Facial approximation for identification purposes: soft tissue thickness in a Caucasian population. Sex and age-related variations.

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ABSTRACT

The aim of this study was to collect soft tissue thickness (STT) values of an Italian population from 12 bone landmarks, to improve the facial approximation process for identification purposes. 100 Italian adults (50 males and 50 females), who had undergone head CT for clinical purposes, were analysed in order to expand the database of the Italian population. Average values, standard deviation and range were collected according to gender and age and the obtained values were statistically analysed in order to evaluate any possible significant difference. Only one landmark was statistically significant associated with sex, females showed significantly higher values for para-zygomaxillary. Two landmarks were statistically significant associated with age, upper incisor and pogonion. The obtained results were compared with the existing literature. Such information can be useful in the forensic craniofacial reconstruction process and can facilitate choosing the most suitable STT values according to osteological analysis of the human remains.

INTRODUCTION

Facial approximation is a method that reproduces the facial soft tissue of an individual, considering tissue depth landmarks on the bone surface of the skull. In recent research, this is a useful tool in the forensic investigation of human identification [1-4]. The reproduction of the facial features is conditioned by the soft tissue thickness and the underlying bone surface [5-8] that is sufficiently distinctive and provides a unique facial appearance even by the application of average facial soft tissue thickness [9]. For this purpose, measurements of soft tissue thickness are taken at predefined bone landmarks. In the first studies aimed at establishing facial soft tissue thickness, these values were taken using the needle puncture technique on cadavers [10-16]. Through the development of medical imaging techniques, subsequent studies were conducted on living individuals in order to minimise the error due to the post-mortem changes [17 18]. These studies used different imaging methods for the soft tissue thickness measurements like cephalometric X-ray [18-22], ultrasound [23-27], magnetic resonance [28, 29], and computed tomography/cone beam computed tomography [9, 30-36].

In forensic facial approximation, as landmarks should be located with precision on the bone surface, it is convenient to utilise CT scans [30, 37]. In the literature, many studies are conducted using this technique with sample size ranging from 1 to 500 individuals but generally these samples tend to include

less than 40 individuals on average [2]. Furthermore, many population groups have been investigated but few studies have been conducted on Caucasian populations [9, 15, 32, 37-41] and only two studies [18, 33] on Italian population groups.
The aim of this study was to obtain STT measurements for a large Italian population group according to gender and age, and to compare the results with the existing literature to assess whether there are significance differences in tissue thicknesses that are useful during facial reconstruction procedures.

MATERIAL AND METHODS

Facial soft tissue thicknesses were measured on the head CT scans of 100 Italian adults: 50 males and 50 females, aged between 18 and 98 years. All of them underwent CT scans for clinical reasons not related to this study, so the individuals were not exposed to radiation only for the purpose of this research. As a retrospective study, patient details such as height and weight could not be obtained since not required at the time of the radiological investigation, thus both thin and obese subjects were included in the sample. Our hospital ethics committee was not involved because CT scans were anonymous and only data on age and sex was available; in addition, we did not introduce a new type of intervention on patients. Furthermore, patients with trauma, fractures, malformations or any other congenital or acquired abnormality that could influence the shape of the face or the measurements of the tissue thickness were excluded from the sample.
For this study, 12 osteological landmarks (listed and described in Table 1) were considered and the tissue thickness of each one was measured. These landmarks were selected because of the ease of their localisation on the CT scans and their representativeness of the inter-individual variation and of the facial physiognomy [33].

Table 1. Description of landmarks. *Landmarks defined by Rhine and Campbell [11] †Landmarks defined by Aulsebrook et al. [8]. ‡Landmarks defined by Cavanagh et al. [37]. §Landmarks defined by De Donno et al. [33}

LANDMARK	DEFINITION
Sub-orbital *	Below the orbit, on the lowermost margin of the orbit.
Nasion *	Midpoint of the suture between the frontal and the two nasal bones.
Rhinion *	Anterior tip of the nasal bones, on the internasal suture.
Zygion †	Point on the maximum lateral outer curvature of the zygoma.
Zygomaxillary †	Lowest point on the suture between the zygomatic and maxillary bones.
Para-zygomaxillary §	Point between the horizontal and the oblique/vertical part of the zygomatic bone.
Para-midphiltrum §	The most internal point of the curvature of the maxillary bone in the midline.
Upper incisor ‡	The most anterior point of the maxillary crest in the midline.
Lower incisor ‡	The most anterior point of the mandibular crest in the midline.
Gonion *	The most lateral point on the mandibular angle.
Pogonion [b]	The most anterior projecting point in the midline on the chin.
Menton [d]	The lowest point on the mandible.

Because the head CT scans were focused on the craniofacial region, it was not possible to consider on each CT scan all the landmarks taken into consideration.

Measurements of facial soft tissue thickness were obtained using a Multi Detector row Computed Tomography (MDCT) available at Interdisciplinary Department of Medicine (DIM), Diagnostic Imaging Section, University of Bari, Italy. CT examinations were performed by a 128-row system (Somatom Definition AS; Siemens Healthcare, Forchheim, Germany), using the following acquisition parameters: collimation 160 x 0.5 mm, increment 0.5mm, rotation time 1 s; 120/200-280 kVp/mAs. Automatic dose modulation system was used in all cases (effective dose: <2 mSv).

