

Review

Skeletal Sex Estimation Methods Based on the Athens Collection

Maria-Eleni Chovalopoulou ^{1,*} , Efstratios Valakos ¹ and Efthymia Nikita ²¹ Animal and Human Physiology Department, Faculty of Biology, School of Sciences, University of Athens, 157 72, Athens, Greece² Science and Technology in Archaeology and Culture Research Centre, The Cyprus Institute, 2121 Nicosia, Cyprus

* Correspondence: marilenachov@biol.uoa.gr

Abstract: The aim of this paper was to present all studies that have used the Athens Collection in order to develop methods for skeletal sex estimations and highlight the importance of documented skeletal reference collections in forensic anthropology. The Athens Collection is housed at the National and Kapodistrian University of Athens, Greece; it consists of 250 individuals and both sexes are well-represented. Several studies have used this collection for skeletal sex estimations. In particular, macroscopic observation methods have been used based on the cranium and pelvis; metric methods, including geometric morphometrics, have been applied to cranial and postcranial elements. These studies involved both the development of methods for the sex estimation of Greek/Eastern Mediterranean assemblages and an examination of the accuracy of the existing methods, thus making this collection a key resource for forensic anthropological and bioarchaeological research.

Keywords: skeletal sex estimation; Athens Collection; Greece



Citation: Chovalopoulou, M.-E.; Valakos, E.; Nikita, E. Skeletal Sex Estimation Methods Based on the Athens Collection. *Forensic Sci.* **2022**, *2*, 715–724. <https://doi.org/10.3390/forensicsci2040053>

Academic Editors: Francisca Alves Cardoso, Vanessa Campanacho and Claudia Regina Plens

Received: 3 October 2022

Accepted: 25 October 2022

Published: 30 October 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Documented skeletal collections are essential in forensic and physical anthropology as they provide the means to develop methods for the estimation of various parameters of the biological profile of an individual such as sex, age at death, and stature.

According to its general definition, “sexual dimorphism is the growth of visible morphological differences between males and females in a species or population” [1] (p. 1). Although the most obvious attribute of sexual dimorphism is stature in humans with males, overall, being taller than females, sexual dimorphism is present in many aspects of the human skeleton. In many skeletal elements, it is present in the form of morphological differences; in others, it exclusively relates to a size variation [1].

Population genetics are the most important contributing factor to sexual dimorphism [2–4], but environmental factors—especially diet [5–8] and mechanical loading [3,9,10]—also affect its expression. Several studies have demonstrated that secular changes associated with lifestyle modifications have led to a variation in the degree of sexual dimorphism, especially in geographically and temporally isolated populations [3,11–14].

Traits that differentiate male from female human skeletons are due to the testosterone hormone [15]. As testosterone levels are low before puberty, sexually dimorphic characteristics develop after skeletal maturity. Therefore, a skeletal sex estimation is usually restricted to adults, although various methods for juveniles have also been proposed [16,17].

Traditional approaches to estimate the sex from skeletal remains include a morphological examination and morphometric methods. The macroscopic observation of several sexually dimorphic traits is the most common method. In most cases, observations are graded (i.e., 1: female; 2: probable female; 3: ambiguous sex; 4: probable male; 5: male) [18–20]. Morphometric methods utilize the dimensional measurements of skeletal remains [21–25]. Morphometric methods may include simple threshold values, above which an individual is considered to be male and below it, female, or they may combine several measurements

into discriminant function formulae for a sex prediction. Geometric morphometrics (GMs) represent more advanced morphometric approaches, which employ 2D or (most commonly) 3D coordinates of homologous landmarks that describe the studied object and, therefore, represent the complete geometric information related to it [26]. In addition, GMs enable the differentiation of variability based on size and shape.

Given the variability in the levels of sexual dimorphism among populations both temporally and spatially, it is important for forensic anthropologists to develop population-specific methods for sex estimation. The purpose of this paper was to present all sex estimation-related studies that applied to the Athens Collection.

2. The Athens Collection

The first part of the collection, known as the Wiener Lab Collection [27], was built at the Malcolm H. Wiener Laboratory for Archaeological Science of the American School of Classical Studies at Athens between the years 1996 and 1997 by Lagia [28,29]. In 1998, the collection, consisting of 72 documented skeletons, was donated to the Department of Animal and Human Physiology at the University of Athens [30] (pp. 45–46). Between the years 2001 and 2003, Eliopoulos added 153 skeletons to the collection [31]. The two parts of this osteological collection are known as the University of Athens Human Skeletal Reference Collection or, in short, The Athens Collection.

The Athens Collection is housed at the Department of Animal and Human Physiology, Faculty of Biology, National and Kapodistrian University of Athens, and consists of 250 individuals (Figure 1). All individuals were acquired from cemeteries in the Athens area. According to the information from the death certificates, 237 out of the 250 individuals are of a known sex, age, occupation, cause of death, and place of birth. The year of death for all individuals ranges between 1960 and 1996; the place of birth covers the entire country. Both sexes (males: 131; females: 115) and all adult age groups are well-represented. However, sub-adults are under-represented for both sexes (Table 1). The under-representation of juveniles has hindered the use of the Athens Collection in the development of skeletal sex estimation standards for sub-adults, but it has had no effect on its use for adults, which is the subject of this review paper. During the last few years, several skeletal parts of the individuals (cranium, scapula, humerus, ulna, femur, tibia, and os coxae of adults) have been digitized and stored as 3D models, mostly by Dr. Andreas Bertsatos, for better preservation and the remote exploitation of the skeletal collection.



