IS POSSIBLE TO USE THE GOLDEN RATIO OF SKULLS IN SKETCHES? STUDY OF A BRAZILIAN SAMPLE

ABSTRACT

INTRODUCTION: The ratios of the human face and body have been analyzed since Antiquity. The bone architecture of the head is based on proportional relationships that are very valuable in the application of auxiliary techniques for identifying individuals of unknown identity. **AIMS:** The objective of this study was to verify the Divine Ratio in a sample of Brazilian skulls from the northeast region, using craniometric measurements and indices and showing their potential in sketches. **MATERIALS AND METHODS:** The measurements were taken directly from the skulls, and 14 craniometric measurements were selected from which 3 geometric formulas, 6 horizontal and 4 vertical relationships, and 6 facial indices were calculated. The data were tabulated and described, using the Confidence Interval of the mean ($p<0.05$). **RESULTS:** The Golden Ratio (1.618) was not found in the population examined; however, it was possible to establish facial indices and coefficients of the measurements themselves, constructing regional anthropometric parameters based on the ratios studied. The ratio of the height of the head in relation to the height of the face (1.69) was the variable that most closely resembled the Golden Number, and the ratio of the height of the nose equaling half the height of the face (0.92) was the variable that most closely approached the equalities. **CONCLUSION:** It was found to be possible to use one craniometric measurement to obtain another one, using the facial indices and the calculated linear regressions, with some of the variables. This study makes a potential contribution to the search for establishing skull ratios that are reproducible for the face, contributing to the improvement of sketch techniques in future studies.

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KEYWORDS

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INTRODUCTION

Golden Ratio, Golden Section, Divine Ratio, and Golden Number are some of the names for proportional trend found in the face and other parts of the human body, analyzed since Antiquity. This is represented by the number 1.618 and symbolized by the letter Φ (PHI) from the Greek alphabet.[1,2]

This topic has also been studied using radiographs and/or photographs, which have detected some Golden Relationships in both the horizontal and vertical directions of the face. This is demonstrated in the hypothesis that the Golden Ratio is present in the human skull.[3]

As many as 42 Golden Relationships were found in one study, making it possible to conclude that the bone architecture of the head is based on proportional relationships, which is very valuable in the field of Forensic Anthropology. The correspondence between the vertical and horizontal relationships, as well as knowledge of facial indices applied to this population, scientifically supports the use of auxiliary identification techniques on individuals of unknown identify, like: facial biometrics, facial reconstruction and the superimposition of images.[4]

The aim of this study was to verify the Divine Ratio in a sample of Brazilian skulls from the northeast region, using craniometric measurements and indices, to show their usefulness in sketches.

MATERIAL AND METHODS

Following approval from the Ethics Committee for protocol 127/11 CAAE 0144.017.00-11, fourteen measurements were taken from 60 skulls that came from the Instituto Médico Legal Nina Rodrigues (IMLNR) (Nina Rodrigues Forensic Medicine Institute) in the city of Salvador (Bahia, Brazil), totaling 840 measurements. A 150 mm digital caliper, a 300 mm digital caliper with elongated shaft, an "L"-shaped millimeter scale and a circular support were used on the skulls. Criteria for inclusion included verifying that the skull had sufficient posterior teeth in the maxilla and mandible to permit a stable occlusion with maximum intercuspation. Criteria for exclusion included the presence of injuries in the facial bones which prohibited obtaining anthropometric measurements, as well as the fact of the skull being totally toothless or using total or partial removable dental prostheses in any of the arches.

The craniometric points Vertex (v), Glabella (g), Nasion (n), Subnasale (sn), Gnathion (gn), Auriculotemporale (at), Ectocanthion (ec), Endocanthion (en), Zygion (zy), Infraorbitale (io), Alare (al) and Gonion (go) were marked with a pen on the skull. The six vertical measurements were: vertex-gnathion distance (v-gn), Glabella-Gnathion distance (g-gn), Nasion-Gnathion distance (n-gn), Nasion-Subnasale distance (n-sn), Subnasale-Gnathion distance (sn-gn), and Nasion-Gnathion/2 distance (n-gn/2). These were variables 01 to 06, measured while the skull was laid on the round base, in the lateral norm, with the calipers being parallel to the rule and the table. The eight horizontal measurements were: Auriculotemporale-Auriculotemporale distance (at-at), Zygion-Zygion distance (zy-zy), Ectocanthion-Ectocanthion distance (ec-ec), Ectocanthion-Endocanthion distance (ec-en), Endocanthion-Endocanthion distance (en-en), Infraorbitale-Infraorbitale distance (io-io), Alare-Alare distance (al-al), and Gonion-Gonion distance (go-go). These were variables 07 to 14, measured while the skull was laid on the round base, the calipers being parallel to the bilateral craniometric points.

