Rom J Leg Med [21] 305-308 [2013]
DOI: 10.4323/rjlm.2013.305

Sex determination in Romanian mandible using discriminant function analysis: Comparative results of a time-efficient method

Mihai Marinescu, Viorel Panaitescu, Mariana Rosu*

Abstract: In a forensic anthropology context, the mandible represents a reliable skeletal element with increased resistance to environmental factors. Sexual dimorphism assessment is most accurately obtained on population-specific computed discriminant functions. A previous study on 100 Romanian population mandibles has provided a discriminant function with an accuracy of 86% based on 7 measurements. The main purpose of the present study is to evaluate whether or not an increase in the sample number (200 mandibles) can produce a different discriminant function that will allow similar accuracy rates, but with fewer measurements.

We have used 3 measurements (chin height, bigonial width and bicondylar breadth) that provided a discriminant function with an overall accuracy of determination of 84%, equal for male and female groups. The most dimorphic singular measurement was bigonial width, which provided a discriminant function with 80.5% accuracy when used alone.

We concluded that a larger study sample allows similar accuracies of sex determination with fewer measurements, which in turn can improve the assessment of sexual dimorphism by using a time-efficient method.

Key Words: sex determination, discriminant function analysis, mandible, Romanian population.

A correct and objective assessment of sexual dimorphism on human skeletal remains reduces by 50% the subsequent police investigation probabilities and ensures a correct further evaluation of ancestry and stature [1-3]. Regarding sex determination methods, discriminant function analysis has gained more and more success since the 1950s. Studies like the ones of Hanihara (1959), Giles and Elliot (1963), Howells (1965), Schulter-Ellis (1983, 1985), Kimura (1982) helped to strengthen the role of discriminant function analysis in this field. The accuracy rates obtained were better than those based only by visual assessment and classic measurements, varying from 83 to 88 percent for crania and 92 to 98 percent (and even 100%) for pelvic bones respectively [4-10]. A more recent series of studies [11-14] have shown that discriminant function is population-specific. Therefore, the best accuracy for any discriminant function will be obtained only when using population-specific methods (national standards). In this respect, over the following years, many researchers have computed population-specific discriminant functions in order to maximize the accuracy rates for sex determination on unknown skeletal remains [15-17].

In a forensic anthropology context, the mandible represents a reliable skeletal element as it shows increased resistance to environmental factors, being usually well-preserved even in archaeological context [18]. There are many studies that focus on the morphological or metrical traits of the mandible [19-23], but as stated above, sexual dimorphism assessment is most accurately obtained on population-specific computed discriminant functions.

The results presented herein are part of a larger study that focuses on sexual dimorphism of the skull (cranium and mandible) on a Romanian population

** Corresponding author: MD, TA, "Carol Davila" University of Medicine and Pharmacy - Bucharest, Romania, E-mail: mihai.marinescu@umf.ro*

sample. The only forensic anthropology study that focuses on discriminant function analysis of Romanian mandibles is that of Ionescu (2007), who calculated discriminant functions on a sample of 100 mandibles (50 males, 50 females) from the "Francisc Rainer" osteological collection [24]. The main purpose of the present study is to evaluate whether or not an increase in the sample number (200 mandibles) can produce a different discriminant function that will allow similar accuracy rates, but with fewer measurements.

MATERIALS AND METHODS

The study sample comprised of 200 adult mandibles of known sex and age (100 males, 100 females, age range from 20 to 86 years, mean age 39 years) belonging to a modern Romanian population sample (early 20th century) selected from the „Rainer" osteological collection, housed at „Francisc Rainer" Anthropology Institute of the Romanian Academy, Bucharest. Only intact mandibles without frontal group edentation were included; edentulous or fragmented mandibles, as well as those showing marked erosions or pathological alterations were excluded from the study.

Three standard mandibular measurements were taken according to Buikstra and Ubelaker standards [25]: Chin Height, Bigonial Width and Bicondylar Breadth. The measurements were taken using a sliding caliper and involved standard anthropometrical landmarks (Table 1).

All collected data were analyzed using SPSS 17.0 statistical software program. Normal descriptive statistics (frequency tables, means, standard deviation, standard error of mean), correlation coefficients as well as discriminant function analyses were performed. The discriminant function formula is as follows: $F(x) = a_1x_1 + a_2x_2 + ... + a_nx_n + c$, where F(x) represents the discriminant function score, x_1 to x_n are the measured variables, a_1 to a_n are the unstandardized coefficients of each variable and c is the function's constant.