Figure 1. Indicative photo of a skeleton.

Table 1. Demographic distribution of the Athens Collection.

Age Interval	Males	Females	Total
0–9	1	9	10
10–19	6	1	7
20–29	15	7	22
30–39	13	9	22
40–49	18	15	33
50–59	16	17	33
60–69	24	15	39
70–79	16	18	34
80–89	15	16	31
90–99	4	2	6
Total	128	109	237

3. Morphological Sex Estimation Methods

Morphological sex estimation methods have been used on the Athens Collection, focusing on well-defined regions of the pelvis and the skull. The earliest study was by Eliopoulos [31] and its aim was to test whether the standards proposed by the European Workshop of Anthropologists [32], Buikstra and Ubelaker [20], and Brickley and McKinley [33] were appropriate for a modern Greek population. Eliopoulos applied 10 morphological traits for sexing the pelvis and 9 for sexing the skull on 202 individuals from the Athens Collection. Regarding the pelvis, he found that the preauricular sulcus was the most accurate trait (89.1% correct sex classification) and the greater sciatic notch had the lowest accuracy (78.2%). The analysis of the skull traits showed a low accuracy for all traits. The author additionally examined the rates of intra- and inter-observer errors in recording the cranial and pelvic traits and found that 8 out of the 10 pelvic traits and 6 out of the 9 skull traits could be scored with consistency by a single observer. The inter-observer agreement was relatively low for almost all traits, except for the preauricular sulcus and the ventral arc.

In a more recent study, Oikonomopoulou and colleagues [34] examined the accuracy of the discriminant functions proposed by Klates et al. [35] and Walker [36] for sex predictions based on pelvic and cranial traits, respectively. More specifically, they studied 4 morphological traits for sexing the pelvis and 5 for sexing the cranium on 194 individuals from the Athens Collection. According to their results, although the Klates et al. [35] equations performed very well on the Greek material, the equations of Walker [36] were highly population-specific. Additionally, they proposed new discriminant functions based on the Athens Collection, achieving very high correct classification rates (97.53% for females and 98.95% for males when using pelvic traits and 93.83% for females and 94.73% for males when using cranial traits). For all cranial and pelvic traits, the intra-observer error was very low. However, the inter-observer error for cranial traits was moderate.

The research carried out by Nikita and Nikitas [37] is also very interesting. They examined the performance of different statistical approaches for sex estimations, employing cranial and pelvic sexually dimorphic traits. The statistical methods tested included a binary logistic regression, probit and cumulative probit regressions, linear and quadratic discriminant analyses, artificial neural networks, and a naïve Bayes classification. These methods were tested on 191 skeletons (106 males and 85 females) from the Athens Collection. According to the results, there were small differences in the classification performance between the methods and the combination of the pelvic and cranial traits via discriminant functions yielded much better predictions than the individual functions.

4. Metric Sex Estimation Methods

Numerous metric sex estimation methods have been developed using different elements of the Athens Collection, either employing single measurements or multiple dimensions. A great emphasis has been placed on the upper and lower limbs. In 2006, Eliopoulos [31] measured the length of the glenoid fossa, the vertical humeral head di-

ameter, the maximum femoral head diameter, and the bicondylar breadth of the femur in order to differentiate males from females in a sample of 202 individuals. According to his results, only the vertical humeral head diameter and the bicondylar breadth of the femur were significantly dimorphic and led to classification accuracies above 75%. The intra- and inter-observer reliability was over 86%, except for the length of the glenoid fossa, which had an inter-observer agreement of 75.8%.

Focusing on the upper limbs, Koukiasa and colleagues [38] studied the scapulae and clavicles of 107 male and 90 female skeletons from the Athens Collection. The authors obtained seven measurements and found that both bones exhibited a significant degree of sexual dimorphism. The sex estimation accuracy of the discriminant functions ranged between 84.9% and 91.4% and no significant inter- or intra-observer errors of measurement were found.

Charisi and colleagues [1] examined the humerus, ulna, and radius to determine the degree of sexual dimorphism and to develop metric standards for sex estimations. The sample consisted of 204 adult skeletons (111 males and 93 females) from the Athens Collection. The measurements taken included the maximum lengths and epiphyseal widths and followed Martin and Saller [39] and Riclan and Tobias [40]. Their results found higher values among the males compared with the females for all dimensions examined. The bone lengths showed the lowest discriminatory power, but the accuracy rates were over 90% and higher on the right side in all cases, except for the left ulna.

