,6	42,1
SAM 1449	M	YA/MA	1	3	2	1	2	F	F	M	F	X	X	108,7	56,1	39,7	39,1
SAM 1457	F	MA	1	2	3	4	X	F	X	X	X	X	X	X	X	34,5	38,4
SAM 1473	F	MA	2	3	4	4	3	M	M	M	M	107,0	89,7	113,4	53,1	X	X
SAM 1871	F	MA	3	5	3	1	3	M	M	M	M	115,8	99,5	108,3	49,0	37,9	42,5
SAM 1878a	M	OA	1	5	4	3	4	M	M	M	M	113,9	98,6	117,6	57,3	X	X
SAM 1878b	F	MA/OA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	40,2
SAM 1879	M	YA/MA	1	4	3	2	2	M	M	M	M	X	90,0	110,4	52,5	37,4	41,4
SAM 1889	M	MA	X	X	X	X	X	X	X	X	X	X	X	X	X	36,6	X
SAM 1893	M	MA	2	3	2	4	X	M	X	X	X	X	X	X	X	X	X
SAM 3026	F	YA	X	1	X	X	X	F	X	X	X	X	X	X	X	35,3	37,9
SAM 4305	M	MA/OA	X	X	X	X	X	X	X	X	X	X	X	X	60,7	37,4	42,2
SAM 4637	F	MA/OA	3	2	4	2	3	M	X	M	M	X	X	X	X	37,3	40,1
SAM 4720	M	YA/MA	X	X	X	X	1	F	M	M	M	X	X	114,1	52,6	X	41,8
SAM 4790	M	MA	2	3	4	3	2	M	M	F	M	117,9	100,5	118,2	62,2	34,9	37,6
SAM 4800	F	MA	X	X	X	X	1	F	F	F	F	X	93,9	X	69,8	36,8	38,7