RESULTS

The mean values of measurements, minimum and maximum values as well as standard error of mean and T values are depicted in Table 2. The mean value of chin height was 29.4 mm for females and 32.1 mm for males respectively. Main bigonial width value ranged from 92.8 to 102.4, while bicondylar breadth was 113.1 in females and 120 in males, with standard deviations between 2.8 and 5.6 mm.

Pearson's correlation coefficients were calculated, resulting in values from 0.299 (between chin height and bicondylar breadth) to 0.429 (chin height – bigonial width) and 0.608 (bigonial width – bicondylar breadth), corresponding to low to moderate correlations between the three measurements that we used (Table 3).

Table 1. Definitions of landmarks and measurements used in the present study (from Buikstra and Ubelaker, 1994) [25]

Landmark/ Measurement	*Symbol*	*Definition*
Infradentale	id	The midline point at the superior tip of the septum between the mandibular central incisors
Gnathion	gn	The most inferior midline point on the mandible
Gonion	go	A point along the rounded posteroinferior corner of the mandible between the ramus and the body
Condylion laterale	cdl	The most lateral point on the mandibular condyle
Chin Height	id-gn	Direct distance from infradentale (id) to gnathion (gn) Instrument: sliding caliper
Bigonial Width	go-go	Direct distance between right and left gonion (go) Instrument: sliding caliper
Bicondylar Breadth	cdl-cdl	Direct distance between the most lateral points on the two condyles (cdl). Instrument: sliding caliper

Table 2. Descriptive statistics of the mandible measurements

Variable	*Sex*	*Mean ± SD*	*Min*	*Max*	*Std.Err. Mean*	*T Value (2-Tailed)*
Chin Height	F	29.4 ± 2.8	23	37	0.280	3.94405E-10
	M	32.1 ± 2.9	25	38	0.287	
Bigonial Width	F	92.8 ± 5.4	82	105	0.541	3.12845E-26
	M	102.4 ± 5.6	90	114	0.562	
Bicondylar Breadth	F	113.1 ± 4.8	103	124	0.476	1.27319E-05
	M	120.0 ± 5.4	110	141	0.544	

Table 3. Pearson's correlation coefficients between measurements

		Chin Height	*Bigonial Width*	*Bicondylar Breadth*
Chin Height	Pearson Correlation	1	0.429**	0.299**
	Sig. (2-tailed)		0	0
Bigonial Width	Pearson Correlation	0.429**	1	0.608**
	Sig. (2-tailed)	0		0
Bicondylar Breadth	Pearson Correlation	0.299**	0.608**	1
	Sig. (2-tailed)	0	0	

A stepwise analysis of the discriminant functions calculated for the three variables measured has produced a sex determination accuracy of 84% based on al three measurements (chin height, bigonial width and bicondylar breadth), equal to male and female groups; Wilk's lambda value was around 0.5 - 0.6, slightly lower for chin height and bigonial width (Table 4).

The results of the discriminant functions based on the constants and coefficients calculated from the sample study measurements are presented in Table 5.

The accuracy of the discriminant function using all 3 variables (F1) is 84%, equal for male and female groups. Removing one measurement (BCB) from the function will lead to an overall accuracy of 82.5%, correctly sexing 80% of males and 85% of females. The most discriminant variable when used alone was bigonial width (BGW), which provided 80.5% accuracy, slightly better for males.

The sectioning point (Z0) for each discriminant function is calculated from the weighted mean of values at the group centroids for males and females using the formula provided by Xavier [26]:

$$Z0=\frac{(Zm\times Nf)+(Zf\times Nm)}{(Nm+Nf)},$$

where Zm and Zf are the group centroids for male and female groups, Nm and Nf being the number of mandibles of males and females respectively. Any value above the sectioning point will be classified as male and the values below the sectioning point will be classified as female.

DISCUSSION

Sexual dimorphism of the mandible is the result of correlated various influences such as environmental, genetic or hormonal, thus being population specific [18, 21, 27]. In this respect, many authors have studied the metrical traits of the mandible and their reliability in sex determination, with accuracy results varying from 60 to 90% [5, 18, 22-24, 28-30]. Most of the authors have measured up to 5-7 variables, and the studies that focus on less than 5 parameters have an accuracy of sex determination of about 80%.