Hand bones have also been used to develop sex estimation methods, given that they are found intact more often than the long bones; thus, they facilitate the application of metric methods. Manolis and colleagues [41] obtained measurements from the metacarpal bones of 151 adult individuals (84 males and 67 females) from the Athens Collection. Their results showed that the male metacarpal diameters were greater than those of the females and there were no significant differences between the sides. The highest correspondence between the true and estimated sex was found in the epiphyses and the percentage of the correct sex classification was very high (83.7–88.1% for the left and 83.8–89.7% for the right metacarpals, respectively).

Karakostis and colleagues [42] measured the proximal hand phalanges to examine the degree of sexual dimorphism. They studied 661 left and right proximal hand phalanges from 160 adult individuals (86 males and 74 females). The authors found that the male proximal hand phalanges were larger than those of the females and the mediolateral diameter proved to be, generally, more sexually dimorphic than the anteroposterior one.

Focusing on the lower limbs, Anastasopoulou and colleagues [43] explored the sexual dimorphism of the proximal portion of the femur by analyzing the biometric data of the Purkait's triangle [44] of 203 individuals (112 males and 91 females). The discriminant equations generated from their study had an overall correct classification rate of 78.3%. As far as bilateral asymmetry was concerned, no statistically significant differences were found. In another study by Kiskira and colleagues [45], the two main long bones of the leg, the femur and tibia, were analyzed to determine their appropriateness for a sex assessment. The authors measured the maximum lengths and epiphyseal widths of 200 adult individuals (111 males and 89 females). According to their results, the rate of the correct sex classification ranged from 91.5% for the left femur to 93.4% for the left tibia and the intra- and inter-observer errors were very low.

Similar to hand bones, foot bones are more likely to be found intact in forensic and archaeological contexts because of their quantity as well as their small surface area [46]. Therefore, Mountrakis and colleagues [47] evaluated the presence of sexual dimorphism in the metatarsals of 186 individuals (97 males and 89 females) from the Athens Collection. A total of 7 measurements, after Martin and Saller [39] and Smith [48], were taken from 1595 metatarsal bones. The analysis of bilateral asymmetry revealed no significant differences in the dimensions between the right and left MT-1 and MT-5. In contrast, the MT-2, MT-3, and MT-4 presented statistically significant size differences, mainly in the mediolateral diameters. According to the results, the mean values of the males were higher

than those of the females in all cases and the mediolateral width at the midshaft was the most sexually dimorphic dimension. The accuracy of the classification obtained from the metatarsals ranged between 80.5 and 90.1%.

Another study focusing on foot bones was by Peckmann and colleagues [49]. Their goal was to derive discriminant function equations for sex estimations from the calcaneus by measuring 9 dimensions of this element on 198 individuals (103 males and 95 females). Their study showed that all variables were sexually dimorphic and the average accuracy of the sex classification ranged from 70% to 90% for the univariate analyses and 82.9% to 87.5% for the multivariate analyses. The same team also developed discriminant function equations for sex predictions based on nine talar measurements [50]. The authors studied 182 individuals (96 males and 86 females) and their equations showed an average accuracy of the sex classification from 65.2% to 93.4% for the univariate analyses and 90% to 96.5% for the multivariate analyses.

A final interesting study that focused on the long bones of the upper and lower limbs was by Bertsatos and colleagues [51], who introduced an automated method for estimating sex based on the diaphyseal cross-sectional geometric properties. The maximum cross-validated classification reached 94.8% for the femur, 94.7% for the tibia, and 97.3% for the humerus.

Concerning other postcranial elements, Garoufi and colleagues [52] evaluated the utility in sex estimations of three easily identifiable vertebrae (T1, T12, and L1), utilizing two modern European populations: a Greek one (Athens Collection) and a Danish one. According to the results, T1 was the best sex diagnostic vertebra and reached a cross-validated accuracy of almost 90%.

The cranium is one of the most commonly employed anatomical areas for morphological sex estimations, as described above. Chovalopoulou and Bertsatos [53] determined the use of the foramen magnum and occipital condyles for sex estimations. Their sample consisted of 154 adult crania (77 males and 77 females) from the Athens Collection. According to the results, the occipital condyles provided higher correct sex classification rates than the foramen magnum and the percentage of correct sex classifications when using a combination of the occipital condyle variables was 74%.

In addition, Chovalopoulou et al. [54] produced sex-predicting logistic regression equations based on the Athens Collection and subsequently applied them to crania from archaeological Greek assemblages. This exercise yielded sex classification accuracies greater than 70% in the sphenoid, maxilla, and overall cranium, suggesting that modern standards may be applied to archaeological populations.

Being resistant to postmortem destruction and fragmentation, teeth have been used for sex estimations in many studies [55–59]. In the Greek population, Eleni Zorba has dealt extensively with teeth. More specifically, Zorba and colleagues [60] examined the degree of sexual dimorphism in the permanent teeth of 133 individuals (70 males and 63 females) from the Athens Collection. They measured the mesiodistal and buccolingual crown as well as the cervical diameters of the maxillary and mandibular teeth and concluded that the canines were the most dimorphic teeth, followed by the first premolars, maxillary second premolars, and mandibular second molars.