SAM 4838a	M	YA/MA	X	X	X	X	X	X	X	X	X	X	X	X	X	39,2	X
SAM 4838b	F	MA	X	X	X	X	X	X	X	X	X	X	X	X	X	35,9	38,1
SAM 4840	F	YA	1	3	4	1	1	M	M	M	M	102,1	89,6	105,1	40,8	34,1	38,1
SAM 4901	M	MA/OA	2	4	3	5	X	M	X	X	X	X	X	X	X	34,5	38,1
SAM 4905	M	MA	1	2	2	1	2	F	F	F	F	110,0	92,9	70,3	55,5	36,7	42,3
SAM 4930	F	MA	1	X	3	1	3	F	F	M	F	X	X	113,5	57,7	38,3	42,3
SAM 4931	M	YA	2	3	3	1	3	M	X	M	M	X	X	113,1	50,6	46,3	45,5
SAM 4934	M	YA/MA	X	X	X	X	X	X	X	X	X	X	X	X	X	40,6	40,0
SAM 4943	F	YA/MA	1	3	4	1	3	F	X	M	M	X	X	X	X	X	35,1
SAM 4964	M	YA	1	4	4	2	2	M	M	M	M	112,3	97,1	109,5	49,5	X	42,0
SAM 5035a	M	YA/MA	3	3	3	5	2	M	M	F	M	112,4	96,9	109,7	41,7	32,6	36,1
SAM 5036	M	YA/MA	X	X	X	X	1	F	M	M	M	111,2	91,8	118,4	51,7	36,7	39,5
SAM 5041	M	YA/MA	1	4	4	5	3	M	M	M	M	X	X	112,1	57,8	35,1	40,2
SAM 5048	M	YA/MA	1	1	4	1	3	F	F	M	M	105,9	93,7	106,5	45,9	44,1	X
SAM 5050	F	MA	1	1	4	1	2	F	F	M	M	104,5	83,4	105,7	48,8	37,7	41,2
SAM 5075	M	MA	X	X	X	X	4	M	M	M	M	105,1	101,6	100,9	47,6	37,6	40,7
SAM 5077 IV/D	M	MA	X	2	X	X	2	F	M	M	M	X	X	X	X	40,7	42,9
SAM 5083	F	MA/OA	2	3	2	2	3	F	M	M	M	107,8	97,5	112,0	52,9	36,9	39,3
SAM 5095	F	MA/OA	2	4	2	2	1	F	F	M	F	102,3	94,4	104,5	46,4	X	38,4
SAM 6020	M	MA	2	4	4	3	3	M	M	M	M	112,7	95,7	120,2	60,6	36,4	40,2
SAM 6023	M	MA	X	X	X	X	X	X	X	X	X	X	X	X	X	39,6	40,5
SAM 6041a	M	YA/MA	4	5	3	4	4	M	M	M	M	107,4	96,1	116,5	58,0	34,6	36,5
SAM 6041b	M	YA/MA	2	3	4	3	3	M	M	M	M	X	100,7	X	X	35,5	38,9
SAM 6049	M	MA/OA	2	2	4	5	3	M	M	M	M	113,9	90,9	50,0		40,0	42,7
SAM 6050	F	MA	X	X	X	X	X	X	X	X	X	X	X	X	X	38,3	44,4
SAM 6051	F	YA/MA	2	3	2	2	3	F	F	M	M	109,4	X	115,1	53,5	36,6	39,2
SAM 6072	M	YA	2	5	3	3	3	M	M	M	M	X	X	116,7	59,0	39,4	42,2
SAM 6075	F	MA	2	3	4	2	4	M	M	M	M	108,7	98,9	113,8	51,7	32,9	36,9
SAM 6147	M	MA	2	4	4	2	X	M	X	M	M	X	X	X	56,4	39,3	39,6
SAM 6149	M	MA/OA	3	4	5	3	3	M	M	M	M	113,7	100,5	119,2	50,6	38,1	41,4
SAM 6264	M	YA	3	3	4	5	2	M	M	M	M	104,4	96,1	115,8	54,6	X	38,5
SAM 6317	M	MA/OA	1	4	4	3	2	M	F	F	F	X	X	X	52,3	34,5	39,8
SAM 6318	M	MA/OA	1	3	4	2	1	M	X	M	M	X	X	X	60,4	43,0	43,3
SAM 6331	F	MA	1	2	4	1	1	F	F	M	M	114,4	95,4	112,8	51,6	35,1	39,2
SAM 6332	M	YA	1	4	5	2	2	M	M	M	M	X	X	103,7	51,1	X	41,0
SAM 6348b	F	MA/OA	1	1	2	2	3	F	F	F	F	110,1	91,1	108,8	50,1	X	X

Pelvic sex estimate determined using Phenice method (1969) and molecular sex results. Molecular sex results were available for 17 individuals from UCT Skeletal Repository (12 males, 5 females), 12 of which had corresponding pelvic sex estimates and the remaining 5 having only molecular sex results.

YA = Young adult (20-34 years old); MA = Middle-aged adult (35-49 years old); OA = Older-aged adult (50+ years old) (Buikstra & Ubelaker, 1994). YA/MA and MA/OA categories refer to individuals with age-at-death estimates extending across more than one of the Buikstra & Ubelaker (1994)-defined age categories.

NC = Nuchal crest, MP = Mastoid process, SOM = supra-orbital margin, Gl = Glabella, ME = Mental eminence, MS = Mandibular shape, GE = Gonial eversion/flaring.

BB= bicondylar breadth (cdl-cdl), BCB = bicoronoid breadth (co-co), CH = coronoid height (co-go), MML = maximum mandible length (cs-pg), HVHD = humeral vertical head diameter (maximum head diameter), FVHD = femoral vertical head diameter.

