Odontometric sex estimation on three populations of the Iron Age from Abruzzo region (central–southern Italy)

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ABBREVIATED TITLE: Sex estimation on three populations of Iron Age

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ABSTRACT

Background: In archaeological contexts, sex identification is a necessary step for a complete reconstruction of the biological profile of the individuals and to know demographic patterns of the population, nutritional stress, diseases, growth and development, and distribution of pathological conditions.

Methods: This study is based on the skeletal remains of 149 individuals from three protohistoric populations in close temporal and geographic proximity in Abruzzo region (central–southern Italy): Opi, Alfedena and Bazzano. It has been possible to develop logistic regression equations based on dental measurements of permanent teeth of adult individuals whose sex had previously been estimated based on pelvic and cranial features. These equations were subsequently applied to the permanent dentition of immature individuals and adult individuals whose sex was estimated as uncertain or unknown in order to estimate their sex.

Results: The mandibular canine is the tooth with the greatest sexual dimorphism in adults, followed by both maxillary and mandibular first and second molars, providing a correct assignment of sex ranging from 83.7 and 95.9% of cases, depending on the dimensions used for the construction of these equations. Of the 29 individuals in the target sample (14 *adultus*, 10 *juvenilis* and 5 *infans*), sex estimation was possible for 23 (10 *adultus*, 8 *juvenilis* and 5 *infans*), representing an applicability rate of 79.31% of the individuals.

Conclusions: The results indicate that odontometrics is a useful tool for sex estimation and allows to increase the data to perform more complete paleodemographic studies on archaeological populations.

Keywords: tooth size; sexual dimorphism; logistic regression analysis; Samnites

1. Introduction

Sex estimation with correct allocation accuracy represents a crucial step in the reconstruction of the biological profile of skeletal remains in paleoanthropological, archaeological or forensic studies.

In archaeological contexts, the importance of sex identification is that it is necessary to know demographic patterns of the population (survival and mortality), nutritional stress, diseases, growth and development, and distribution of pathological conditions (e.g. caries, traumas, infectious diseases, etc.), among others. This is particularly important in subadult individuals because, as a rule, anthropological studies on archaeological populations have left aside these individuals, focusing on the adult sample. Thus, important aspects remain hidden and a bias in the paleodemographic profile is produced.

Sexually dimorphic differences between males and females have been quantified in numerous ways in physical anthropology and osteoarchaeology based on both morphological and metric criteria for most of the human skeletal elements.[1–6]

The accuracy in sex estimation depends on the integrity of the skeletal remains due to the usual fragmented state of preservation of human remains. Nevertheless, because of the hardness, durability, and resistance to postmortem insults of dentition, some teeth may be recovered when bones are in deficient condition.[7–10]

In recent years, great interest has been generated in determining the usefulness of dentition in sexing archaeological populations in cases when other criteria are absent (e.g. lack of the expression of sex–related skeletal characteristics in subadult remains or deoxyribonucleic acid not available for analysis). Recent papers have identified sexual differences in odontometrical characteristics and have found high percentages of success in differentiating males and females.[11–16] However, such methods tend to be population specific.

Thus, for sex estimation using odontometrics, the best way to solve the problem of population specificity is to use dental data of permanent dentition from adult individuals whose sex estimates are based on well–defined descriptive features of the pelvis and/or skull. These data are used to develop the methodology for sex estimation and then the population–specific equations can be applied to permanent dentition of subadults or to other adults of the same population whose sex is unknown or defined as uncertain. This methodology has been used by Rösing[17], Beyer–Olsen and Alexandersen[18], Okazaki[19], Viciano et al.[20] and Thompson[21] with satisfactory results.

2. The Samnites

The Samnites were a protohistoric people living in Samnium, a region of central–southern Italy located in the Apennine Mountains, during the Iron Age.[22] The Samnite's territory was rich in fluvial resources and abundant pastures, although most of the region is mountainous, barren and unsuitable for agriculture. Although archaeologists have provided different information on farming activities in this population, the most important economic activity appears to have been stock–raising. Herding took the form of annual short–distance "vertical" transhumance, so that the herds were moved to the highlands during the summer and down to the valleys during the winter.[23] Thus, the socio–economic livelihood of this protohistoric population was agro–pastoral.[24]

The Samnite people were organized into a confederation or alliance of communities or tribes which was called the Samnite League, which emerged as a political and military unit. It was a complex society with aristocracies organized in tribal confederacies based on multiple–patrilinear alliances[23], which were used in order to protect resources (including land, animals and crops).[24]

The burial patterns reflect the presence of an aristocratic organization, held together by great family alliances. Graves were arranged in well–defined family areas outlined with stones placed in semicircular and circular structures, where can be distinguished a number of male and female burials with rich grave goods.[23–27] Thus, in each circle there are a variable number of individual burials with subjects of different sex, age and social status, but probably belonging to the same family or clan. Within circles, tombs show a particular position with respect to the cardinal points; the individuals were buried with the head facing east, probably in relation to sunrise and sunset. Many graves contained funerary personal objects, comprised jewelry or weapons depending on the sex of the individual[26,28].

The existence of multiple–patrilinear alliances is supported by the analysis of skeletal and dental epigenetic traits presumably subject to a closer genetic control and benign neoplasias with an hereditary component, suggesting that men buried in the same funerary circle shared a close–kin relationship.[23–25,29,30] The locations of burials and grave goods are also useful for the justification of this point.[23]

At the same time, the increasing social complexity was accompanied by changes in the ideology of the protohistoric societies, based on extolling warfare and male audacity.[23] Warrior paraphernalia constitute the main grave goods found in the burials of male individuals, suggesting that men were farmer–warriors. Skeletal evidence of warfare activities can be found in the extraordinary incidence of injuries by sword and cranial trauma in many necropolises from the Iron Age, including the populations of this study, especially in men.[23,24,31]

With this background, the aims of this study were (i) to determine the degree of dental sexual dimorphism of the adult individuals, (ii) to develop population–specific logistic regression equations for sex estimation based on metric data from permanent teeth, and (iii) to use these equations to estimate the sex of subadult and adult individuals whose sex is unknown or uncertain. This will provide us the necessary data to carry out a more complete paleodemographic analysis of these populations, allowing the reconstruction of the behaviors of the pre–Roman populations of central Italy.

3. Material and Methods

3.1. Sites backgrounds

3.1.1. Necropolis of Alfedena (V–III centuries BCE)

The site of Alfedena is located in the Sangro Valley (L'Aquila, Abruzzo, Italy) and it was found by chance in 1847; the first excavations were carried out between 1876–1889, and then continued extensively between 1895–1901, allowing the identification and inspection of 1400 graves. Since 1974, excavations began again and were able to uncover further 132 graves.[27] Unfortunately, most of the skeletal material has been lost or is scattered in various institutions, so relatively few skeletal remains are available for their study.

3.1.2. Necropolis of Opi (VI–V centuries BCE)

Located in the heart of the Natural National Park of Abruzzo (L'Aquila, Abruzzo, Italy), the necropolis was discovered in the early XVIII century; later, weapons and jewelry were found as a result of agricultural activities in these lands. In 1994 began the systematic excavations of this necropolis and 105 tombs with skeletal remains were discovered.[26,28,32]

3.1.3. Necropolis of Bazzano (VI–III centuries BCE)

The necropolis of Bazzano was discovered in 1992 as a result of the management works in the industrial core of Bazzano (L'Aquila, Abruzzo, Italy). From then until today, about 1500 graves of the Iron Age have been brought to light, covering a time interval ranging from X–I centuries BCE.[33] The individuals here examined are dated to the Hellenistic period (VI–III centuries BCE).

3.2. Sample

This study was conducted on well preserved skeletal remains of 149 individuals (Table 1) from archaeological sites representing three Samnite populations of the geographical region of Abruzzo: Opi (VI–V centuries BCE), Alfedena (V–III centuries BCE), and Bazzano (VI–III centuries BCE) (Figure 1). These individuals are housed in the University Museum of Chieti, Italy. All of them either preserve fully erupted permanent teeth or at least completely formed tooth crowns. The biological profile of each individual was previously estimated considering all the available bones. For adult individuals, sex was estimated following standard descriptive and metric criteria[34,35] according to cranial and pelvic features (Supporting Information Table S1 shows the percentage of preservation of the crania and pelves of the specimens studied, on which descriptive and metric criteria were used to estimate sex). The estimated age of all individuals was based on the degree of dental wear[36,37], the appearance of the pubic symphyseal surface[38] and the ilium auricular surface[39], the epiphyseal union of long bones[40] and dental development[41]. According to the estimated ages at death, the individuals were divided into three age groups following the conventional anthropological categories (modified from Vallois[42]): *infans* (from birth to twelve years of age), *juvenilis* (from thirteen to twenty years of age), and *adultus* (from twenty–one to sixty years of age).

