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THE INAPPLICABILITY OF THE CARREA INDEX TO ESTIMATE THE HEIGHT OF THE YANESHA NATIVE COMMUNITY.

La inaplicabilidad del índice de Carrea para estimar la estatura de la comunidad nativa Yanesha.

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ABSTRACT

Human identification is an important area of forensic sciences, especially when it comes to victims of natural disasters and those caused by humans. Stature is one of the four essential factors in determining personal identification along with age, sex, and ethnicity. The sample consisted of 88 plaster models of the lower jaw of the inhabitants of the Yanesha Native Community (Peru). The mesiodistal width of the central incisors, lateral incisors, and canines on the left side was measured to estimate height using Carrea's index. Multiple linear regression was performed to obtain a new formula and improve the accuracy of stature estimates. When comparing the actual mean stature and the estimated mean stature an overall overestimation of 24.5 cm was obtained (overestimation in 100% of cases); furthermore, no successful estimates were found between actual and estimated heights. By applying the modification to Carrea's index, an improvement in the overall estimation with a slight overestimation of 0.1 cm was achieved; successful estimates were obtained in 14.8% of cases, 40.9% of under-estimation, and 44.3% of overestimation. Therefore, the application of Carrea's method for stature estimation in the Yanesha population in Peru would not be suitable as it shows a significant difference from the actual stature.

KEYWORDS

Forensic odontology; Forensic anthropology; Peru.

INTRODUCTION

In Peru, when unidentified bodies and/or skeletal remains are found, they are transferred to the Institute of Legal Medicine and Forensic Sciences for forensic examination with the aim of determining the cause of death and identification[1]. Forensic dentistry plays a crucial role in human identification, particularly when conventional methods such as fingerprints and facial recognition cannot be applied, often due to advanced decomposition, carbonization, or fragmentation of the body[2]. Therefore, dental identification becomes one of the most reliable methods, as teeth and dental structures may withstand postmortem conditions[3]. The 'big fours' essential factors

considered in personal identification are age, sex, stature, and ethnicity[4].

In 1920, Juan Ubaldo Carrea[5] published his thesis "Ensayos Odontométricos," where he stated that "every living being carries within itself its measuring pattern, and all organic elements maintain precise proportional relationships". By studying the proportionality of the human body, Carrea[5] proposed an index to estimate an individual's stature based on measurements taken from mandibular anterior teeth.

In the current literature on stature estimation, there is a lack of studies related to the Peruvian scenario. Therefore, the purpose of this research was to compare the original method of Carrea and its modification in estimating the stature of individuals from the native Yanesha community in Peru.

MATERIALS AND METHODS

Ethical approval for conducting the study was obtained from the Ethical Committee of Científica del Sur University (Peru). Subjects participating in this study were informed about the study's purpose before obtaining their written voluntary informed consent.

The sample comprised 88 plaster models of the lower dental arch from native inhabitants of the Yanesha community, collected from December 2018 to December 2019. We chose to work with this specific community because the Yanesha are indigenous people located in the central jungle of Peru, characterized by the resilience of their ethnic identity over time[6]. The ages of the individuals ranged from 18 to 39 years. Subjects meeting the following inclusion criteria were recruited: those with pure ancestry (both parents of Yanesha origin) and lower anterior teeth without lesions, complete from the lower right to the left canine. Subjects were excluded if they had lower limb disabilities, any type of restorative treatment on the lower anterior teeth, or wear of the incisal third of their teeth.

Before data collection, intra- and inter-examiner calibration was performed by analyzing 8 plaster models not included in the study. For intra-examiner calibration, the researcher performed mesiodistal measurements of the same teeth twice with a 7-day interval. Concerning inter-examiner calibration, it was conducted with a Forensic Dentistry specialist. Measurements of the mesiodistal widths of central incisors, lateral incisors, and left lower canines were taken for each sample. With these data, the dental arch measurement (in millimeters) was obtained as the sum of mesiodistal widths of the three teeth. The value of the chord radius for each study model was then calculated using the formula: Chord-radius = dental arch x 0.954. The obtained values were substituted into Carrea's method to determine the minimum, maximum, and estimated stature as follows:

$$\text{Minimum stature} = \frac{\text{Chord-radius} \times 6 \times 3.1416 \times 100}{2}$$

$$\text{Maximum stature} = \frac{\text{Dental arch} \times 3.1416 \times 100}{2}$$

$$\text{Estimated stature} = \frac{\text{Minimum stature} + \text{Maximum stature}}{2}$$

Statistical analysis was conducted using SPSS 22 software. Multiple linear regression was performed with the

variables chord-radius and sex, as well as dental arch and sex, to obtain a new formula adapted to the Yanesha population. Paired t-test analysis was carried out to compare the accuracy of the original and new formula.