Appendix C: Data analysis - Observer error assessment

Results of Cohen's kappa assessment of morphological data (sex and age) are summarised in Table C1 and C2 below (where *Cohen's Kappa coefficient formula: K = Po - Pe/1 – Pe,* and *Po = n(agree)/total; Pe = P(correct) + P(incorrect)).*

Table C1: Sex observer error analysis – Cohen's kappa assessment.

Cohen's Kappa assessment - Sex (intra-observer)				
	O1			
O2	*M*	*F*	x/?	Total
M	6	0	3	9
F	0	11	0	11
x/?	1	0	0	1
Total	7	11	3	21
Agreement	6	11	0	20
By chance	3	5,761	0,142	8,9047
Kappa	0,917322835			

Cohen's Kappa assessment - Sex (inter-observer)			
	O1		
O2	*M*	*F*	Total
M	6	1	7
F	2	7	9
Total	8	8	16
Agreement	6	7	13
By chance	3,5	4,5	8
Kappa	0,625		

- Pelvic sex estimate determined using Phenice method (1969) and molecular sex results. Molecular sex results were available for 17 individuals from UCT Skeletal Repository (12 males, 5 females), 12 of which had corresponding pelvic sex estimates and the remaining 5 having only molecular sex results.

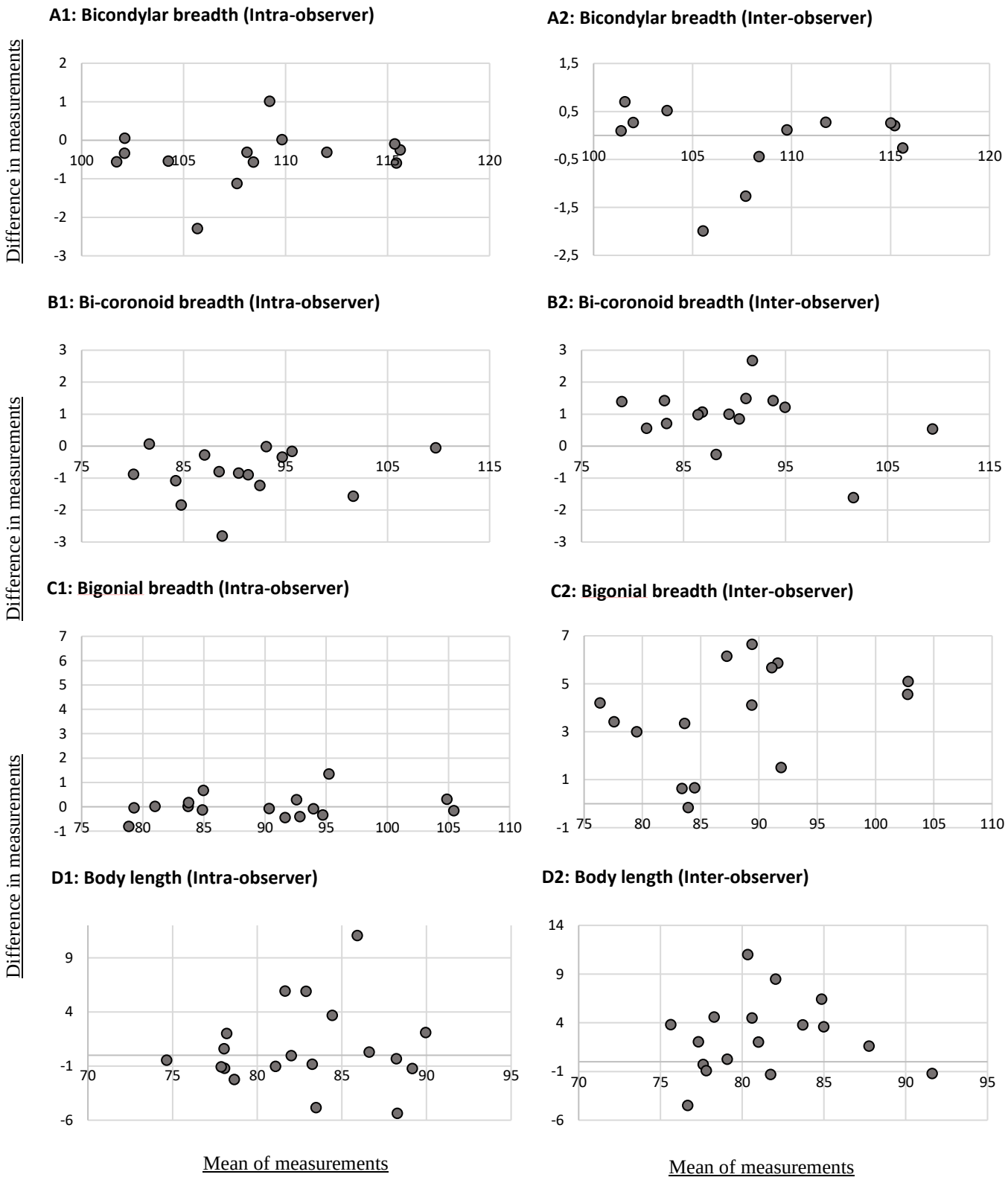
Table C2: Age observer error analysis – Cohen's kappa assessment.