The sample was divided into a *reference sample* consisting of 120 adult individuals from the pooled populations aged between 21 and 60 years whose sex was previously estimated from cranial and pelvic features (81 males and 39 females), and an *identification sample* consisting of the remaining 29 individuals (14 adult individuals whose sex was estimated as uncertain or unknown and 15 subadult individuals aged between 4–20 years). In this *identification sample,* for juvenile individuals, when possible, sex was also estimated following the Ferembach et al.[34] method.

The *reference sample* provided the odontometric data used for logistic regression analysis. The equations calculated from these data were applied to the *identification sample* to estimate their sex.

3.3. Procedure of collecting measurements

Digital dental caliper (Masel Orthodontics Inc, USA) with a precision of 0.01 mm was used to collect crown and cervical measurements from both sides of the dental arches. Tooth dimensions were obtained by measuring mesiodistal and buccolingual crown and cervical diameters of all teeth, and the diagonal crown and cervical diameters only in molars. These measurements were taken according to the definitions of Hillson et al.[43] except for the mesiodistal cervical diameter, which was measured following the criteria outlined by Vodanović et al.[44] (Supporting Information Table S2 shows the measurement definitions). Measurements were performed on either the left or right side depending on their availability. In cases like this a fluctuating asymmetry is expected (rather than directional). If both contralateral teeth were available, to avoid the use of more sophisticated techniques for the analysis of asymmetry, the average was calculated to adjust the values. The measurements were collected only from permanent dentition with completely formed crowns.

Prior the collection of the different measurements, teeth were evaluated to detect diverse limiting factors that may affect negatively the odontometric analysis. These factors include (i) dental pathologies (caries, hypoplastic defects, traumas, etc.), (ii) dental anomalies (e.g. anomalies of number, volume, and shape), and (iii) notably wear. For crown dimensions, the mesiodistal diameter was measured for incisors with a stage 3 (according to Smith[45]) or less of occlusal attrition, and with stage 4 or less for other tooth classes (canines, premolars and molars). Buccolingual crown diameters and diagonal crown diameters of molars were taken in teeth with a stage 5 or less.

After evaluation of the limiting factors and excluding the affected measurements in each examined tooth, the different measurements were collected.

Four dimensions were taken for incisors, canines, and premolars and eight dimensions for molars, providing 88 possible dimensions to measure and tabulate in both dental arches for each individual in an "ideal" permanent dentition, i.e., with all teeth present and no presence of limiting factors.

A further 52 randomly selected individuals (32 from Opi, 11 from Alfedena and 9 from Bazzano) were re–measured by the same observer to evaluate the intraobserver error, with a minimum period of two weeks and a maximum of one month between the two measurements. Both contralateral teeth were measured when present in these individuals. For this reason, the *N* values in Tables 2 and 3 do not represent the number of individuals studied but rather the total number of teeth measured.

3.4. Statistical analysis

Data measurements were first assessed for normality using the Kolmogorov–Smirnov one–sample test and for homogeneity of variance using the Levene test on the pooled populations. Next, a descriptive analysis of each population was performed to calculate the sample size and the mean and standard deviation for each measurement. This analysis characterized the study populations and allowed us to detect any possible major errors in the database collection or processing.

The main effects of the population origin of the individuals on the different measurements were tested by the non–parametric one–way Kruskal–Wallis *H* analysis. Next, the differences between the mean values of males and females for the *reference sample* were analyzed using the independent Students' *t*–test and Mann–Whitney *U*–test. The independent Student *t*–test was employed in cases where the homogeneity of variance is fulfilled; in the other cases, the non–parametric Mann–Whitney *U*–test was applied.

We also analyzed the differences between the mean values in all dimensions collected at two different times in order to assess possible intraobserver error. Three different widely used precision estimates were calculated: (i) the absolute technical error of measurement (TEM), (ii) the relative technical error of measurement (rTEM), and (iii) the coefficient of reliability (R). The use of three errors estimates can provide most of the information needed to determine whether a series of anthropometric measurements can be considered precise.[46–48]

The absolute TEM is the most commonly used measure of precision, which is calculated with the following formula

$$TEM = \sqrt{\frac{\sum D^2}{2N}}$$

where *D* is the difference between repeated measurements and *N* is the number of individuals measured. The TEM is expressed in the same units as those used to make the original measurements. The lower the TEM obtained, the better is the precision of the measurement. However, the positive association between TEM and size of measurement is problematic, since comparative imprecision of different measurements cannot be assessed. In order to compare TEM collected on different variables or different populations, Norton and Olds[49] recommended the conversion of the absolute TEM into rTEM in order to obtain the error expressed as percentage corresponding to the total average of the variable to be analyzed. So, the following formula was used

$$rTEM = \frac{TEM}{VAV} \times 100$$

where *VAV* is the variable average value (the arithmetic mean of the mean between repeated measurements obtained for each individual for the same anthropometrical measurement).

The R was calculated as percentage with the following formula

$$R = 1 - \frac{TEM^2}{SD^2}$$

where *SD* is the standard deviation of all measurements, including measurement error. This coefficient shows the proportion of between–subject variance free from measurement error. Scores can range from 0 to 1, where a value of 0 indicates that all between–subject variation was due to measurement error and a value of 1 indicates that no measurement error was present. We considered R values greater than 0.95 to be sufficiently precise, according to Ulijaszek and Kerr[47].

Finally, a logistic regression analysis was performed for the *reference sample* to create a set of equations that, applied to the *identification sample*, would distinguish between males and females. Separated logistic regression analyses were conducted for the maxillary and mandibular teeth, and we noted which equations produced the highest percentage of correct classifications of males and females. In order to maximize the applicability in these archaeological populations, the equations were calculated for a maximum combination of two measurements.

Logistic regression analysis produces coefficients for each measurement included in a model as well as a constant. In order to use this information to assess the sex of an individual, a log–odd or logit must first be calculated using the following equation:

$$L_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n$$

where the logit (L_i) is a linear function of the independent variable(s) X_1, β_0 is the value for the constant, β_1 is the first coefficient, X_1 is the first measurement, and so on. The logit value can also be used to calculate the probability of female sex (p_f) using the function:

$$p_f = \frac{1}{1 + e^{-L_i}}$$

The probability of male sex is simply $p_m = 1 - p_f$. In practice, if $p_f > 0.5$, then the most likely sex is female, and if $p_f < 0.5$, the most likely sex is male. In the present context, the closer the value of p_f is to 1, the greater the probability that the individual is female, and the closer the value of p_f is to 0, the greater the probability that the individual is male. When the value of p_f is close to the sectioning point of 0.5, the probability of correctly classifying an individual is lower because it is an area of overlap between the groups.

To assess the fit of an equation to the data, a goodness of fit statistic represented by the –2 log likelihood (–2LL) was calculated.

All statistical analyses were performed using the SPSS 15.0 software (SPSS Inc, Chicago, IL, USA).

4. Results

4.1. Intraobserver error analysis

Tables 2 and 3 show the differences between mean values, the absolute technical error of measurement (TEM), the relative technical error of measurement (rTEM), and the coefficient of reliability (R) for the repeated measurements.

The mean differences take into account whether or not the first measurement gave consistently higher or lower values than the second measurement, and thus vary from negative to positive. In maxillary teeth, most of them are between –0.02 and +0.02 mm and in mandibular teeth between –0.03 and +0.03 mm; they are not consistently positive or negative in a way that would imply a strong methodological difference between the two repeated measurements. The values of the TEM are very low, varying between 0.017–0.061 mm in maxillary teeth, with the exception of the $BLcervM^2$ (this measurement has a value of 0.117

mm), and between 0.017–0.057 mm in mandibular dentition. The conversion of the TEM into rTEM also provides very low percentages. The maximum percentages of intraobserver error obtained are 1.03% and 1.00% in maxillary and mandibular teeth, respectively. Finally, the high values of R in all variables ($R > 0.95$) also indicate a great precision of the measurements.

4.2. Differences between the populations

Considering the entire sample (all populations pooled), the Kolmogorov–Smirnov test showed that all the measurements were normally distributed. The results of homogeneity of variance test indicate that the entire sample is statistically homogeneous for 60 of the 88 measurements compared. Because some assumptions have been violated (e.g. heterogeneity of variance in some measurements, and unbalanced sample sizes) the use of the one–way ANOVA is inappropriate. Thus, the non–parametric one–way Kruskal–Wallis *H*–test was applied.