The 14 combined measurements formed three geometric shapes (facial square, facial rectangle and nasal rectangle, variables 15-17); four vertical relationships, variables 18-21; six horizontal relationships, variables 22-27; and, six craniometric indices, variables 28-33.

RESULTS

The data of the horizontal and vertical ratios were compared with the Golden Value (1.618), with a Confidence Interval of 95%, using the t-test.

Four groups of variables were compared for equality using the paired t-test. Finally, the vertical and horizontal ratios, the equalities and the facial indices were analyzed using the Spearman correlation and were represented by linear regression lines for each pair of variables.

Table 1 describes the Golden Ratios and the equality relationships. The normality of the measurements was verified using the Skewness/ Kurtosis test and, as the variables were considered parametric, the paired t-test was used to compare the 9 ratios to the Golden Value (1.618).

None of the variables showed statistically significant Golden Values ($p<0.001$). However, variable 18 (V18) appeared close to the Divine Ratio, and variable 20 (V20) close to the equality. It was noticed that all values followed a proportional trend. Four groups of variables were compared for equality, using the paired t-test, and were not considered to be equal ($p<0.001$).

Table 2 compares the six variables (V28 to V33) with a new suggested standard that was based on Facial Indices. There was not a sufficient number of female skulls, in the sample selected, to differentiate the results of the study by sex. For this reason, weights of nine (9) male and one (1) female were established for the indices found, after which a mean of these indices was calculated to which the results were compared. This process was repeated for all six indices studied and new standards were established for comparison, which are shown in Table 2. It may be seen that all variables differ from the standard value, demonstrating the characteristic of the population studied.

Table 3 shows the results of the correlations between the equalities and the Golden Relations. A linear regression is shown for each combination of variables, such that it is possible to obtain the value of one measurement from the other one.

These data are highly valuable in cases of fractures or bone loss of the skull, severe burns in which skull reconstruction is necessary prior to facial reconstruction or superimposition of images. The Spearman Correlation classifies the values found between 0.00-0.40 as weak, between 0.41-0.80 as moderate, and between 0.81-1.00 as high.

Variable 19 (n-gn/sn-gn) relates the height of the face (distance from the Nasion to the Gnathion) to the lower third of the face (distance from the Subnasal to the Gnathion). This shows the best correlation with the value of 0.837, which is considered high, and indicates a reliable estimate for using the linear regression formula to obtain one distance from the other one.

Table 1. Comparison among the ratios, the Golden Standard (a), and Standard of Equality (b). It is noted that variable 18 (V18) was closest to the Divine Ratio, and variable 20 (V20) was closest in relation to the Equality.

Variables	Mean	SD	Min	Max	P
Golden Standard	**1.62**	-	**1.60**	**1.69**	-
V16 (v-gn/at-at) [a]	1.82	0.14	1.56	2.08	<0.001*
V17 (n-sn/al-al) [a]	2.07	0.22	1.68	2.51	<0.001*
V18 (v-gn/n-gn) [a]	**1.69**	0.06	1.57	1.81	<0.001*
V19 (n-gn/sn-gn) [a]	1.83	0.06	1.64	1.99	<0.001*
V22 (zy-zy/at-at) [a]	1.21	0.06	1.08	1.34	<0.001*
V23 (zy-zy/ec-ec) [a]	1.31	0.04	1.24	1.46	<0.001*
V24 (ec-ec/io-io) [a]	1.94	0.12	1.70	2.13	<0.001*
V25 (io-io/al-al) [a]	2.00	0.16	1.70	2.49	<0.001*
V26 (en-ec/en-en)[a]	1.84	0.20	1.50	2.23	<0.001*
Standard of Equality	**1.00**	-	**1.05**		-
V15 (g-gn=at-at) [b]	1.15	0.09	0.95	1.33	<0.001*
V20 (n-sn=n-gn/2) [b]	**0.92**	0.04	0.80	1.00	<0.001*
V21 (n-sn=sn-gn) [b]	0.84	0.07	0.66	0.99	<0.001*
V27 (al-al=en-en) [b]	1.17	0.10	0.94	1.37	<0.001*

a = compared with the Golden Standard; b = compared with the Standard of Equality. * Statistically significant

Table 2. Comparison among six indices and their standards. It can be seen that all variables differ from the Golden Standard, demonstrating the characteristic of the population studied.