Subsequently, Zorba and colleagues [61] evaluated the sex estimation potential of the molar crown and cervical diagonal diameters. They examined 344 permanent molars from 107 individuals (53 males and 54 females) from the Athens Collection and found that the most dimorphic molars were the maxillary second molar and the mandibular second and first molars. The accuracy rates were higher for the cervical than the crown diagonal diameters; for the total sample, the classification accuracy was 93%. In 2013, Zorba and colleagues [62] conducted a more in-depth investigation into the sex discriminatory potential of molars, examining 101 individuals (51 males and 50 females) from the Athens Collection. The authors confirmed that the sex classification accuracy of the diagonal diameters was higher than that of the traditional mesiodistal and buccolingual diameters.

Finally, Zorba and colleagues [63] tested the existence of sexual dimorphism in the root length of single-rooted teeth. Roots are not affected by wear and root measurements require less experience than most crown measurements [64]. The sample consisted of 102 individuals (58 males and 44 females). The maxillary teeth were more dimorphic than the mandibular ones. Moreover, the buccal and mesial measurements appeared to be more dimorphic, followed by the distal and lingual measurements. The correct sex classification rates ranged from 58.6% to 90.0%.

5. Geometric Morphometrics Methods

Geometric morphometrics (GMs) are a sub-category of metric sex estimation methods that employ landmark coordinates instead of linear measurements. Using GMs, researchers can preserve geometric information about the relative positions of the coordinates of points, visualize the results of multivariate analyses as configurations of landmarks in the original space of the organism, and assess variations in structures with few or no landmarks [65].

Most of the research on sex estimations using GMs in the Athens Collection has been carried out on the skull. Chovalopoulou and colleagues [66–68] tested the workability and validity of GMs when applied to the sexually dimorphic characteristics of the human skeleton. For this purpose, they examined certain anatomical regions of the cranium (palate, cranial base, craniofacial form, and vault), using 80 landmarks on the outer surface of the skull of 176 adult individuals (94 males and 82 females). According to the results, there were statistically significant shape differences between the sexes. The highest correct classification rate was obtained from the craniofacial region (83.1%) and the lowest from the palate (68.9%). In a more in-depth analysis of the same ectocranial landmarks, Bertsatos and colleagues [69] explored a novel approach to identify those distance and angle measurements that could be most effectively used in sex assessments. The authors reported 13 cranio-metric distances with a classification accuracy over 85% and 7 angles with a classification accuracy over 78% as well as certain multivariate combinations yielding sex classification accuracies of over 95%. Furthermore, utilizing a few of the 80 landmarks, Bertsatos and colleagues [70] evaluated the reliability of 3D-ID software <https://www.3d-id.org/home> (accessed on 13 May 2018) to identify the ancestry and sex of 158 test subjects from the Athens Collection. They concluded that the software exhibited a moderate reliability in the ancestry estimation and an adequate reliability in the sex estimation.

Nikita and Michopoulou [71] developed a method for the quantification of the shape of key cranial sexually dimorphic traits (glabella, mastoid process, and external occipital protuberance) using digital photographs of the lateral view of 65 crania from the Athens Collection. The best cross-validated results ranged from 75.8 to 85.1% for males and 81.1 to 94.6% for females.

A more advanced approach focusing on the three-dimensional analysis of morphological cranial features was carried out by Bertsatos and colleagues [72]. In this particular study, the authors proposed an automated method that extracted and evaluated various cranial sex diagnostic traits. This was developed using two European population samples, a Czech sample (170 crania) and a Greek sample (156 crania). The accuracy for the individual morphometric features ranged from 71.7 to 96.7%.

Finally, with regard to the mandible, Bertsatos and colleagues [73] examined the most sexually dimorphic mandibular traits, analyzing 194 adult mandibles (105 males and 89 females) from the Athens Collection and calculating 20 linear and 3 angular measurements from the 3D coordinates of anatomical landmarks. According to the results, the coronoid height, ramus height, and maximum mandibular length were the most sexually dimorphic metric traits and the produced sex discriminant functions yielded a classification accuracy of up to 85.7%.

6. Discussion

The Athens Collection has been extensively used to test the existing methods for sex estimations and to develop new ones for modern Greek/Eastern Mediterranean populations.

The results of the studies conducted to date have highlighted the population specificity of several metric and morphological methods as well as the highly variable performance of different skeletal traits in sex estimations. According to Table 2, we concluded that the pelvis was the most sexually dimorphic trait, followed by the humerus. Note that the high dimorphism of the pelvis, followed by the long bones (instead of the cranium), was in agreement with Spradley and Jantz [74]. The cranium appeared to exhibit the least sexual dimorphism when studied using morphological and metric methods; this was not the case when it was analyzed with geometric morphometrics. When using geometric morphometrics, the cranium exhibited almost the same levels of sexual dimorphism as the humerus.

Table 2. The highest accuracy rates achieved by the methods developed for sex estimations utilizing the Athens Collection.