Results of the Kruskal–Wallis *H* analysis revealed statistically significant differences between populations for 24 of 88 measurements ($P \leq 0.05$), 12 in maxillary and 12 in mandibular teeth (Tables 4 and 5). For this reason, we decided to remove from the dataset the measurements that show significant differences between populations, and include the rest for subsequent sexual dimorphism and logistic regression analyses. The populations were grouped in order to increase the sample size. Because the number of individuals in some of the populations is reduced, it is not possible to develop methodologies for sex identification with satisfactory accuracy using each of them separately.

4.3. Univariate sexual dimorphism

Due to the removal of 24 measurements from the dataset of pooled populations, the Kolmogorov–Smirnov and the Levene tests were performed again with the selected 64 measurements. The Kolmogorov–Smirnov test showed that all the measurements were normally distributed and the results of homogeneity of variance tests indicate that the sample is statistically homogeneous for 26 of the 64 measurements.

Table 6 shows the sample size, mean and standard deviation, t value, U value and the degree of significance of the differences between the male and female individual means of the selected measurements for the *reference sample*.

In the maxilla, 11 of the 32 dimensions show a higher value in males compared with females, and in the mandible, 12 of the 32 dimensions show a higher value in males compared with females; these differences were statistically significant at $P \leq 0.05$ level. There is one exceptional measurement ($MDcrnPM^1$), which shows a reverse sexual dimorphism (where females show statistically significant higher values than males).

There are no significant differences in any analyzed diameters in the maxillary lateral incisor (I^2), second premolar (PM^2) or third molar (M^3), and in the mandibular central (I_1) and lateral (I_2) incisors and first (PM_1) and second (PM_2) premolars.

Taking the dentition as a whole, the most sexually dimorphic teeth are the mandibular canine ($C_,$) and the maxillary first molar (M^1), represented by mesiodistal, buccolingual and diagonal diameters of the crown and the cervix. Next comes the mandibular first molar (M_1), followed by the second molars (M^2, M_2), in both the maxilla and the mandible, and maxillary canine (C').

4.4. Logistic regression analysis

Tables 7 and 8 exhibit the logit equations and their allocation accuracy. The equations with a discriminant power below 75% were excluded because they are of little utility for reliable sex estimation. Only logit equations in which a minimum of 30 cases were used for their construction are shown.

The following example illustrates the methodological procedure of the logit equations developed. If the maximum buccolingual crown diameter of the maxillary central incisor (*BLcrnI*^{1}) is 6.95 mm and the maximum buccolingual diameter at cervical level of the maxillary first molar (*BLcervM*^{1}) is 10.39 mm in an individual of unknown sex, the sex can be estimated if logit equation L_1 listed in Table 7 is applied. The procedure is as follows:

$$p_f = \frac{1}{1 + e^{-(46.148-(1.183\times6.95)-(3.501\times10.39))}} = 0.8250$$

This value is above the sectioning point of 0.5; therefore, this individual is diagnosed as female, with an allocation accuracy of 82.50%.

Table 8 shows the correct allocation accuracy of these equations. It can be observed that the allocation accuracy ranges from 86.7 to 100% in males and from 70.0 to 87.5% in females. Therefore, males are classified more accurately than females for all logistic regression equations. For the pooled sexes, overall allocation accuracy ranges between 83.7 and 95.9%.

Analyzing as a whole the 21 logit equations obtained, it is evident that the first molar, in both the maxilla and mandible, and the mandibular second molar are the key teeth as significant predictor of sex in these populations, given that at least one dimension of them figure in all equations. On the other hand, multivariate analysis provides an advantage over the univariate analysis, because no equations with one dimension alone were obtained.

4.5. Odontometric sex estimation

The logit equations obtained from the logistic regression analysis for the *reference sample* sexed by skeletal morphology were applied to the permanent dentition of subadult and adult individuals of uncertain or unknown sex (*identification sample*). Because multiple equations were often applied to a single individual, the following criteria were implemented to deal with conflicting sex estimates:

1. One or more estimates of the same group without any other conflicting estimates, with at least one estimate having a probability of group membership equal or above 75%.
2. A probability of group membership for any estimate equal or above 85% and the probability of group membership for any conflicting estimate equal or below 70%.
3. The number of estimates for a given group, with a probability of membership equal or above 75%, is at least 50% higher than the conflicting estimates (i.e. the number of estimates for a given group with a probability of membership equal or above 75% is more than twice that conflicting estimates).

If none of the described criteria were met, the sex was assigned as uncertain (i.e. probable male or probable female) if the number of estimates for a given group is approximately similar than the conflicting estimates and one of the groups have a higher probability of membership than the other.

Supporting Information Table S3 shows the complete results of sex assignment of each individual, based on the odontometric analysis, as well as, when was possible, the sexual diagnosis based on skeletal descriptive analysis for comparison. Table 9 summarizes the results of sex assessment for each of the three populations.

Of the 29 individuals, sex was established for 23 of them by odontometric analysis (10 *adultus*, 8 *juvenilis* and 5 *infans*). This represents an applicability rate of 79.31% of the individuals. Within these 23 subjects, 14 were classified as males (60.87%) and nine as females (39.13%). Two individuals (6.90%; one *juvenilis* and one *adultus*) could not be identified due to the impossibility of obtaining the key dimensions to apply any of the logit equations developed in this study. In four cases (13.79%; one *juvenilis* and three *adultus*) the sex estimated was uncertain (probable male or probable female).

If we compare the sex of the 12 individuals estimated by odontometric analysis to the sex estimated by descriptive characteristics, we see a correspondence in sex assignment in two cases (16.66%); the uncertain sex (probable male or probable female) was confirmed by odontometrics in five cases (41.67%). Thus, the results of the odontometric and skeletal analyses match in these seven individuals (58.33%), including two *adultus* (individuals *Opi 020A* and *Bazzano 117*) and five *juvenilis* aged between 15–20 years (individuals *Opi 081* and *110*; *Alfedena 12a*; *Bazzano 106* and *125*). Sex estimation could not be confirmed in five cases (41.67%), comprising three *adultus* (individuals *Opi 111* and *136*; *Bazzano 097*) and two *juvenilis* (individuals *Opi 049* and *Bazzano 140*). All the individuals whose sex could not be estimated previously by skeletal descriptive characteristics or by the odontometric method (nine *adultus*, three *juvenilis* and five *infans*) were excluded from the comparison.

5. Discussion

The Samnite populations consisted of a biologically very homogeneous complex correlated with the existence of strongly endogamic clans or family groups. In addition, the distance of these populations from the sea, as well as the presence of the Apennine chain, might lend support that these human populations were geographically isolated and economically independent.[29] This situation may have conditioned the low variability of morphometric cranial and postcranial data and the high frequency of dental non–metric traits observed within these populations, where the gene flow plays a relatively slight role[27,29], so we expected to find large differences in the odontometric data between the populations studied. However, historical–archaeological documents seem to indicate striking cultural dynamics taking place throughout this area, conceivably associated with a long–lasting phase of genic exchanges among the human groups settled between neighboring regions.[29] Thus, this situation seems to support the relatively few significant differences found in dental dimensions analyzed in this study between the populations of Opi, Alfedena and Bazzano.

This study reveals that the mandibular canine (C,) and the maxillary first molar (M^1) are the teeth with the greatest degree of sexual dimorphism, with larger values statistically significant in males than females. These are followed by the mandibular first molar (M_1) and the maxillary and mandibular second molars (M^2, M_2). The results generally match reports in the dental literature on the greater sexual dimorphism of canines[12,13,20,21,50–52] and on the sexual dimorphism of first and second molars[13,14,51,53–56], due to some variations in the classification of the dimensions with greater sexual dimorphism have been described depending on the diameter of the tooth that has been analyzed. Nevertheless, one measurement, $MDcrnPM^1$, shows a reverse sexual dimorphism (females with larger values statistically significant than males). Several authors have reported reverse sexual dimorphism in diverse populations[54,55,57,58], wherein some dental dimensions were, on the average, larger in females than males, although the differences were statistically insignificant in the vast majority. According to Garn et al.[59], teeth behaved in many and different ways through the course of human evolution, with the reduction of the entire dentition or a simple reduction of one group of teeth in relation to another. This situation, influenced both by genetic and environmental factors, resulted in large variations in the magnitude of sexual dimorphism, including reduced dimorphism, across diverse populations. For Frayer and Wolpoff[60] the cause for reduction in sexual dimorphism is complex, but they attribute it to "a convergence in the requirements of male and female roles". Thus, through the course of human evolution, dimorphic tendencies have increasingly become monomorphic. Therefore, sexual variations are continuous rather than discrete and an overlap between the sexes can be expected[61], and the reduced sexual dimorphism and consequent male–female overlap has extended to include reverse sexual dimorphism.[54] However, only one dimension of the 64 analyzed in the univariate analysis (from the pooled populations) shows reverse dimorphism. It is necessary to perform additional analyses to confirm the presence of reverse dimorphism in each of these populations.