RESULTS

In both intra- and inter-examiner calibrations, the ICC indicated a reliable result (>0.75). A total of 88 plaster lower models were evaluated, comprising 44 from females and 44 from males, with an average actual stature of 1.57 m (Table 1). Applying Carrea's index, we obtained a mean estimated stature of 1.81 m, a mean minimum estimated height of 1.77 m, and a mean maximum estimated stature of 1.85 m (Table 1). Multiple linear regression was performed considering predictor variables such as chord-radius and gender (r=0.748), as well as dental arch and gender (r=0.749), with the latter showing a higher correlation coefficient with actual stature.

Using the new formula derived from dental arch and gender, a modified mean estimated stature of 1.57 m was obtained (Table 1). When analyzing stature measurements according to original Carrea's index and its modification, a higher correlation was found between actual stature and estimated stature from the modified Carrea's index (Table 1).

Table 1. Comparison of actual and estimated statures.

Stature		n (%)	Mean (m)	SD	Correlation
Actual	Total	88 (100)	1.57	0.066	-
	Women	44 (50)	1.52	0.044	-
	Men	44 (50)	1.61	0.048	-
Estimated (Carrea's index)	Total		1.81	0.078	0.527
	Women		1.77	0.066	-
	Men		1.85	0.069	-
Estimated mínimum (Carrea's index)	Total		1.77	0.076	-
	Women		1.73	0.064	-
	Men		1.80	0.069	-
Estimated maximum (Carrea's index)	Total		1.85	0.080	-
	Women		1.81	0.069	-
	Men		1.89	0.073	-
Estimated (modified Carrea's index)	Total		1.57	0.049	0.727
	Women		1.52	0.022	-
	Men		1.61	0.020	-

SD: Standar Deviation

Paired t-test analysis to compare the accuracy of the original Carrea's index and the Peruvian modification indicated that, using the original method, there were significant overestimations in the total sample (mean=0.245m) (Table 2). However, the modified index generated a no significant overestimation (mean=0.001m) (Table 2).

Finally, successful predictions between stature estimates and actual stature were compared. It was observed that using the modified Carrea's index, there were more cases of successful stature estimates (14.8%), especially when applied to males (Table 3).

Table 2. Paired t-test evaluating the mean of differences between actual and estimated statures

Paired samples		r	Mean	95% CI		sig
				Lower	Upper	
Actual stature / Carrea's index	Total	0.527	-0.245	-0.259	-0.229	,000
	Women	0.150	-0.253	-0.275	-0.230	,000
	Men	0.364	-0.236	-0.257	-0.216	,000
Actual stature / modified Carrea's index	Total	0.727	-0.001	-0.010	0,009	,889
	Women	0.038	-0.004	-0.019	0.011	,575
	Men	0.444	0.003	-0.010	0.016	,679

Table 3. Comparison of percentages of successful, sub- and over-estimations

		Successful estimation n (%)	Under-estimation n (%)	Overestimation n (%)
Actual stature / Carrea's index	Total	0 (0)	-	88 (100)
	Women	0 (0)	-	44 (100)
	Men	0 (0)	-	44 (100)
Actual stature / modified Carrea's index	Total	13 (14.8)	36 (40.9)	39 (44.3)
	Women	6 (13.6)	16 (36.4)	22 (50)
	Men	7 (15.9)	20 (45.5)	17 (38.6)

DISCUSSION

In most natural and man-made disasters, forensic and legal dentistry has made countless contributions to the identification of remains in official investigations[7]. The four essential factors in determining personal identification are age, sex, stature, and ethnicity[4].

Stature estimation is a crucial aspect of reconstructing an individual's identity, with the skull, jaws, and teeth being the parts of the body that best preserve this

individuality when exposed to the environment. However, stature estimation from dentition has rarely been explored[8].

The initial contributions to stature estimation through dental dimensions were made by the Argentine professor Juan Ubaldo Carrea[5] in 1920. He developed a mathematical calculation to estimate height based on the dimensions of the mandibular anterior teeth.

Carrea's index measures the mesiodistal diameters of the central incisor, lateral incisor, and canine of the lower jaw, obtaining the dental arch and chord-radius. These parameters allow for the determination of the minimum, maximum, and estimated stature of an individual[5].

In this study, measurements were taken of the lower left anterior teeth. According to the "Principle of Bilateral Symmetry" proposed by Carrea[5]), any half-arch can be used for height estimation, accepting small variations as physiological asymmetries. Regarding this, Lima et al. (2011)[9] demonstrated that either side of the dental arch can be used for height estimation, as their study found no statistically significant difference between the right and left half-arch.