Method	Researchers	Year	Skeletal Element	Highest Accuracy
Morphological	Oikonomopoulou et al.	2017	Pelvis	98.95%
Metric	Eliopoulos	2006	Humerus/femur	>75%
	Manolis et al.	2009	Metacarpals	89.7%
	Mountrakis et al.	2010	Metatarsals	90.1%
	Zorba et al.	2011/2012/2013/2014	Teeth	93%
	Charisi et al.	2011	Humerus/ulna/radius	>90%
	Anastasopoulou et al.	2014	Femur	78.3%
	Peckmann et al.	2015	Calcaneus/talus	90%/96.5%
	Chovalopoulou and Bertsatos	2017	Foramen magnum/occipital condyles	74%
	Chovalopoulou et al.	2017	Cranium	>70%
	Koukiasa et al.	2017	Scapula/clavicle	91.4%
	Bertsatos et al.	2020	Humerus	97.3%
	Garoufi et al.	2020	Vertebrae	Almost 90%
	Kiskira et al.	2022	Femur/tibia	93.4%
Geometric Morphometrics	Chovalopoulou et al.	2013	Cranium	83.1%
	Nikita and Michopoulou	2018	Cranium	94.6%
	Bertsatos et al.	2019	Mandible	85.7%
	Bertsatos et al.	2018/2020	Cranium	96.7%

Note that the Athens Collection is not the only skeletal reference collection in Greece. Another important collection is the Cretan collection, housed at the Department of Forensic Sciences at the University of Crete, which was assembled in 2005 by Elena Krianioti, and consists of 213 skeletons [75]. The individuals comprising the Cretan collection died between 1968 and 1983, covering a shorter time range compared with the Athens Collection. Several studies on sexual dimorphism have also been conducted on that collection [29]. Several of them confirmed the results obtained from the Athens Collection and others revealed different patterns of sexual dimorphism, highlighting the complexity of sexual dimorphism, even at an intra-population level.

Despite the systematic research on sex estimations based on the Athens Collection, there is still the prospect of a lot more work to explore the sex discriminatory potential of even more skeletal elements and to validate the new methods published. In addition, to the best of our knowledge, no studies by other researchers have yet evaluated the models for sex estimations generated from the Athens Collection on other/foreign assemblages. Therefore, with this paper, we urge researchers toward this direction. We would also like to take the opportunity to invite scholars to get in touch with the corresponding author if they would like to access the collection.

Author Contributions: Conceptualization, M.-E.C.; writing—original draft preparation, M.-E.C.; writing—review and editing, E.N. and E.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