The logistic regression equations developed yielded high percentages of correct assignment of sex ranging from 83.7 to 95.9%, depending on the dimensions used for their construction. However, the results of correct allocation accuracy of sex may be overestimated due to the small sample sizes used for the construction of these equations. Logistic regression analysis is commonly used in anthropological research, but this type of statistical model does not always guarantee accurate results. A common problem occurs when the outcome has few events with respect to the number of candidate predictors. There is no consensus on the number of events needed per variable, and it has been proposed a rule of thumb with a minimum of 10 outcome events per predictor variable to use logistic regression models[62,63]; below this value the results should be interpreted with caution and the statistical model may not be valid. Other authors, as Harrell et al.[64] and Concato and Feinstein[65], propose that 10–20 events per predictor variable are necessary, and more recently Vittinghoff and McCulloch[66] relax the rule and propose a minimum of five events. Nevertheless, our results are reassuring because each logit equation is constructed with only two predictor variables, and only logit equations with a minimum 30 cases were developed.

After the application of the logistic regression equations to the teeth of the 29 immature and adult individuals of the same population whose sex could not be estimated by previous bony assessments, sex could be established in a total of 23. Initially, it was only possible to sex a total of 120/149 of the population (80.54%; all adult individuals) by skeletal features. Thanks to the odontometric analysis, this percentage has increased to reach a total sex identification of 143/149 (95.97%) of the individuals, including immature subjects. Moreover, if we compare the sex of the 12 individuals estimated by odontometric analysis with the sex estimated by descriptive characteristics of the pelvis and cranium, we see a match in 58.33% of the cases; the sex estimation in the remaining 41.67% could not be confirmed. The consistency of results with the skeletal descriptive methods indicates that dimensions of the permanent dentition can be useful for sex estimation of *adultus* and *juvenilis* age groups in archeological contexts when the bony remains are not well–preserved and are not possible to apply the standard skeletal descriptive methods. Although the comparison with the *infans* age group (aged between 4 and 12 years) could not be made, all of them were sexed by odontometrics.

Calcification of the permanent dentition is entirely postnatal (from birth to 10 years). The first molar is the first permanent tooth to complete the crown formation (2.5–3 years) and to emerge into the oral cavity (6–7 years).[67] Thus, four logit equations (L_6, L_{16}, L_{17} and L_{18}) can be applied for sex estimation in an early stage of development of the immature individuals. As age progresses and completely formed dental crowns are present in the tooth crypts or oral cavity, a larger number of logit equations can be applied. However, more studies must be made to confirm the correct sex assessment by odontometrics on infants and young children.

On the other hand, the mesiodistal and buccolingual crown diameters are the most used dimensions in odontometrics,[68] but there are diverse limiting factors that may impede the collection of these dental measurements (e.g. wear, caries, calculus deposits, hypoplastic defects, etc.) because of the frequent appearance of these features in populations. However, even in the presence of certain limiting factors, if they have a minimal effect on the tooth or are in specific locations (i.e., not on the reference points for the different measurements) it is possible to obtain a sufficiently large sample of teeth for odontometric analysis. In sex estimation methods based on odontometrics the most common limiting factor is dental wear. The buccolingual crown diameter is only affected by advanced stages of wear when the most of the crown has been lost; however, the mesiodistal crown diameter is affected even at the earliest stages of interproximal attrition. In archaeological contexts, adult individuals may show severe interproximal attrition having a large effect in the collection of the measurements because the mesiodistal dimension of the tooth is being reduced.[43,69] The alternative dental measurements used in this study are more suitable for the worn teeth that make up the bulk of the archaeological specimens. This is particularly evident for the diagonal diameters of the molar crowns and dimensions collected at the cervical level of the teeth, where these alternative measurements avoid the effect of the wear even in moderate/severe amounts of interproximal attrition, and open up the possibility of comparing the little–worn teeth of immature individuals with the more heavily worn teeth of adults for sex estimation purposes. Analyzing the 21 logit equations developed, 18 of them are a combination of diagonal crown diameters and/or cervical diameters and, therefore, avoid the problem of the effect of interproximal attrition or moderate/severe incisal/occlusal wear. Only three equations (L_4, L_{10} and L_{11}) include a mesiodistal crown measurement; therefore, these three logit equations should be used with caution.

Finally, we want to highlight that the logistic regression equations developed here are specific for these populations, but they also can be applied to other populations with similar odontometric characteristics if they are tested previously. When an odontometric method is applied to a population that differs significantly from the population whose metric data were used to develop the method, the logistic regression equations developed give poor or biased results.[70]

6. Conclusions

Although initially the sex diagnosis was limited by the fragmented state of preservation of skeletal remains in adult individuals and/or the lack of the expression of sex–related skeletal characteristics in subadult remains, odontometrics is a useful tool that has allowed us to increase considerably the sex estimation of these populations. Thus, this methodology will allow us to perform a more complete paleodemographic profile of the Samnite populations by increasing the number of individuals considered for the paleodemographic analysis for the reconstruction of the behaviors of the protohistoric populations of central–southern Italy.

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Fig. 1 – Geographical location of the three Samnite populations in the region of Abruzzo (Italy).

Table 1─ Distribution of the three populations by sex and age group.

	Subadult individuals			Adult individuals				
	birth–6years	7–12 years	13–20 years	21–40 years	41–60 years	>60 years	Unknown	TOTAL
Opi								
Male	0	0	0	25	24	0	5	54
Female	0	0	0	7	13	0	6	26
Unknown	**1**	**3**	**2**	**3**	0	0	**4**	13
Probable male	0	0	**3**	**1**	0	0	0	4
Probable female	0	0	0	**1**	0	0	**1**	2
Subtotal	1	3	5	37	37	0	16	99
Alfedena								
Male	0	0	0	7	4	0	0	11
Female	0	0	**1**	5	4	0	0	10
Unknown	0	0	0	0	0	0	0	0
Probable male	0	0	0	0	0	0	0	0
Probable female	0	0	0	0	0	0	0	0
Subtotal	0	0	1	12	8	0	0	21
Bazzano								
Male	0	0	0	8	5	0	3	16
Female	0	0	**2**	0	4	0	0	6
Unknown	**1**	0	0	0	0	0	**2**	3
Probable male	**0**	**1**	0	0	0	0	0	1
Probable female	0	0	**1**	**1**	0	0	**1**	3
Subtotal	1	1	3	9	9	0	6	29
TOTAL	2	4	9	58	54	0	22	149

In **bold** are highlighted the individuals of the *identification sample*. The remaining individuals (corresponding to the *reference sample*) are used to develop the logistic regression equations. More details about these two subsamples are given in the text.

Table 2 ─ Intraobserver error analysis in maxillary teeth measurements.