Cohen's Kappa assessment - Age (intra-observer)				
	O1			
O2	*YA*	*MA*	*OA*	Total
YA	3	0	0	3
MA	2	13	0	15
OA	0	0	3	3
Total	5	13	3	21
Agreement	3	12	4	19
By chance	0,714286	9,2857	0,42857	10,42
Kappa	0,810811			

Cohen's Kappa assessment - Age (inter-observer)				
	O1			
O2	*YA*	*MA*	*OA*	Total
YA	2	0	0	2
MA	1	12	0	13
OA	0	1	1	2
Total	3	13	1	17
Agreement	2	12	1	15
By chance	0,352941	9,9411	0,117647	10,411
Kappa	0,696429			

- YA = Young adult (20-34 years old); MA = Middle-aged adult (35-49 years old); OA = Older-aged adult (50+ years old) (Buikstra & Ubelaker, 1994). YA/MA and MA/OA categories refer to individuals with age-at-death estimates extending across more than one of the Buikstra & Ubelaker (1994)-defined age categories.

Inter- and intra-observer error assessment of metrical data are summarised in Figure C1: Bland-Altmann plots (difference in observer measurements plotted again mean of measurements) for metrical parameters assessed to determine agreement *(bigonial breadth, body length and ramus height excluded from further analysis due to poor agreement).*