- Charisi, D.; Eliopoulos, C.; Vanna, V.; Koiliias, C.G.; Manolis, S.K. Sexual dimorphism of the arm bones in a modern Greek population. *J. Forensic Sci.* **2010**, *56*, 10–18. [\[CrossRef\]](#) [\[PubMed\]](#)
- Gustafsson, A.; Werdelin, L.; Tullberg, B.S.; Lindenfors, P. Stature and sexual stature dimorphism in Sweden, from the 10th to the end of the 20th century. *Am. J. Hum. Biol.* **2007**, *19*, 861–870. [\[CrossRef\]](#) [\[PubMed\]](#)
- Safont, S.; Malgosa, A.; Subirà, M.E. Sex assessment on the basis of long bone circumference. *Am. J. Phys. Anthropol.* **2000**, *113*, 317–328. [\[CrossRef\]](#)
- Liu, P.-Y.; Qin, Y.-J.; Recker, R.R.; Deng, H.-W. Evidence for a major gene underlying bone size variation in the Chinese. *Am. J. Hum. Biol.* **2003**, *16*, 68–77. [\[CrossRef\]](#) [\[PubMed\]](#)
- İşcan, M.Y.; Loth, S.R.; King, C.A.; Shihai, D.; Yoshino, M. Sexual dimorphism in the humerus: A comparative analysis of Chinese, Japanese and Thais. *Forensic Sci. Int.* **1998**, *98*, 17–29. [\[CrossRef\]](#)
- Stini, W.A. Nutritional stress and growth: Sex difference in adaptive response. *Am. J. Phys. Anthropol.* **1969**, *31*, 417–426. [\[CrossRef\]](#)
- Stinson, S. Sex differences in environmental sensitivity during growth and development. *Am. J. Phys. Anthropol.* **1985**, *28*, 123–147. [\[CrossRef\]](#)
- Cowgill, L.W.; Hager, L.D. Variation in the development of postcranial robusticity: An example from çatalhöyük, Turkey. *Int. J. Osteoarchaeol.* **2007**, *17*, 235–252. [\[CrossRef\]](#)
- Ruff, C. Sexual dimorphism in human lower limb bone structure: Relationship to subsistence strategy and sexual division of labor. *J. Hum. Evol.* **1987**, *16*, 391–416. [\[CrossRef\]](#)
- Carlson, K.J.; Grine, F.E.; Pearson, O.M. Robusticity and sexual dimorphism in the postcranium of modern hunter-gatherers from Australia. *Am. J. Phys. Anthropol.* **2007**, *134*, 9–23. [\[CrossRef\]](#)
- Holden, C.; Mace, R. Sexual dimorphism in stature and women's work: A phylogenetic cross-cultural analysis. *Am. J. Phys. Anthropol.* **1999**, *110*, 27–45. [\[CrossRef\]](#)
- Barrier, I.L.O.; L'Abbé, E.N. Sex determination from the radius and ulna in a modern South African sample. *Forensic Sci. Int.* **2008**, *179*, 85.e1–85.e7. [\[CrossRef\]](#) [\[PubMed\]](#)
- Frutos, L.R. Metric determination of sex from the humerus in a Guatemalan forensic sample. *Forensic Sci. Int.* **2005**, *147*, 153–157. [\[CrossRef\]](#)
- Steyn, M.; İşcan, M.Y. Osteometric variation in the humerus: Sexual dimorphism in South Africans. *Forensic Sci. Int.* **1999**, *106*, 77–85. [\[CrossRef\]](#)
- Mays, S. *The Archaeology of Human Bones*; Routledge: London, UK, 1998.
- Stull, K.E.; L'Abbé, E.N.; Ousley, S.D. Subadult sex estimation from diaphyseal dimensions. *Am. J. Phys. Anthropol.* **2017**, *163*, 64–74. [\[CrossRef\]](#) [\[PubMed\]](#)
- Wilson, L.A.B.; Humphrey, L.T. Voyaging into the third dimension: A perspective on virtual methods and their application to studies of juvenile sex estimation and the ontogeny of sexual dimorphism. *Forensic Sci. Int.* **2017**, *278*, 32–46. [\[CrossRef\]](#) [\[PubMed\]](#)
- Acsádi, G.; Nemeskéri, J.; Balás, K. *History of Human Life Span and Mortality*; Akadémiai Kiadó: Budapest, Hungary, 1970.
- Meindl, R.S.; Lovejoy, C.O.; Mensforth, R.P.; Carlos, L.D. Accuracy and direction of error in the sexing of the skeleton: Implications for paleodemography. *Am. J. Phys. Anthropol.* **1985**, *68*, 79–85. [\[CrossRef\]](#)
- Buikstra, J.E.; Ubelaker, D.H. Standards for data collection from human skeletal remains. *Ark. Archeol. Surv.* **1994**, *44*, 272.
- Hanihara, K. Sex diagnosis of Japanese skulls and scapulae by. *J. Anthropol. Soc. Nippon* **1959**, *67*, 191–197. [\[CrossRef\]](#)
- Giles, E.; Elliot, O. Sex determination by discriminant function analysis of Crania. *Am. J. Phys. Anthropol.* **1963**, *21*, 53–68. [\[CrossRef\]](#)
- Giles, E. Sex determination by discriminant function analysis of the mandible. *Am. J. Phys. Anthropol.* **1964**, *22*, 129–135. [\[CrossRef\]](#) [\[PubMed\]](#)
- Birkby, W.H. An evaluation of race and sex identification from cranial measurements. *Am. J. Phys. Anthropol.* **1966**, *24*, 21–27. [\[CrossRef\]](#) [\[PubMed\]](#)
- Henke, W. Zur Methode der diskriminanzanalytischen Geschlechtsbestimmung am Schädel. *Homo J. Comp. Hum. Biol.* **1974**, *24*, 99–117.
- Slice, D.E. Geometric morphometrics. *Annu. Rev. Anthropol.* **2007**, *36*, 261–281. [\[CrossRef\]](#)