		Measurement 1		Measurement 2					
	N	Mean	SD	Mean	SD	Diff	TEM	rTEM	R
Dental crown									
M^3									
MDcrn	22	9.068	0.580	9.101	0.586	–0.033	0.061	0.672	0.989
BLcrn	27	10.93	0.958	10.94	0.960	–0.007	0.033	0.304	0.999
MBDLcrn	28	11.05	0.955	11.06	0.957	–0.008	0.030	0.272	0.999
MLDBcrn	25	9.552	0.734	9.586	0.740	–0.034	0.056	0.585	0.994
M^2									
MDcrn	24	9.777	0.397	9.806	0.393	–0.029	0.046	0.474	0.986
BLcrn	39	11.81	0.707	11.83	0.709	–0.021	0.034	0.285	0.998
MBDLcrn	41	12.15	0.627	12.16	0.631	–0.005	0.031	0.251	0.998
MLDBcrn	42	10.75	0.886	10.76	0.878	–0.012	0.035	0.328	0.998
M^1									
MDcrn	33	10.58	0.551	10.60	0.539	–0.021	0.040	0.376	0.995
BLcrn	41	11.82	0.539	11.82	0.537	–0.004	0.030	0.251	0.997
MBDLcrn	40	12.73	0.409	12.73	0.420	0.002	0.043	0.339	0.989
MLDBcrn	42	11.62	0.590	11.61	0.587	0.010	0.039	0.339	0.996
PM^2									
MDcrn	41	6.712	0.315	6.712	0.323	0.000	0.033	0.486	0.990
BLcrn	50	9.188	0.548	9.128	0.545	–0.009	0.020	0.224	0.999
PM^1									
MDcrn	38	6.908	0.321	6.913	0.325	–0.005	0.035	0.506	0.988
BLcrn	50	8.903	0.431	8.908	0.425	–0.006	0.028	0.310	0.996
C’									
MDcrn	35	7.918	0.282	7..921	0.281	–0.004	0.017	0.208	0.997
BLcrn	50	8.445	0.331	8.450	0.336	–0.001	0.017	0.195	0.998
I^2									
MDcrn	33	6.815	0.544	6.814	0.530	0.001	0.035	0.514	0.996
BLcrn	40	6.519	0.396	6.527	0.397	–0.008	0.017	0.255	0.998
I^1									
MDcrn	25	8.686	0.370	8.690	0.370	–0.004	0.026	0.303	0.995
BLcrn	34	7.378	0.242	7.382	0.244	–0.004	0.032	0.436	0.982
Dental cervix									
M^3									
MDcerv	18	6.893	0.393	6.871	0.404	0.022	0.046	0.667	0.987
BLcerv	23	10.08	0.943	10.07	0.961	0.010	0.056	0.555	0.997
MBDLcerv	20	10.28	0.985	10.27	1.001	0.008	0.031	0.301	0.999
MLDBcerv	21	8.596	0.958	8.613	0.953	–0.017	0.048	0.552	0.998
M^2									
MDcerv	30	7.704	0.308	7.707	0.314	–0.004	0.036	0.467	0.987
BLcerv	39	11.26	0.800	11.28	0.857	–0.022	0.117	1.034	0.980
MBDLcerv	38	11.68	0.830	11.68	0.836	–0.002	0.028	0.240	0.999
MLDBcerv	41	10.16	0.799	10.18	0.792	–0.018	0.039	0.384	0.998
M^1									
MDcerv	36	8.033	0.254	8.027	0.258	0.006	0.034	0.418	0.983
BLcerv	38	11.29	0.627	11.31	0.630	–0.025	0.046	0.410	0.995
MBDLcerv	40	11.96	0.590	11.95	0.585	0.011	0.030	0.250	0.998
MLDBcerv	36	10.57	0.607	10.57	0.591	0.001	0.040	0.379	0.996
PM^2									
MDcerv	39	4.740	0.353	4.747	0.355	0.001	0.031	0.660	0.992
BLcerv	43	8.230	0.536	8.222	0.539	0.008	0.020	0.244	0.999
PM^1									
MDcerv	38	4.740	0.351	4.735	0.347	0.005	0.038	0.806	0.988
BLcerv	41	8.083	0.521	8.084	0.519	–0.001	0.020	0.241	0.999
C’									
MDcerv	49	5.996	0.516	6.006	0.513	–0.009	0.028	0.467	0.997
BLcerv	46	8.045	0.562	8.042	0.562	0.003	0.022	0.271	0.999
I^2									
MDcerv	41	5.135	0.450	5.126	0.454	0.009	0.040	0.774	0.992
BLcerv	43	5.905	0.458	5.901	0.455	0.005	0.035	0.588	0.994
I^1									
MDcerv	41	6.884	0.570	6.875	0.577	0.009	0.044	0.638	0.994
BLcerv	37	6.674	0.396	6.677	0.401	–0.003	0.023	0.348	0.997

N number of teeth; *Mean* overall measurement mean; *SD* standard deviation; *Diff* mean difference between repeated measurements; *TEM* technical error of measurement; *rTEM* relative technical error of measurement; *R* coefficient of reliability.

Table 3 ─ Intraobserver error analysis in mandibular teeth measurements.

		Measurement 1		Measurement 2					
	N	Mean	SD	Mean	SD	Diff	TEM	rTEM	R
Dental crown									
M_3									
MDcrn	19	10.60	0.815	10.63	0.818	–0.035	0.036	0.339	0.998
BLcrn	22	9.806	0.751	9.818	0.749	–0.012	0.031	0.312	0.998
MBDLcrn	20	10.61	0.820	10.62	0.807	–0.014	0.030	0.282	0.999
MLDBcrn	20	10.81	0.769	10.81	0.765	0.000	0.018	0.169	0.999
M_2									
MDcrn	22	11.11	0.715	11.12	0.694	–0.010	0.032	0.287	0.998
BLcrn	33	10.31	0.725	10.34	0.720	–0.020	0.036	0.349	0.997
MBDLcrn	32	11.64	0.643	11.63	0.647	0.005	0.024	0.210	0.999
MLDBcrn	32	11.58	0.637	11.59	0.634	–0.015	0.023	0.198	0.999
M_1									
MDcrn	26	11.59	0.728	11.60	0.731	–0.009	0.023	0.198	0.999
BLcrn	33	10.89	0.530	10.89	0.544	–0.006	0.035	0.324	0.996
MBDLcrn	35	12.07	0.512	12.07	0.525	0.006	0.028	0.234	0.997
MLDBcrn	32	11.61	0.595	11.62	0.586	–0.010	0.023	0.201	0.998
PM_2									
MDcrn	40	7.262	0.341	7.265	0.336	–0.004	0.022	0.304	0.996
BLcrn	41	8.296	0.408	8.307	0.420	–0.011	0.028	0.342	0.995
PM_1									
MDcrn	45	7.075	0.304	7.081	0.305	–0.007	0.018	0.259	0.996
BLcrn	47	7.782	0.308	0.789	0.316	–0.013	0.025	0.320	0.994
C,									
MDcrn	39	7.139	0.398	7.144	0.396	–0.005	0.020	0.273	0.998
BLcrn	47	8.038	0.454	8.040	0.455	–0.002	0.025	0.315	0.997
I_2									
MDcrn	41	6.207	0.362	6.207	0.360	0.000	0.018	0.295	0.997
BLcrn	48	6.514	0.316	6.510	0.314	0.003	0.018	0.273	0.997
I_1									
MDcrn	27	5.586	0.224	5.593	0.229	–0.008	0.016	0.277	0.995
BLcrn	42	6.123	0.323	6.123	0.323	0.000	0.015	0.247	0.998
Dental cervix									
M_3									
MDcerv	12	8.651	0.567	8.647	0.592	0.004	0.032	0.367	0.997
BLcerv	16	8.708	0.592	8.672	0.597	0.036	0.057	0.661	0.991
MBDLcerv	15	9.194	0.820	9.195	0.820	–0.001	0.026	0.277	0.999
MLDBcerv	12	9.179	0.710	9.181	0.701	–0.002	0.032	0.348	0.998
M_2									
MDcerv	20	9.363	0.465	9.379	0.435	–0.016	0.056	0.592	0.985
BLcerv	27	9.434	0.696	9.432	0.677	0.002	0.027	0.285	0.999
MBDLcerv	24	10.62	0.728	10.61	0.746	0.010	0.031	0.295	0.998
MLDBcerv	21	10.38	0.553	10.39	0.563	–0.017	0.029	0.278	0.997
M_1									
MDcerv	25	9.331	0.435	9.342	0.427	–0.009	0.031	0.339	0.998
BLcerv	26	9.141	0.623	9.150	0.615	–0.011	0.031	0.329	0.995
MBDLcerv	29	10.99	0.675	11.00	0.669	–0.008	0.035	0.322	0.997
MLDBcerv	30	10.39	0.614	10.40	0.615	–0.011	0.035	0.337	0.997
PM_2									
MDcerv	32	5.287	0.365	5.276	0.359	0.010	0.019	0.364	0.997
BLcerv	39	7.344	0.551	7.341	0.550	0.004	0.025	0.339	0.998
PM_1									
MDcerv	49	4.985	0.355	4.981	0.364	0.004	0.032	0.646	0.992
BLcerv	40	6.802	0.477	6.809	0.480	–0.008	0.019	0.281	0.998
C,									
MDcerv	52	5.715	0.542	5.700	0.545	0.014	0.033	0.583	0.996
BLcerv	45	7.950	0.643	7.956	0.642	–0.006	0.027	0.342	0.998
I_2									
MDcerv	44	3.878	0.273	3.885	0.275	–0.007	0.039	1.000	0.980
BLcerv	42	6.166	0.313	6.163	0.316	0.003	0.032	0.526	0.989
I_1									
MDcerv	37	3.526	0.211	3.515	0.191	0.011	0.034	0.954	0.972
BLcerv	36	5.669	0.356	5.663	0.361	0.006	0.018	0.321	0.997

N number of teeth; *Mean* overall measurement mean; *SD* standard deviation; *Diff* mean difference between repeated measurements; *TEM* technical error of measurement; *rTEM* relative technical error of measurement; *R* coefficient of reliability.