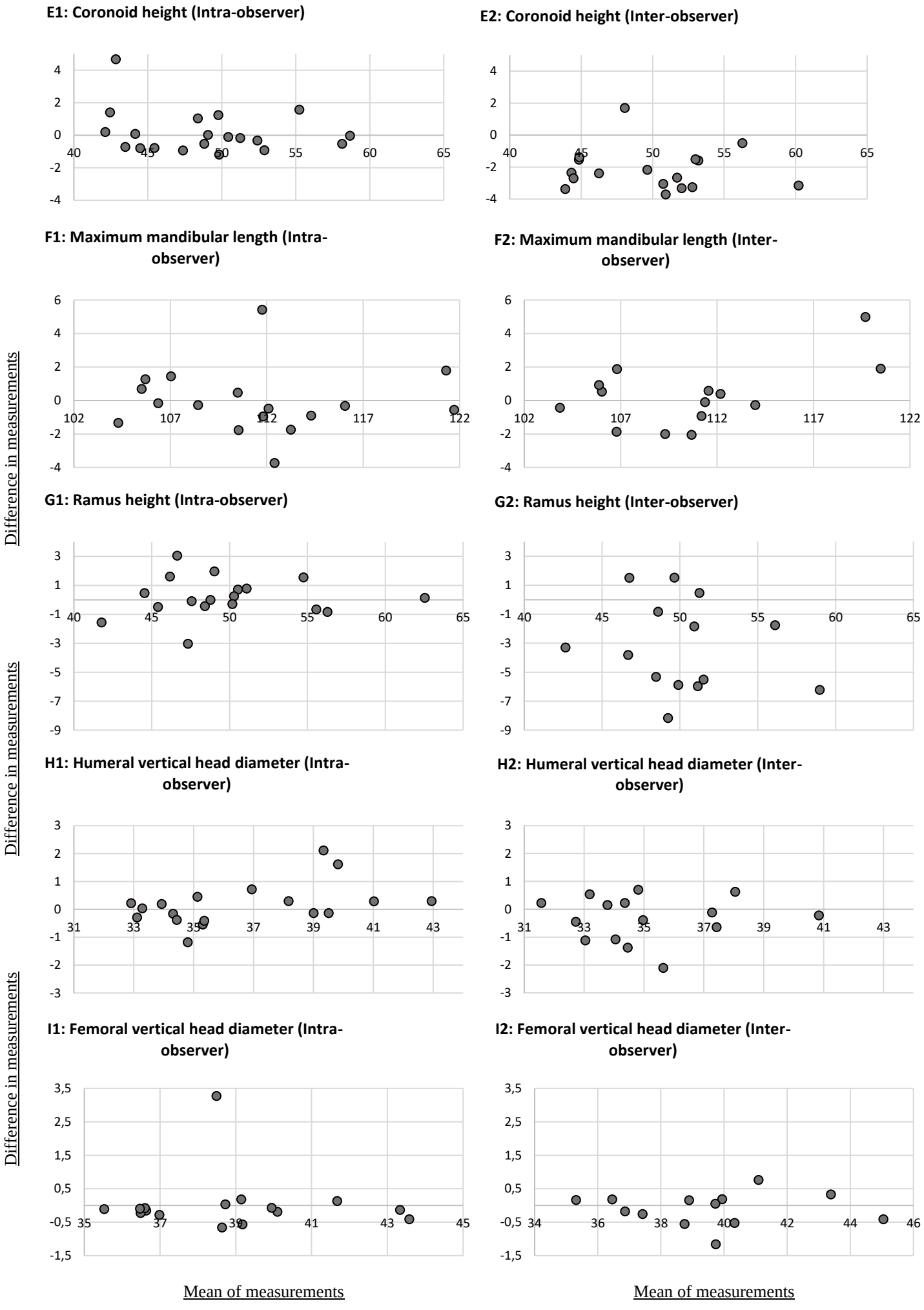


Figure C1: Bland-Altmann plots of inter- and intra-observer error assessment of metrical data. Difference in observer measurements plotted again mean of measurements to determine agreement.

Appendix D: Data analysis - Supplementary data outputs

Table D1: Chi-squared *p*-values obtained from preservation assessment.

Trait/parameter	**Concordance accuracy**		
	Pooled sample	*Female*	*Male*
Morphological traits			
Nuchal crest	**.000**	**.000**	**.000**
Mastoid process	**.000**	**.000**	**.000**
Supra-orbital margin	**.000**	**.000**	**.000**
Glabella	**.000**	**.000**	**.000**
Mental eminence	**.000**	**.000**	**.000**
Mandibular shape	**.000**	**.001**	**.000**
Gonial eversion/flaring	**.000**	**.000**	**.000**
Metrical parameters			
BB	.095	.569	.084
BCB	.544	.305	.919
CH	**.000**	**.000**	**.000**
MML	**.004**	**.004**	.187
HVHD	**.000**	**.000**	**.000**
FVHD	**.000**	**.000**	**.000**
Values that meet statistical significance are indicated in bold (*p*-value ≤ 0.05)			

Table D2: Chi-squared *p*-values obtained from morphological assessment.