27. Pike, S. The Wiener laboratory. *Paleopathol. Assoc. Newslett* **1997**, *100*, 8–9.
28. Eliopoulos, C.; Lagia, A.; Manolis, S. A modern, documented human skeletal collection from Greece. *HOMO* **2007**, *58*, 221–228. [[CrossRef](#)]
29. Nikita, E. Documented skeletal collections in Greece: Composition, research, and future prospects. *Am. J. Phys. Anthropol.* **2020**, *174*, 140–143. [[CrossRef](#)]
30. Roberts, C.; Tsaliki, A.; Triantaphyllou, S.; Lagia, A.; Bourbou, C. Health and disease in Greece: Past, present and future. In *Health in Antiquity*; Routledge: London, UK, 2005; pp. 32–57.
31. Eliopoulos, C. The Creation of a Documented Human Skeletal Reference Collection and the Application of Current Aging and Sexing Standards on a Greek Skeletal Population. Ph.D. Thesis, University of Sheffield, Sheffield, UK, 2006.
32. Ferembach, D.; Schwidetzky, I.; Stoukal, M. Recommendations for age and sex diagnoses of skeletons. *J. Hum. Evol.* **1980**, *9*, 517–549.
33. Brickley, M.; McKinley, J.I. *Guidelines to the Standards for Recording Human Remains*; BABAO, Dept. of Archaeology, University of Southampton: Southampton, UK, 2004.
34. Oikonomopoulou, E.-K.; Valakos, E.; Nikita, E. Population-specificity of sexual dimorphism in cranial and pelvic traits: Evaluation of existing and proposal of new functions for sex assessment in a Greek assemblage. *Int. J. Leg. Med.* **2017**, *131*, 1731–1738. [[CrossRef](#)]
35. Klates, A.R.; Ousley, S.D.; Vollner, J.M. A revised method of sexing the human innominate using Phenice's nonmetric traits and statistical methods. *Am. J. Phys. Anthropol.* **2012**, *149*, 104–114. [[CrossRef](#)]
36. Walker, P.L. Sexing skulls using discriminant function analysis of visually assessed traits. *Am. J. Phys. Anthropol.* **2008**, *136*, 39–50. [[CrossRef](#)] [[PubMed](#)]
37. Nikita, E.; Nikitas, P. Sex estimation: A comparison of techniques based on binary logistic, probit and cumulative probit regression, linear and quadratic discriminant analysis, neural networks, and naïve Bayes classification using ordinal variables. *Int. J. Leg. Med.* **2019**, *134*, 1213–1225. [[CrossRef](#)] [[PubMed](#)]
38. Koukiasa, A.E.; Eliopoulos, C.; Manolis, S.K. Biometric sex estimation using the scapula and clavicle in a modern Greek population. *Anthropol. Anz.* **2017**. [[CrossRef](#)] [[PubMed](#)]
39. Martin, R.; Saller, K. *Lehrbuch der Anthropologie*; Gustav Fischer Verlag: Stuttgart, Germany, 1959.
40. Ricklan, D.E.; Tobias, P.V. Unusually low sexual dimorphism of endocranial capacity in a Zulu cranial series. *Am. J. Phys. Anthropol.* **1986**, *71*, 285–293. [[CrossRef](#)] [[PubMed](#)]
41. Manolis, S.K.; Eliopoulos, C.; Koiliak, C.G.; Fox, S.C. Sex determination using metacarpal biometric data from the Athens Collection. *Forensic Sci. Int.* **2009**, *193*, 130.e1–130.e6. [[CrossRef](#)]
42. Karakostis, F.A.; Zorba, E.; Moraitis, K. Sexual dimorphism of proximal hand phalanges. *Int. J. Osteoarchaeol.* **2013**, *25*, 733–742. [[CrossRef](#)]
43. Anastopoulou, I.; Eliopoulos, C.; Valakos, E.D.; Manolis, S.K. Application of Purkait's triangle method on a skeletal population from southern Europe. *Forensic Sci. Int.* **2014**, *245*, 203.e1–203.e4. [[CrossRef](#)]
44. Purkait, R. Triangle identified at the proximal end of femur: A new sex determinant. *Forensic Sci. Int.* **2005**, *147*, 135–139. [[CrossRef](#)]
45. Kiskira, C.; Eliopoulos, C.; Vanna, V.; Manolis, S.K. Biometric sex assessment from the femur and tibia in a modern Greek population. *Leg. Med.* **2022**, *59*, 102126. [[CrossRef](#)]
46. Byers, S.; Akoshima, K.; Curran, B. Determination of adult stature from metatarsal length. *Am. J. Phys. Anthropol.* **1989**, *79*, 275–279. [[CrossRef](#)]
47. Mountrakis, C.; Eliopoulos, C.; Koiliak, C.G.; Manolis, S.K. Sex determination using metatarsal osteometrics from the Athens Collection. *Forensic Sci. Int.* **2010**, *200*, 178.e1–178.e7. [[CrossRef](#)] [[PubMed](#)]
48. Smith, S.L. Attribution of foot bones to sex and population groups. *J. Forensic Sci.* **1997**, *42*, 186–195. [[CrossRef](#)] [[PubMed](#)]
49. Peckmann, T.R.; Orr, K.; Meek, S.; Manolis, S.K. Sex determination from the calcaneus in a 20th century Greek population using discriminant function analysis. *Sci. Justice* **2015**, *55*, 377–382. [[CrossRef](#)] [[PubMed](#)]
50. Peckmann, T.R.; Orr, K.; Meek, S.; Manolis, S.K. Sex determination from the talus in a contemporary Greek population using discriminant function analysis. *J. Forensic Leg. Med.* **2015**, *33*, 14–19. [[CrossRef](#)]
51. Bertsatos, A.; Garoufi, N.; Chovalopoulou, M.-E. Advancements in sex estimation using the diaphyseal cross-sectional geometric properties of the lower and upper limbs. *Int. J. Leg. Med.* **2020**, *135*, 1035–1046. [[CrossRef](#)]
52. Garoufi, N.; Bertsatos, A.; Chovalopoulou, M.-E.; Villa, C. Forensic sex estimation using the vertebrae: An evaluation on two European populations. *Int. J. Leg. Med.* **2020**, *134*, 2307–2318. [[CrossRef](#)]
53. Chovalopoulou, M.-E.; Bertsatos, A. Estimating sex of modern greeks based on the foramen Magnum region. *J. Anthropol.* **2017**, *2017*, 1–7. [[CrossRef](#)]
54. Chovalopoulou, M.E.; Bertsatos, A.; Manolis, S.K. Landmark based sex discrimination on the crania of archaeological Greek population. A comparative study based on the cranial sexual dimorphism of a modern Greek population. *Mediterr. Archaeol. Archaeom.* **2017**, *17*, 37–46.
55. İşcan, M.Y.; Kedici, P.S. Sexual variation in bucco-lingual dimensions in Turkish dentition. *Forensic Sci. Int.* **2003**, *137*, 160–164. [[CrossRef](#)]
56. Ateş, M.; Karaman, F.; İşcan, M.Y.; Erdem, T.L. Sexual differences in Turkish dentition. *Leg. Med.* **2006**, *8*, 288–292. [[CrossRef](#)]