Table 4 – Descriptive statistics for maxillary teeth measurements and Kruskal–Wallis *H*–test results for evaluating differences between the different populations.

	Opi			Alfedena			Bazzano				
	N	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*H*	*P*
Dental crown											
MDcrnM^3	30	9.380	0.690	9	8.554	0.750	14	9.159	0.339	8.614	**0.013**
MDcrnM^2	50	10.422	0.691	3	9.610	0.560	26	9.808	0.506	14.585	**0.001**
MDcrnM^1	60	11.104	0.483	8	10.215	0.673	28	10.400	0.553	32.821	**0.000**
MDcrnPM^2	57	6.624	0.277	7	6.956	0.429	28	6.859	0.315	12.097	**0.002**
MDcrnPM^1	60	6.943	0.379	8	7.158	0.343	24	6.985	0.268	2.305	0.316
MDcrnC’	67	7.881	0.310	13	7.923	0.206	22	7.846	0.317	2.139	0.343
MDcrnI^2	51	6.765	0.423	11	7.335	0.246	25	6.635	0.469	19.509	**0.000**
MDcrnI^1	36	8.741	0.350	8	8.616	0.390	13	8.499	0.386	3.475	0.176
BLcrnM^3	29	11.048	0.983	15	11.063	1.186	15	10.855	0.449	0.526	0.769
BLcrnM^2	76	11.989	0.582	17	11.988	0.796	28	11.946	0.667	0.137	0.934
BLcrnM^1	78	11.825	0.429	13	11.836	0.653	28	11.956	0.428	1.462	0.481
BLcrnPM^2	72	9.378	0.473	17	9.102	0.689	28	9.088	0.451	7.785	**0.020**
BLcrnPM^1	74	9.099	0.493	19	8.731	0.412	26	8.827	0.413	11.512	**0.003**
BLcrnC’	77	8.533	0.327	19	8.554	0.287	26	8.418	0.431	2.216	0.330
BLcrnI^2	68	6.542	0.382	19	6.602	0.387	27	6.467	0.473	2.308	0.315
BLcrnI^1	59	7.375	0.340	7	7.306	0.266	24	7.436	0.256	2.473	0.290
MBDLcrnM^3	29	11.174	1.001	15	11.377	1.211	14	11.044	0.477	2.139	0.343
MBDLcrnM^2	73	12.427	0.646	18	12.396	0.667	28	12.289	0.488	1.657	0.437
MBDLcrnM^1	79	12.819	0.426	12	12.786	0.471	28	12.823	0.335	0.038	0.981
MLDBcrnM^3	30	10.241	0.780	13	9.235	0.752	15	9.691	0.733	14.587	**0.001**
MLDBcrnM^2	80	11.080	0.660	18	10.903	1.149	28	10.685	1.034	2.553	0.279
MLDBcrnM^1	80	11.571	0.439	12	12.786	0.471	28	11.575	0.642	0.909	0.635
Dental cervix											
MDcervM^3	20	6.873	0.595	8	6.623	0.782	11	7.001	0.437	1.226	0.542
MDcervM^2	56	7.808	0.463	6	7.665	0.384	26	7.743	0.373	0.331	0.847
MDcervM^1	65	8.010	0.358	5	7.900	0.394	28	8.000	0.251	1.202	0.548
MDcervPM^2	58	4.826	0.266	11	4.744	0.424	28	4.711	0.375	2.862	0.239
MDcervPM^1	52	4.875	0.271	11	4.567	0.270	23	4.741	0.422	10.026	**0.007**
MDcervC’	65	5.921	0.435	19	6.274	0.412	26	6.035	0.563	9.533	**0.009**
MDcervI^2	52	5.009	0.408	20	5.122	0.576	22	5.029	0.577	0.564	0.754
MDcervI^1	53	6.576	0.495	17	6.984	0.353	23	6.933	0.672	8.638	**0.013**
BLcervM^3	18	10.275	0.865	12	10.066	1.102	11	9.911	0.376	1.261	0.532
BLcervM^2	64	11.408	0.622	16	11.022	0.912	28	11.281	0.646	3.849	1.146
BLcervM^1	69	11.228	0.493	14	11.248	0.749	28	11.293	0.571	0.151	0.927
BLcervPM^2	68	8.154	0.557	19	8.185	0.552	28	8.300	0.581	2.553	0.279
BLcervPM^1	63	8.084	0.516	19	7.972	0.504	25	7.985	0.541	1.12	0.571
BLcervC’	68	8.015	0.454	19	8.115	0.636	25	8.042	0.583	0.295	0.863
BLcervI^2	57	5.839	0.387	23	5.947	0.460	21	5.753	0.518	2.754	0.252
BLcervI^1	52	6.478	0.411	16	6.696	0.453	22	6.521	0.326	2.201	0.333
MBDLcervM^3	19	10.635	0.975	13	10.026	1.098	11	10.160	0.462	2.646	0.266
MBDLcervM^2	66	11.908	0.691	15	11.177	0.815	28	11.569	0.673	11.354	**0.003**
MBDLcervM^1	72	12.063	0.551	15	11.775	0.769	28	11.895	0.489	3.682	0.159
MLDBcervM^3	18	8.921	0.822	13	8.462	1.069	12	8.405	0.701	3.081	0.214
MLDBcervM^2	66	10.273	0.560	16	10.056	0.976	28	9.969	0.323	4.415	0.110
MLDBcervM^1	77	10.558	0.494	12	10.474	0.658	28	10.521	0.566	0.841	0.657

N number of teeth; *Mean* overall measurement mean; *SD* standard deviation; *H* Kruskal–Wallis *H*–test; *P* p–value (values statistically significant at $P \leq 0.05$ level are in **bold**).

Table 5 – Descriptive statistics for mandibular teeth measurements and Kruskal–Wallis *H*–test results for evaluating differences between the different populations.