A comparison of the present study with the results published by other authors (see above) leads to the conclusion that Romanian population mandible has well-defined dimorphic traits, similar to other east-European populations.

As mentioned above, the only forensic anthropology study in Romania that focuses on sexing mandible using discriminant function analysis is that of Simona Ionescu in 2007 [24]. She measured 7 mandible parameters on a sample of 100 mandibles (50 males,

Table 4. Stepwise discriminant function analysis (*Chin Height; **Bigonial Width; ***Bicondylar Breadth)

Step/ measurement	*Standardized coefficients*	*Unstandardized coefficients*	*DF's constant*	*Wilk's lambda*	*Group centroids*	*Correctly assigned*
1 / CH*	0.293	0.104	-24.207	0.524	+0.989 (M) -0.989 (F)	84%
2 / BGW**	0.659	0.120		0.542		
3 / BCB***	0.410	0.080		0.611		

Table 5. DF formulas, group centroids, accuracy (*Chin Height; **Bigonial Width; ***Bicondylar Breadth)

Discriminant Functions	*Group centroids*		*Correctly assigned*		
	M	*F*	*M*	*F*	*T*
F1: All variables (CH*0.104)+(BGW*0.12)+(BCB*0.08)-24.207	+0.989	-0.989	84%	84%	84%
F2: Chin height and bigonial width (CH*0.111)+(BGW*0.160)-19.037	+0.915	-0.915	80%	85%	82.5%
F3: Chin height only (CH*0.353)-10.855	+0.466	-0.466	73%	62%	67.5%
F4: Bigonial width only (BGW*0.181)-17.696	+0.870	-0.870	81%	80%	80.5%
F5: Bicondylar breadth only (BCB*0.196)-22.798	+0.678	-0.678	70%	77%	73.5%

Table 6. Accuracies in sexing mandible using DFA in various populations – by Pokhrel [29]

Author(s), population	*Number of parameters used*	*Accuracy %*
(Hanihara, 1959), Japan	4	88.6
(Giles, 1964), USA	3-6	82.0-88.0
(Potsch-Schneider *et al.*,1985), Germany	17	71.6-81.7
(Steyn and Iscan, 1998), South Africa	5	81.5
(Barthelemy *et al.*, 1999), France	2-7	87.3
(Munoz *et al.*, 2001), Spain	1-14	78.3-88.7
(Vodanović *et al.*, 2006), Croatia	1-9	74.1-92.1
(Ionescu *et al.*, 2007), Romania	5-7	86.0
(Saini *et al.*, 2011), India	1-5	60.3-80.2
(Pokhrel and Bhatnagar, 2012), India	2	70.9-82.9
Current study, 2013, Romania	1-3	67.5-84.0

50 females) obtaining an 86% accuracy discriminant function.

By increasing the number of the sample study to 200 mandibles (100 males, 100 females) we have achieved 84% accuracy in correctly sexing the mandibles with only 3 measurements: chin height, bigonial width and bicondylar breadth. Furthermore, a discriminant function computed with only one variable - bigonial width – has produced a sex determination accuracy of 80.5%. The three measurements used are suitable for discriminant function analysis, as they are complementary with each other (correlation coefficients between them were of 0.3 to 0.42 and 0.6, corresponding to low-to-moderate correlation). On the other hand, many of the other mandible measurements are derivates of the 3 variables used in the present study, therefore increasing the number of variables of the discriminant function will not lead to a significant increase in accuracy.

CONCLUSION

Based on the results presented, we can conclude that using a larger population sample can provide either a better accuracy of determination or similar accuracies but with fewer measurements. Hence, we hope that the study presented here can improve sex determination in mandible by applying a quick and time-efficient method with similar accuracy results.