Variables	Mean	SD	Min	Max	P
V28 (n-gn/zy-zy*100)	89.82	5.41	75.81	110.84	0.029*
Standard V28	88.27	-	83.85	92.68	
V29 (n-sn/n-gn*100)	46.56	2.06	39.75	50.38	<0.001*
Standard V29	43.71	-	41.52	45.90	
V30 (en-en/ec-ec*100)	23.01	1.62	19.31	26.02	<0.001*
Standard V30	36.76	-	34.92	38.60	
V31 (go-go/zy-zy*100)	74.63	4.20	65.22	86.31	<0.001*
Standard V31	70.73	-	67.19	74.27	
V32 (en-en/al-al*100)	89.52	8.08	75.17	113.78	<0.001*
Standard V32	65.09	-	61.09	68.34	
V 33 (al-al/n-sn*100)	46.84	5.32	36.13	59.38	<0.001*
Standard V33	65.66	-	62.37	68.94	

Each variable compared with its standard. * Statistically significant

Table 3. Correlation and linear regression of the ratios and equalities. Variable 19 (n-gn/sn-gn), which relates the height of the face to the lower third of the face, shows a high correlation, indicating a reliable estimate that enables obtaining one distance from the other.

Variables	Spearman's Correlation	Classification	p	Linear Regression	P
V15 A=(g-gn);B=(at-at)	0.097	Weak	0.460	A=98.27+0.23B	0.166
V16 A=(v-gn);B=(at-at)	0.002	Weak	0.846	A=127.95+0.66B	0.144
V17 A=(n-sn);B=(al-al)	0.236	Weak	0.069	A=103.21+0.81B	0.031*
V18 A=(v-gn);B=(n-gn)	0.767	Moderate	<0.001*	A=-2.77+1.72B	<0.001*
V19 A=(n-gn);B=(sn-gn)	**0.837**	**High**	**<0.001***	**A=54.98+0.973B**	**<0.001***
V20 A=(n-sn);B=(n-gn/2)	0.665	Moderate	<0.001*	A=12.72+0.71B	<0.001*
V21 A=(n-sn);B=(sn-gn)	0.288	Weak	0.042	A=40.42+0.22B	0.025*
V22 A=(zy-zy);B=(at-at)	0.452	Moderate	<0.001*	A=69.19+0.56B	<0.001*
V23 A=(zy-zy);B=(ec-ec)	0.713	Moderate	<0.001*	A=30.83+1.01B	<0.001*
V24 A=(ec-ec);B=(io-io)	0.654	Moderate	<0.001*	A=63.44+0.68B	<0.001*
V25 A=(io-io);B=(al-al)	0.539	Moderate	<0.001*	A=25.50+0.98B	<0.001*
V26 A=(en-ec);B=(en-en)	0.265	Weak	0.040*	A=35.31+0.23B	0.090
V27 A=(al-al);B=(en-en)	0.591	Moderate	<0.001*	A=7.85+0.77B	<0.001*

Weak correlation, 0.00 to 0.40; Moderate, 0.41 to 0.80; High, 0.81 to 1.00. * Statistically significant.