	Opi			Alfedena			Bazzano				
	N	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*H*	*P*
Dental crown											
MDcrnM$_3$	41	10.528	0.904	6	9.730	0.409	14	11.075	0.628	12.792	**0.002**
MDcrnM$_2$	54	11.137	0.508	5	11.026	0.918	21	11.417	0.660	3.489	0.175
MDcrnM$_1$	58	11.444	0.486	5	11.562	1.142	23	11.720	0.531	5.867	0.053
MDcrnPM$_2$	55	7.250	0.323	16	7.256	0.391	28	7.438	0.356	4.414	0.110
MDcrnPM$_1$	80	6.957	0.323	20	7.071	0.311	28	7.073	0.370	3.712	0.156
MDcrnC,	56	6.989	0.351	19	7.211	0.349	23	7.143	0.402	5.391	0.067
MDcrnI$_2$	58	5.944	0.392	14	6.353	0.306	22	6.141	0.406	12.581	**0.002**
MDcrnI$_1$	38	5.369	0.265	10	5.621	0.230	11	5.614	0.316	10.031	**0.007**
BLcrnM$_3$	42	9.934	0.664	11	9.281	0.609	12	10.078	0.552	9.412	**0.009**
BLcrnM$_2$	65	10.374	0.529	11	10.966	0.521	22	10.448	0.567	0.102	0.950
BLcrnM$_1$	64	10.753	0.482	11	10.966	0.521	26	10.989	0.471	4.956	0.084
BLcrnPM$_2$	75	8.351	0.457	20	8.280	0.271	28	8.336	0.342	0.143	0.931
BLcrnPM$_1$	92	7.779	0.405	30	7.875	0.284	28	7.744	0.295	3.395	0.183
BLcrnC,	99	7.983	0.476	26	7.972	0.524	28	7.882	0.397	1.370	0.504
BLcrnI$_2$	90	6.416	0.362	24	6.652	0.295	28	6.552	0.258	10.663	**0.005**
BLcrnI$_1$	80	6.105	0.336	26	6.109	0.442	17	6.267	0.346	2.000	0.368
MBDLcrnM$_3$	42	10.552	0.737	10	9.960	0.512	11	11.354	0.644	16.897	**0.000**
MBDLcrnM$_2$	64	11.688	0.562	11	11.589	0.628	19	11.907	0.503	2.084	0.353
MBDLcrnM$_1$	56	12.049	0.442	12	11.992	0.489	27	12.232	0.416	3.021	0.221
MLDBcrnM$_3$	43	10.711	0.776	8	9.988	0.424	13	11.345	0.701	15.769	**0.000**
MLDBcrnM$_2$	63	11.590	0.520	12	11.650	0.715	21	11.842	0.496	2.282	0.320
MLDBcrnM$_1$	64	11.489	0.440	14	11.723	0.725	24	11.829	0.292	15.450	**0.000**
Dental cervix											
MDcervM$_3$	14	8.654	0.922	6	8.268	0.346	7	8.849	0.600	2.199	0.333
MDcervM$_2$	34	9.408	0.350	7	9.127	0.487	17	9.288	0.587	2.852	0.240
MDcervM$_1$	49	9.246	0.292	7	8.744	0.366	26	9.175	0.595	9.254	**0.010**
MDcervPM$_2$	49	5.182	0.262	11	5.237	0.358	28	5.180	0.462	0.894	0.640
MDcervPM$_1$	75	4.992	0.264	21	5.000	0.403	28	4.815	0.444	7.271	**0.026**
MDcervC,	78	5.616	0.398	21	5.624	0.693	28	5.500	0.621	0.465	0.793
MDcervI$_2$	69	3.945	0.309	21	3.880	0.287	28	3.777	0.300	5.508	0.064
MDcervI$_1$	66	3.564	0.270	21	3.448	0.202	24	3.458	0.250	5.836	0.054
BLcervM$_3$	21	8.688	0.660	10	8.401	0.543	8	9.009	0.530	4.432	0.109
BLcervM$_2$	46	9.280	0.521	14	9.440	0.885	15	9.321	0.794	1.461	0.482
BLcervM$_1$	49	9.415	0.435	12	9.470	0.611	25	9.376	0.308	1.387	0.500
BLcervPM$_2$	63	7.228	0.509	19	7.295	0.596	28	7.269	0.500	0.282	0.869
BLcervPM$_1$	73	6.721	0.371	21	6.799	0.473	28	6.745	0.513	0.222	0.895
BLcervC,	85	7.891	0.530	21	7.736	0.658	28	7.814	0.633	1.702	0.427
BLcervI$_2$	88	6.157	0.425	21	6.195	0.260	28	6.108	0.342	1.796	0.407
BLcervI$_1$	77	5.671	0.391	21	5.628	0.416	20	5.682	0.388	1.203	0.548
MBDLcervM$_3$	19	9.193	0.632	11	8.761	0.579	8	9.744	0.721	8.162	**0.017**
MBDLcervM$_2$	36	10.570	0.591	14	10.408	0.474	15	10.637	0.800	1.201	0.549
MBDLcervM$_1$	43	11.000	0.506	16	11.116	0.847	26	10.955	0.408	0.716	0.699
MLDBcervM$_3$	11	8.972	0.921	9	8.826	0.274	7	9.561	0.643	5.042	**0.080**
MLDBcervM$_2$	30	10.433	0.444	13	10.358	0.628	15	10.307	0.581	0.323	0.851
MLDBcervM$_1$	48	10.335	0.431	16	10.493	0.702	28	10.344	0.486	1.100	0.577

N number of teeth; *Mean* overall measurement mean; *SD* standard deviation; *H* Kruskal–Wallis *H*–test; *P* p–value (values statistically significant at $P \leq 0.05$ level are in **bold**).

Table 6 – Descriptive statistics for maxillary and mandibular teeth measurements and *t*–test and *U*–test results for mean differences between the sexes.

	Maxillary teeth									Mandibular teeth								
Measurement	Male			Female						Male			Female					
	N	Mean	SD	*N*	Mean	SD	*t*	*U*	*P*	*N*	Mean	SD	*N*	Mean	SD	*t*	*U*	*P*
Dental crown																		
MDcrnM3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MDcrnM2	—	—	—	—	—	—	—	—	—	48	11.332	0.564	10	10.895	0.459	2.293	—	**0.026**
MDcrnM1	—	—	—	—	—	—	—	—	—	47	11.585	0.631	13	11.249	0.446	1.798	—	0.077
MDcrnPM2	—	—	—	—	—	—	—	—	—	53	7.313	0.336	21	7.201	0.310	1.319	—	0.191
MDcrnPM1	47	6.918	0.325	20	7.134	0.390	–2.339	—	**0.022**	75	7.024	0.324	31	7.002	0.384	0.304	—	0.762
MDcrnC	62	7.937	0.307	18	7.734	0.220	2.611	—	**0.011**	57	7.114	0.343	23	7.063	0.446	0.557	—	0.579
MDcrnI2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MDcrnI1	21	8.577	0.317	13	8.871	0.472	—	83.00	0.058	—	—	—	—	—	—	—	—	—
BLcrnM3	28	11.028	0.968	15	11.209	1.075	–0.563	—	0.577	—	—	—	—	—	—	—	—	—
BLcrnM2	72	12.114	0.648	29	11.737	0.568	2.734	—	**0.007**	60	10.540	0.541	19	10.147	0.672	2.600	—	**0.011**
BLcrnM1	67	11.955	0.407	29	11.606	0.412	3.842	—	**0.000**	54	11.033	0.453	19	10.525	0.404	4.322	—	**0.000**
BLcrnPM2	—	—	—	—	—	—	—	—	—	77	8.361	0.454	25	8.432	0.221	—	841.00	0.344
BLcrnPM1	—	—	—	—	—	—	—	—	—	81	7.811	0.356	39	7.741	0.362	1.022	—	0.309
BLcrnC	76	8.595	0.334	24	8.396	0.342	2.527	—	**0.013**	81	8.102	0.424	39	7.761	0.490	4.172	—	**0.000**
BLcrnI2	64	6.552	0.420	21	6.581	0.357	–0.280	—	0.780	—	—	—	—	—	—	—	—	—
BLcrnI1	52	7.463	0.342	15	7.274	0.191	—	264.00	0.058	79	6.123	0.421	25	6.204	0.258	—	927.50	0.648
MBDLcrnM3	27	11.213	1.025	16	11.400	0.996	–0.583	—	0.563	—	—	—	—	—	—	—	—	—
MBDLcrnM2	68	12.571	0.575	30	12.161	0.549	3.291	—	**0.001**	55	11.878	0.539	19	11.531	0.518	2.437	—	**0.017**
MBDLcrnM1	65	12.935	0.347	30	12.624	0.436	3.735	—	**0.000**	55	12.247	0.397	17	11.839	0.421	3.651	—	**0.001**
MLDBcrnM3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MLDBcrnM2	74	11.125	0.902	30	10.573	0.806	2.916	—	**0.004**	57	11.783	0.556	21	11.532	0.448	1.854	—	0.068
MLDBcrnM1	71	11.729	0.547	26	11.266	0.433	3.883	—	**0.000**	—	—	—	—	—	—	—	—	—
Dental cervix																		
MDcervM3	20	6.866	0.462	7	6.456	0.671	1.796	—	0.085	10	8.974	0.834	10	8.485	0.502	1.588	—	0.130
MDcervM2	52	7.853	0.403	14	7.720	0.320	1.141	—	0.258	35	9.436	0.438	9	9.167	0.416	1.659	—	0.105
MDcervM1	52	8.126	0.308	19	7.877	0.190	—	249.50	**0.001**	—	—	—	—	—	—	—	—	—
MDcervPM2	56	4.831	0.326	21	4.780	0.379	0.585	—	0.560	53	5.279	0.343	16	5.192	0.344	0.886	—	0.379
MDcervPM1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MDcervC	—	—	—	—	—	—	—	—	—	76	5.742	0.455	33	5.427	0.631	2.937	—	**0.004**
MDcervI2	47	5.177	0.424	20	4.969	0.514	1.724	—	0.089	69	3.933	0.298	29	3.910	0.339	0.332	—	0.741
MDcervI1	—	—	—	—	—	—	—	—	—	66	3.551	0.259	22	3.527	0.233	0.392	—	0.696
BLcervM3	19	10.054	0.870	11	10.110	1.028	–0.160	—	0.874	19	8.966	0.475	12	8.395	0.518	3.146	—	**0.004**
BLcervM2	69	11.531	0.668	19	10.810	0.550	4.316	—	**0.000**	48	9.494	0.469	15	9.093	0.841	—	234.50	**0.043**
BLcervM1	59	11.416	0.481	24	10.995	0.597	3.369	—	**0.001**	49	9.493	0.350	14	9.190	0.613	—	211.50	**0.030**
BLcervPM2	62	8.282	0.606	26	8.025	0.454	1.946	—	0.055	64	7.346	0.485	24	7.213	0.614	1.063	—	0.291
BLcervPM1	60	8.036	0.541	23	8.019	0.465	0.133	—	0.894	74	6.812	0.443	34	6.641	0.404	1.921	—	0.057
BLcervC	64	8.092	0.541	27	7.955	0.554	1.097	—	0.275	80	8.001	0.484	36	7.598	0.674	—	904.00	**0.001**
BLcervI2	54	5.935	0.396	23	5.791	0.494	1.358	—	0.179	80	6.199	0.418	35	6.175	0.299	0.305	—	0.761
BLcervI1	44	6.672	0.340	24	6.376	0.513	2.854	—	**0.006**	73	5.664	0.452	27	5.706	0.288	—	944.50	0.750
MBDLcervM3	18	10.524	1.066	12	10.189	0.944	0.880	—	0.386	—	—	—	—	—	—	—	—	—
MBDLcervM2	—	—	—	—	—	—	—	—	—	42	10.836	0.484	13	10.014	0.610	5.207	—	**0.000**
MBDLcervM1	60	12.229	0.497	28	11.631	0.508	5.213	—	**0.000**	49	11.155	0.509	13	10.785	0.645	2.201	—	**0.032**
MLDBcervM3	21	8.589	0.934	9	8.584	0.873	0.013	—	0.990	—	—	—	—	—	—	—	—	—
MLDBcervM2	63	10.243	0.727	22	9.873	0.565	2.164	—	**0.033**	36	10.570	0.411	10	10.029	0.508	3.498	—	**0.001**
MLDBcervM1	65	10.702	0.493	26	10.266	0.576	3.622	—	**0.000**	57	10.459	0.512	13	10.241	0.509	1.389	—	0.170