Morphological trait	**Concordance accuracy**			**Classification accuracy**		
	Pooled sample	*Female*	*Male*	*Pooled sample*	*Female*	*Male*
Nuchal crest	**.000**	**.000**	**.000**	**.000**	**.000**	.806
Mastoid process	**.000**	**.001**	**.003**	**.000**	**.003**	**.001**
Supra-orbital margin	**.001**	**.003**	.132	**.001**	**.008**	.043
Glabella	**.000**	**.000**	**.001**	**.000**	**.000**	**.000**
Mental eminence	.368	**.004**	.566	.323	**.047**	.527
Mandibular shape	**.000**	**.001**	**.002**	**.000**	**.001**	**.002**
Gonial eversion/flaring	**.004**	**.000**	.622	**.004**	**.000**	.622
Combined cranial sex	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**
Combined mandibular sex	**.000**	**.000**	**.000**	**.000**	**.000**	**.030**
Values that meet statistical significance are indicated in bold (*p*-value ≤ 0.05)						

Table D3: SPSS Discriminant function analysis outputs obtained from metrical assessment (The figures below represent the statistical outputs obtained through univariate DFA of a single variable, *i.e.*, Bicondylar breadth (cdl-cdl). Statistical outputs for additional DFA analyses conducted are available on request).

Analysis Case Processing Summary

Unweighted Cases		N	Percent
Valid		76	43.7
Excluded	Missing or out-of-range group codes	0	.0

	At least one missing discriminating variable	98	56.3
	Both missing or out-of-range group codes and at least one missing discriminating variable	0	.0
	Total	98	56.3
Total		174	100.0

Group Statistics

Sex		Mean	Std. Deviation	Valid N (listwise) Unweighted	Weighted
Female	cdlxcdl	107.0360	5.23324	36	36.000
Male	cdlxcdl	109.8534	9.15111	40	40.000
Total	cdlxcdl	108.5188	7.63754	76	76.000

Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
cdlxcdl	.966	2.635	1	74	.019

Pooled Within-Groups Matrices

		cdlxcdl
Correlation	cdlxcdl	1.000

Analysis 1

Box's Test of Equality of Covariance Matrices

Log Determinants

Sex	Rank	Log Determinant
Female	1	3.310
Male	1	3.133
Pooled within-groups	1	3.221

The ranks and natural logarithms of determinants printed are those of the group covariance matrices.

Test Results

Box's M		.290
F	Approx.	.286
	df1	1
	df2	16300.373
	Sig.	.593

Tests null hypothesis of equal population covariance matrices.

Summary of Canonical Discriminant Functions

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.169[a]	100.0	100.0	.380

a. First 1 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.885	11.487	1	<,001

Standardized Canonical Discriminant Function Coefficients

	Function
	1
cdlxcdl	1.000

Structure Matrix

	Function
	1
cdlxcdl	1.000

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.

Canonical Discriminant Function Coefficients

	Function
	1
cdlxcdl	.200
(Constant)	-21.817

Unstandardized coefficients

Functions at Group Centroids

	Function
Sex	1
Female	-.428
Male	.385

Unstandardized canonical discriminant functions evaluated at group means

Classification Statistics

Classification Processing Summary

Processed		174
Excluded	Missing or out-of-range group codes	0
	At least one missing discriminating variable	98
Used in Output		76

Prior Probabilities for Groups

		Cases Used in Analysis	
Sex	Prior	Unweighted	Weighted
Female	.474	36	36.000

Male	.526	40	40.000
Total	1.000	76	76.000

Classification Results[a,c]

			Predicted Group Membership		
		Sex	Female	Male	Total
Original	Count	Female	23	13	36
		Male	11	29	40
	%	Female	63.9	36.1	100.0
		Male	27.5	72.5	100.0
Cross-validated[b]	Count	Female	23	13	36
		Male	11	29	40
	%	Female	63.9	36.1	100.0
		Male	27.5	72.5	100.0

a. 68,4% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 68,4% of cross-validated grouped cases correctly classified.