DISCUSSION

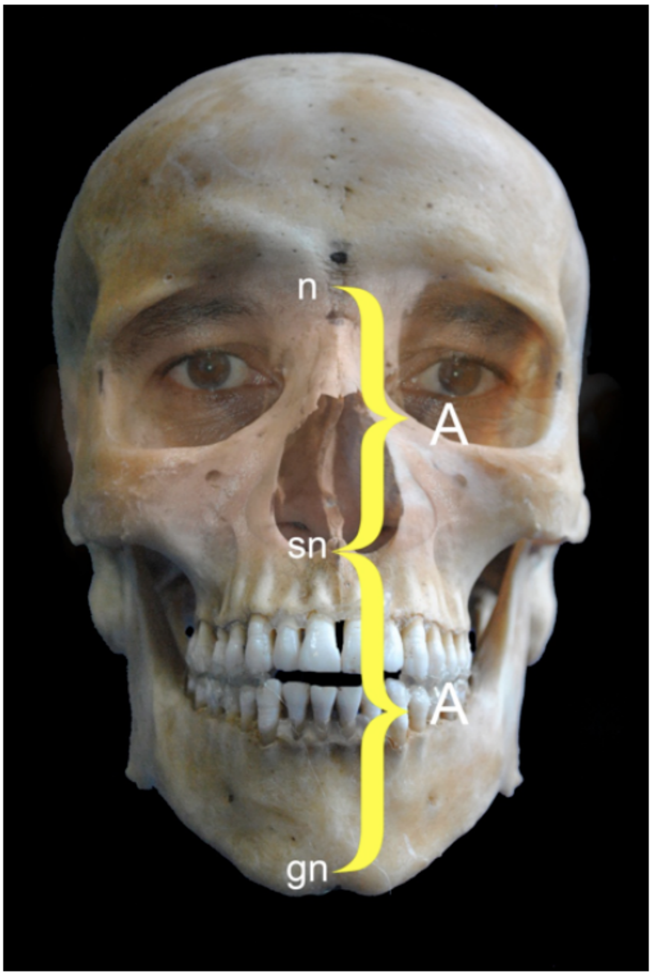
The results of the study consider a deviation of more or less 5%, resulting in an interval of 1.605 to 1.699 for a measurement to be considered as Golden, and of 0.95 to 1.05 for the equalities.

By decreasing the interval, the number of measurements that would fit this pattern is consequently reduced. Table 2 shows the mean of the results of the vertical and horizontal relationships (a) and the comparison with Golden Standard of 1.62, as well as (b) the means verified in the equality relationships. According to the interval proposed by this study, the mean of 1.69 obtained in the relationship (v-gn/n-gn) for variable 18, corresponding to the relationship of the height of the skull relative to the height of the face, was the value that most closely approached the established interval. Among the equality relationships, the mean of 0.92 obtained in the relationship (n-sn=n-gn/2) for variable 20, corresponding to the relationship of the nasal height being equal to half the height of the face, was the value that most closely approached the established interval.

This dimension has proven useful for several auxiliary identification techniques when the graphic or three-dimensional reproduction of the face is necessary, as shown in Figure 1.

All other values differed from the Golden standard of 1.618, although it was possible to observe a proportional trend for the population studied. The coefficients shown in Table 2 are representative of the sample and, from this study, other studies may be developed using these specific proportional indicators.

Figure 1. Demonstrating the applicability of the study for auxiliary techniques, like the sketch, where A=A (best proportion of equality found in the population).



When analyzing sex in anthropometric studies, different intervals are proposed for each group of ratios analyzed. The existing intervals are quite broad when compared with the research in question, where sex was not a variable that was considered due to the sample being predominantly male.[5] The justification of this fact is that the number of female skeletons sent to IMLNR was scarce; all the skulls of this sex in the sector were selected between 2007 and 2011, but the number was not representative for a differentiated analysis between the sexes.

One of the impediments to attaining success with facial reconstructions from human bones is the lack of direct correspondence among segments of soft tissues such as the nose, lips and eyes with specific points on the skull, hindering the determination of the size and shape of the face.[6,7] This limitation is identified in the research relative to the Chelion Point, which determines the width of the lips.[8] This point is located in soft tissue, in the labial commissure, and there is no exact correspondence in the skull. Accordingly, it is based on studies[9] that have related the infra-orbital foramen, an easily-located craniometric point, to the width of the lips. Thus, associations were made between the width of the infra-orbital foramen and the width of the eyes and the nose (variables 24 and 25) such that these precious data were not discarded.