N number of teeth; *Mean* overall measurement mean; *SD* standard deviation; *t* Student's *t*–test; *U* Mann–Whitney *U*–test; *P* p–value (values statistically significant at $P \leq 0.05$ level are in **bold**).

Table 7 – Logistic regression equations*.

	Logit equations[a]
Maxillary teeth	
Central incisor – First molar	$L_1 = 46.148 - 1.183(\mathrm{BLcrnI}^1) - 3.501(\mathrm{BLcervM}^1)$ $L_2 = 80.126 - 1.547(\mathrm{BLcrnI}^1) - 5.893(\mathrm{MBDLcervM}^1)$
Lateral incisor – First molar	$L_3 = 41.773 - 0.291(\mathrm{MDcervI}^2) - 3.671(\mathrm{MBDLcervM}^1)$
First premolar – First molar	$L_4 = 50.386 + 4.544(\mathrm{MDcrnPM}^1) - 7.023(\mathrm{MBDLcervM}^1)$
Second premolar – First molar	$L_5 = 55.170 + 5.079(\mathrm{MDcervPM}^2) - 6.776(\mathrm{MBDLcervM}^1)$
First molar	$L_6 = 46.917 - 0.793(\mathrm{MBDLcrnM}^1) - 3.150(\mathrm{MBDLcervM}^1)$
First molar – Second molar	$L_7 = 36.976 - 3.470(\mathrm{MBDLcervM}^1) + 0.287(\mathrm{MBDLcrnM}^2)$
Mandibular teeth	
Lateral incisor – Second molar	$L_8 = 37.638 + 0.989(\mathrm{MDcervI}_2) - 4.093(\mathrm{MBDLcervM}_2)$ $L_9 = 35.495 + 4.758(\mathrm{BLcervI}_2) - 6.321(\mathrm{MBDLcervM}_2)$
Canine – Second molar	$L_{10} = 52.139 + 1.352(\mathrm{MDcrnC},) - 6.129(\mathrm{MBDLcervM}_2)$ $L_{11} = 52.560 - 4.399(\mathrm{BLcrnC},) - 1.744(\mathrm{MDcrnM}_2)$ $L_{12} = 38.983 + 0.933(\mathrm{BLcrnC},) - 4.605(\mathrm{MBDLcervM}_2)$
First premolar – First molar	$L_{13} = 33.723 + 0.042(\mathrm{BLcervPM}_1) - 3.276(\mathrm{BLcrnM}_1)$
First premolar – Second molar	$L_{14} = 27.293 + 2.209(\mathrm{BLcervPM}_1) - 4.116(\mathrm{MBDLcervM}_2)$
Second premolar – Second molar	$L_{15} = 102.236 - 2.348(\mathrm{MDcervPM}_2) - 9.070(\mathrm{MBDLcervM}_2)$
First molar	$L_{16} = 48.236 - 2.126(\mathrm{BLcrnM}_1) - 2.823(\mathrm{BLcervM}_1)$ $L_{17} = 58.119 - 3.995(\mathrm{BLcrnM}_1) - 1.481(\mathrm{MBDLcervM}_1)$ $L_{18} = 47.967 - 3.156(\mathrm{BLcrnM}_1) - 1.462(\mathrm{MLDBcervM}_1)$
First molar – Second molar	$L_{19} = 96.588 + 0.352(\mathrm{BLcrnM}_1) - 9.919(\mathrm{MBDLcervM}_2)$ $L_{20} = 295.669 - 2.642(\mathrm{MBDLcrnM}_1) - 26.357(\mathrm{MBDLcervM}_2)$
Second molar	$L_{21} = 75.549 + 2.109(\mathrm{MLDBcrnM}_2) - 9.935(\mathrm{MBDLcervM}_2)$

* See text for an example of the application of a logistic regression equation to estimate sex.

[a] See Table 8 for an assessment of the fit of each logit equation.

Table 8 – Assessment of the fit of logistic regression equations*.

Logit equations[a]	N	–2LL	Female correct		Male correct		Total
			n	%	n	%	
Maxillary teeth							
L_1	40	30.300	7/10	70.0	28/30	93.3	87.5
L_2	40	26.609	8/11	72.7	27/29	93.1	87.5
L_3	43	35.062	10/13	76.9	26/30	86.7	83.7
L_4	37	18.670	9/11	81.8	25/26	96.2	91.9
L_5	48	26.139	11/13	84.6	33/35	94.3	91.7
L_6	68	57.885	16/22	72.7	44/46	95.7	88.2
L_7	56	44.585	12/16	75.0	39/40	97.5	91.1
Mandibular teeth							
L_8	35	22.340	7/9	77.8	25/26	96.2	91.4
L_9	36	15.647	7/8	87.5	27/28	96.4	94.4
L_{10}	30	14.900	5/7	71.4	21/23	91.3	86.7
L_{11}	49	26.767	6/8	75.0	41/41	100.0	95.9
L_{12}	41	23.670	7/9	77.8	31/32	96.9	92.7
L_{13}	38	32.875	7/10	70.0	26/28	92.9	86.8
L_{14}	39	30.873	11/13	84.6	24/26	92.3	89.7
L_{15}	33	10.786	7/8	87.5	23/25	92.0	90.9
L_{16}	46	32.879	10/12	83.3	32/34	94.1	91.3
L_{17}	40	25.082	8/11	72.7	27/29	93.1	87.5
L_{18}	46	33.957	8/11	72.7	34/35	97.1	91.3
L_{19}	34	12.231	6/7	85.7	26/27	96.3	94.1
L_{20}	33	5.116	5/6	83.3	26/27	96.3	93.9
L_{21}	40	11.557	6/7	85.7	32/33	97.0	95.0

N indicates the total number of individuals used to develop the logit equations; *–2LL* –2 log likelihood value; *n* indicates the number of individuals correctly classified compared with the total of individuals used for the classification.

* Only logit equations with a minimum of cases of 30 used for their construction are presented.

[a] See Table 7 for the complete logit equations developed.

Table 9 – Summary of the distribution of skeletal and odontometric sex estimates.

		Skeletal sex assessment				Odontometric sex assessment			
	N	Male	Female	Uncertain	Unknown	Male	Female	Uncertain	Unknown
Adultus									
Opi	10	0	0	3	7	3	4	2	1
Alfedena	0	0	0	0	0	0	0	0	0
Bazzano	4	0	0	2	2	2	1	1	0
Subtotal	14	0	0	5	9	5	5	3	1
Juvenilis									
Opi	6	0	0	3	3	4	1	0	1
Alfedena	1	0	1	0	0	0	1	0	0
Bazzano	3	0	2	1	0	0	2	1	0
Subtotal	10	0	3	4	3	4	4	1	1
Infans									
Opi	5	0	0	0	5	4	1	0	0
Alfedena	0	0	0	0	0	0	0	0	0
Bazzano	0	0	0	0	0	0	0	0	0
Subtotal	5	0	0	0	5	4	1	0	0
TOTAL	29	0	3	9	17	14	9	4	2

N number of individuals evaluated for sex estimation based in their skeletal characteristics and dentition.