Success in estimations is achieved when the actual stature falls within the intervals of minimum and maximum estimated stature. In this study, no cases of successful estimation were found using the Carrea's index because, in all cases, the actual stature was lower than the minimum estimated stature (overestimation in 100% of cases). However, Sruthi et al. (2016)[10] reported a successful stature estimation rate of 76.5%. Similarly, a high rate of successful estimation was observed in the studies of Anand et al. (2023)[11] (83.75%) and Rangari et al. (2018)[12] (82% for the left half-arch and 72% for the right half-arch). In addition to this, Anita et al. (2016)[13] pointed out Carrea's method as valid for height estimation among Aryan men (84% success) and Dravidian men (80% success), which are the two main racial subgroups in India.

Making specific reference to the Peruvian population, there was limited evidence related to the use of Carrea's index. Moreno et al. (2020)[14] found, for both sexes, an overestimation of the estimated height compared to the actual height by 3.5 cm for women and 5.1 cm for men. The study by Villanueva (2017)[15] indicated a slight general underestimation of 0.01 cm when using Carrea's index ($p = 0.1774$), where the mean actual height was 1.67 m and the mean estimated height was 1.66 m. In this study, Carrea's index resulted in a general overestimation of 25.3 cm for women and 23.6 cm for men. Since there were no cases of successful stature estimations, a modification to the Carrea's formula was made, resulting in an improvement in 14.8% of cases (overestimation of 0.1 cm for women, and underestimation of 0.3 cm for men).

In the literature, only one study was found that made modifications to the Carrea's index. Due to the low cases of succesful stature estimations (17.2%), Quiroz (2018)[16] evaluated the predictive power of the variables estimated height ($p=0.026$, $r=0.279$) and estimated height along with chord-radius ($p=0.000$, $r=0.779$) by making regression models. Results

showed a better significance and a higher level of correlation in the second group. In this study, our multiple linear regression considered the variables chord-radius and gender (r=0.748) and dental arch and gender (r=0.749), choosing the formula derived from the second set of variables due to its higher correlation.

Overall, when analyzing the previous information regarding Carrea's index, positive outcomes were observed moslty in studies conducted in India (10-13). However, in this study and in those conducted in other populations, the inefficacy of the Carrea's method for estimating stature is demonstrated. Regarding this, Medina (2017)[17] in her study with different ethnic groups in Ecuador found that in 100% of cases, the actual stature was below the minimum estimated stature. Similarly, Garrido et al. (2012)[17] demonstrated the inefficacy of the Carrea's method in temporary dentition by finding negative results in all 46 cases analyzed in Chilean population. Likewise, De Sousa e Silva (2014)[19] and Duarte da Silva (2012)[20] concluded that Carrea's method is not suitable for the Portuguese and Brazilian population, respectively.

Therefore, given the results obtained by using the Carrea's index in the Yanesha and other diverse populations, this research suggests that this method may not be reliable for estimating stature.

CONCLUSION

Carrea's index for stature estimation resulted in a mean overall overestimation of 24.5 cm, making its use not advisable for the Yanesha population in Peru. The modification of Carrea's index yielded stature estimations without significant differences, both overall and by gender. However, the estimation of stature using the Carrea's new formula would also not be useful for personally identifying these inhabitants (success: 14.8%; underestimated: 40.9%; and overestimated: 44.3%).

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RESUMÉN

La identificación humana es un área importante de las ciencias forenses, especialmente cuando se refiere a víctimas de desastres naturales y en aquellos provocados por el hombre. La altura es uno de los cuatro factores esenciales en la determinación de la identificación personal junto con la edad, el sexo, y la etnia. La muestra estuvo conformada por 88 modelos de estudio del maxilar inferior de los pobladores de la Comunidad Nativa Yanesha (Perú). Se midió el ancho mesiodistal de los incisivos centrales, incisivos laterales y caninos del lado izquierdo para estimar la estatura utilizando el método de Carrea. Se realizó una regresión lineal múltiple para obtener una nueva fórmula y mejorar la exactitud de las estimaciones de altura. Al comparar la estatura real media y la altura estimada media, se obtuvo una sobrestimación general de 24.5 cm (sobreestimación en el 100% de los casos); además, no se encontraron estimaciones exitosas entre las alturas reales y estimadas. Al aplicar la modificación a la fórmula de Carrea se logró una mejoría en la estimación general con una ligera sobrestimación de 0.1 cm; se obtuvieron estimaciones exitosas en el 14.8% de los casos, 40.9% de subestimaciones y 44.3% de sobreestimaciones. La aplicación del método de Carrea para la estimación de altura en la población peruana Yanesha no sería conveniente al presentar diferencia significativa con la altura real.

PALAVRAS CLAVE
Odontología forense; Antropología forense; Perú.

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