Knowing the proportional relationships found in the architecture of the head is very important in facial reconstructions intended for forensic identification. Craniometric indices are used in anthropological studies with various goals such as the determination of sex, classification of facial types, and even to the estimation of ancestry.[4]

Six indices were selected for analysis in this study. The original work used frontal photographs of Caucasian women and men. The data in Table 2 compare the indices obtained from the skulls in the sample with the proposed indices and the methodology was adapted to incorporate differentiated weights for the sexes, obtaining a new standard for comparison. All the variables differed from the standard, pointing to the belief that large-scale miscegenation among the Bahian population, a component of the sample, is the factor responsible for the results attained. In addition, the measurements that are taken from photographs are more subject to distortions than the measurements that are taken directly from the skull.[9,10]

The facial standard is determined genetically, but environmental factors may modify it. This is one of the definitions of phenotype with which the present authors agree. Classifying the individual according to facial morphology as brachyfacial, mesofacial, or dolichofacial is important for establishing guidelines in forensic facial reconstruction for identification purposes. For this reason, the relevance of the facial indices being analyzed is understood from a perspective that is differentiated and appropriate for the population studied.

In Table 3, of the four vertical measurements that relate the upper third (n-sn) and the lower third (sn-gn) of the face in some way (variables 18 to 21) only one was considered weak, variable 21, which is an equality relationship. The authors who considered the balance among facial thirds as mandatory delineated their studies with individuals having occlusions considered normal. This factor was not considered in this study due to the inclusion criteria being limited to skulls having sufficient teeth to allow stable, maximum intercuspation and maintaining the vertical dimension of occlusion. No skulls with occlusion problems were discarded, which certainly influenced the upper and lower facial dimensions.

Among the horizontal measurements (variables 22 to 27), only one correlation was considered weak (V26), which relates the width of an orbit to the width between the eyes; its linear regression is less advisable for obtaining one of the measurements from the other one.

Table 3 also shows a mathematical equation called the linear regression line for variables 15 to 27 (V15 to 27), corresponding to the facial square, facial rectangle, nasal rectangle, vertical relaltionships, equalities, and horizontal relationships. With these equations, the value of one measurement can be obtained from another one. Variable 19 was the most meaningful, showing a Spearmen correlation considered high and, therefore, a reliable measure. Seven relationships were considered moderate, with their equations highly representative for obtaining measurements. Five were considered weak, and are the least recommended for obtaining measurements.

Inferring craniometric points having anatomical details for support and manipulating the distances in photographs, with the purpose of finding a more balanced shape, have been subterfuges of some researchers in order to obtain standards of beauty appropriate to modern society, modifying the concept of the Divine Ratio to their own treatments.

Studies conducted in homogeneous populations[4] found a satisfactory number of Golden Relationships in the face. Others have demonstrated the existence of the Divine Ratio in some measurements.[3,11] What can be observed in other studies is that the Golden Number of 1.618 is not present in all relationships studied, but that there are other standards which come close to it.[4,10] The present study was based on the intent of the Golden Ratio. However, more important than affirming whether or not it exists precisely in the skull, is having the awareness of the dynamic in human civilization arising from geographic migration and resulting in miscegenation among the population.

The Bahian population from which the sample was taken is highly mixed, with different ethnic types expressing the phenotype strongly in the facial characteristics, although the facial proportions may vary within different ethnic groups, altering the facial profile.[12]

Given all these considerations, anthropometric parameters such as sex, age, and ancestry; as well as dental ones such as type of occlusion, orthodontic treatment or previous surgeries are clearly evident. In addition to the specific methodology of each study (photographs, radiographs or direct measurements), these parameters may influence substantially the results in a positive or a negative way when considering the exact value of the Divine Ratio to be 1:1.618.

Knowledge of the characteristics of the population being studied was the greatest contribution made by this study, in addition to the realization that the implementation of a universal parameter (1.618) may be applied cautiously.

The present study provides useful indicators for other anthropometric studies that use craniofacial relationships with specific populations. Although the study of the Golden Ratio was conducted in the northeast region of Brazil, it is necessary to deepen such indicators in an attempt to construct tables, indices, measurements and coefficients suitable to be used in future forensic work in each population to be studied, concurring with identification techniques and with Brazilian forensic anthropology.

The relevance of this study lies precisely in the need for regional anthropometric standards, with which more accurate studies will be developed in the field of Anthropology. Joining the artistic and subjective aspects into one design manual with consistent, measurable data, the forensic use for these parameters is a potential contributor to the development of more credible expertise, according to the profile of the specific population which, in this case, was the Bahian population.

CONCLUSION

The possibility was found of being able to use some variables from a craniometric measurement to be able to obtain another measurement, using the facial indices and the calculated linear regressions. This study makes a potential contribution to the search for establishing skull ratios that are reproducible for the face, contributing to the improvement of sketch techniques in future studies.

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