57. Acharya, A.B.; Mainali, S. Univariate sex dimorphism in the Nepalese dentition and the use of discriminant functions in gender assessment. *Forensic Sci. Int.* **2007**, *173*, 47–56. [[CrossRef](#)] [[PubMed](#)]
58. Prabhu, S.; Acharya, A.B. Odontometric sex assessment in Indians. *Forensic Sci. Int.* **2009**, *192*, 129.e1–129.e5. [[CrossRef](#)] [[PubMed](#)]
59. Pereira, C.; Bernardo, M.; Pestana, D.; Santos, J.C.; Mendonça, M.C. Contribution of teeth in human forensic identification—discriminant function sexing odontometrical techniques in Portuguese population. *J. Forensic Leg. Med.* **2010**, *17*, 105–110. [[CrossRef](#)]
60. Zorba, E.; Moraitis, K.; Manolis, S.K. Sexual dimorphism in permanent teeth of modern greeks. *Forensic Sci. Int.* **2011**, *210*, 74–81. [[CrossRef](#)] [[PubMed](#)]
61. Zorba, E.; Moraitis, K.; Eliopoulos, C.; Spiliopoulou, C. Sex determination in modern greeks using diagonal measurements of molar teeth. *Forensic Sci. Int.* **2012**, *217*, 19–26. [[CrossRef](#)]
62. Zorba, E.; Spiliopoulou, C.; Moraitis, K. Evaluation of the accuracy of different molar teeth measurements in assessing sex. *Forensic Sci. Med. Pathol.* **2013**, *9*, 13–23. [[CrossRef](#)]
63. Zorba, E.; Vanna, V.; Moraitis, K. Sexual dimorphism of root length on a Greek population sample. *HOMO* **2014**, *65*, 143–154. [[CrossRef](#)]
64. Cardoso HF, V. Sample-specific (universal) metric approaches for determining the sex of immature human skeletal remains using permanent tooth dimensions. *J. Archaeol. Sci.* **2008**, *35*, 158–168. [[CrossRef](#)]
65. Adams, D.C.; Rohlf, F.J.; Slice, D.E. Geometric morphometrics: Ten Years of progress following the ‘revolution’. *Ital. J. Zool.* **2004**, *71*, 5–16. [[CrossRef](#)]
66. Chovalopoulou, M.-E.; Valakos, E.D.; Manolis, S.K. Sex determination by three-dimensional geometric morphometrics of the palate and cranial base. *Anthropol. Anz.* **2013**, *70*, 407–425. [[CrossRef](#)]
67. Chovalopoulou, M.-E.; Valakos, E.D.; Manolis, S.K. Sex determination by three-dimensional geometric morphometrics of the vault and midsagittal curve of the neurocranium in a modern Greek population sample. *HOMO* **2016**, *67*, 173–187. [[CrossRef](#)] [[PubMed](#)]
68. Chovalopoulou, M.-E.; Valakos, E.D.; Manolis, S.K. Sex determination by three-dimensional geometric morphometrics of craniofacial form. *Anthropol. Anz.* **2016**, *73*, 195–206. [[CrossRef](#)] [[PubMed](#)]
69. Bertsatos, A.; Papageorgopoulou, C.; Valakos, E.; Chovalopoulou, M.-E. Investigating the sex-related geometric variation of the human cranium. *Int. J. Leg. Med.* **2018**, *132*, 1505–1514. [[CrossRef](#)] [[PubMed](#)]
70. Bertsatos, A.; Christaki, A.; Chovalopoulou, M.-E. Testing the reliability of 3D-id software in sex and ancestry estimation with a modern Greek sample. *Forensic Sci. Int.* **2019**, *297*, 132–137. [[CrossRef](#)] [[PubMed](#)]
71. Nikita, E.; Michopoulou, E. A quantitative approach for sex estimation based on cranial morphology. *Am. J. Phys. Anthropol.* **2017**, *165*, 507–517. [[CrossRef](#)]
72. Bertsatos, A.; Chovalopoulou, M.-E.; Brůžek, J.; Bejdová, Š. Advanced procedures for skull sex estimation using sexually dimorphic morphometric features. *Int. J. Leg. Med.* **2020**, *134*, 1927–1937. [[CrossRef](#)]
73. Bertsatos, A.; Athanasopoulou, K.; Chovalopoulou, M.-E. Estimating sex using discriminant analysis of mandibular measurements from a modern Greek sample. *Egypt. J. Forensic Sci.* **2019**, *9*, 25. [[CrossRef](#)]
74. Spradley, M.K.; Jantz, R.L. Sex estimation in forensic anthropology: Skull versus postcranial elements. *J. Forensic Sci.* **2011**, *56*, 289–296. [[CrossRef](#)]
75. Kranioti, E.F. Identification of Sex Based on Digital Radiographs of the Skeleton. Ph.D. Thesis, University of Crete, Crete, Greece, 2009.