References

1. Panaitescu V: Metode de investigatie in practica medico-legala. Bucuresti: Ed. Litera; 1984.
2. Panaitescu V: Identificarea medico-legala. In: Tratat de medicina legala. Edited by Belis V. Bucuresti: Ed. medicala; 1995.
3. Pickering R, Bachman D: The use of forensic anthropology, second edn. Boca Raton: CRC Press; 2009.
4. Giles E, Elliot O: Sex determination by discriminant function analysis of crania. Am J Phys Anthrop 1963, 21:53-68.
5. Hanihara K: Sex diagnosis of Japanese skulls and scapulae by means of discriminant functions. J Anthropol Soc Nippon 1959, 67:21-27.
6. Howells WW: Determination du sexe du bassin par fonction discriminante: Etude du material du Doctor Gaillard. Bull et Mem de la Soc d'Anthropol de Paris 1965, XI serie(7):95-105.
7. Kimura K: Sex differences of the hip bone among several populations. Okajima's Folia Anat Japonica 1982, 58:266-273.
8. Luo Y-C: Sex determination from the pubis by discriminant function analysis. Forensic Sci Int 1995, 74 (1):89-98.
9. Schulter-Ellis F, Hayek L, Schmidt O: Determination of sex with a discriminant analysis of new pelvic bone measurements: part II. J Forensic Sci 1985, 30:178-185.
10. Schulter-Ellis F, Schmidt D, Hayek L, Craig J: Determination of sex with a discriminant analysis of new pelvic bone measurements: part I. J Forensic Sci 1983, 28:169-180.
11. Deshmukh AG, Devershi DB: Comparison of cranial sex determination by univariate and multivariate analysis. Journal of the Anatomical Society of India 2006, 55:48-51.
12. Guyomarc'h P, Bruzek J: Accuracy and reliability in sex determination from skulls: A comparison of Fordisc 3.0 and the discriminant function analysis. Forensic Science International 2011, 208 (1):180.e181-180.e186.
13. Iscan MY: Rise of forensic anthropology. Am J Phys Anthropol 1988, 31:203-229.
14. Jantz RL: Cranial change in Americans:1850-1975. J Forensic Sci 2001, 46:784-787.
15. Krogman WM, Iscan MY: The human skeleton in forensic medicine. , 2nd edn. Springfield IL: Charles C Thomas Pub Ltd; 1986.
16. Loth S, Iscan Y: Anthropology: Sex Determination. In: Encyclopedia of Forensic Sciences. Edited by Siegel J, Knupfer G, Saukko P: Academic Press; 2000: 252-260.
17. Saukko P, Knight B: Knight's Forensic Pathology, 3rd edn. London: Hodder Arnold; 2004.
18. Vodanovic M, Dumancic J, Demo Ž, Mihelic D: Determination of sex by discriminant function analysis of mandibles from two croatian archaeological sites. Acta Stomatol Croat 2006, 40:263-277.
19. Balci Y, Yavuz MF, Cagdir S: Predictive accuracy of sexing the mandible by ramus flexure. HOMO-Journal of Comparative Human Biology 2005, 55 229-237.
20. Kharoshah MA, Almadani O, Ghaleb SS, Zaki MK, Fattah YA: Sexual dimorphism of the mandible in a modern Egyptian population. Journal of Forensic and Legal Medicine 2010, 17 213-215.
21. Loth SR: Sexual dimorphism in the human mandible: a developmental and evolutionary perspective. Johannesburg, South Africa: University of the Witwatersrand; 1996.
22. Steyn M, Iscan MY: Sexual dimorphism in the crania and mandibles of South African Whites. Forensci Sci Int 1998, 98:9-16.
23. Giles E: Sex determination by discriminant function analysis of the mandible. Am J Phys Anthropol 1964, 22:129-135.
24. Ionescu S, Işcan MY, Panaitescu V: Discriminant function analysis of sexual dimorphism in the romanian mandible. Rom J Leg Med 2007, 15(2):111-114.
25. Buikstra JE, Ubelaker DH: Standards for data collection from human skeletal remains. Arkansas Arch Survey 1994, 44.
26. Xavier MJ: A Practical Guide to Analyzing Survey data. Boston: Houghton Miffin Company; 2004.
27. Humphrey LT, Dean MC, Stringer CB: Morphological variation in great ape and modern human mandibles. J Anat 1999, 195:451-513.
28. Munoz P, Sanchez J, Carrero J: Sex estimate in the mandible through discriminant functions. Cuadernos de Medicina Forense 2001, 26:21-28.
29. Pokhrel R, Bhatnagar R: Sexing of mandible using ramus and condyle in Indian population: a discriminant function analysis. Eur J Anat 2013, 17 (1):39-42.
30. Saini V, Srivastava R, Narayan S, Singh TB, Pandey AK, Tripathi SK: Sex determination using mandibular ramus flexure: A preliminary study on Indian population. Journal of Forensic and Legal Medicine 2011, 18 208-212.