The obtained data were transferred and analysed on a workstation (HP XW 8600) equipped with image reconstruction software (Vitrea FX 2.1, Vital Images, Minneapolis, MN, USA). In order to take accurate measurements, this tool allows the visualisation of three planes of study: axial, coronal, and sagittal at the same time.

The measurements were taken using an optimal soft tissue window (window width: 350–400 Hounsfield Unit (HU) and window level: 20–60 HU), as follows: first, the landmarks were precisely localised on the skull according to the three planes, then the measurements were taken perpendicular to each landmark, the length of the line projecting from the skeletal to the facial landmark was considered the thickness of the facial soft tissue (Figure 1 and 2). To assess measurement reliability, these steps were repeated by two independent blinded radiologists with 23 and 2 years of experience in CT; any disagreement was resolved by open discussion and consensus.

Figure 1. Coronal, sagittahorizontal slices: example of STT measurements.

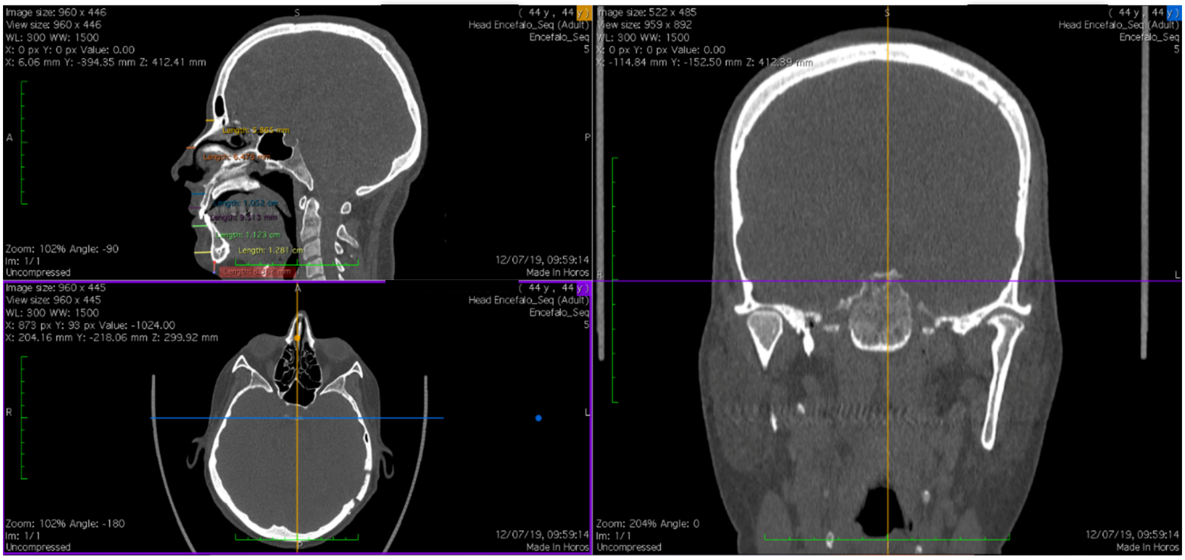

Figure 2. Example of STT measurements.

Data were reported in an Excel database and a statistical analysis was performed using Stata13MP software (StataCorp LLC, College Station, Texas). First, basic descriptive statistics including mean, range (between minimum and maximum), standard deviation, and interquartile range were calculated for each landmark and, in future, these values could be used for facial reconstruction purposes.

The differences between the sexes and the association with age was assessed using Student's t-test and linear regression. All independent variables with a p-value ≤ 0.25 were considered eligible for inclusion into the multivariate analysis. Then, multivariate logistic and linear regression models were used to investigate independent characteristics associated with sex (Model 1) and age (Model 2).

The following independent variables were included in both Models: sub-orbital, nasion, rhinion, zygion, zygomaxillary, para-zygomaxillary, para-midphiltrum, upper incisor, lower incisor, gonion, pogonion, and menton. A stepwise procedure was applied to obtain the final models and the results of the multivariate analysis were expressed in odds ratios (ORs) and 95% confidence intervals (CIs), with a statistically significant level of p-value 0.05.

RESULTS

Table 2 shows the descriptive statistics for the facial soft tissue thickness and the comparisons between males and females. 12 biometric measurements were taken into consideration on 100 head CT scans of Italians adults (50 males and 50 females) aged between 18 and 98 years. The mean age was 58.5 for females and 60.3 for males. Every measurement in this study could not be recorded for each CT scan because some scans included only the upper half of the face. Therefore, measurements had different sample size (N): the sample was complete for sub-orbital, nasion, zygion, and zygomaxillary; for the other landmarks the sample are smaller (rhinion=94; para-zygomaxillary=99; para-midphiltrum=52; upper incisor=48; lower incisor/pogonion/menton=21, and gonion=20). The smallest values were obtained from three landmarks of the upper area of the skull: rhinion, nasion, and zygion; the largest, from para-midphiltrum, upper incisor, and lower incisor that are landmarks of the lower area. The standard deviation (SD) was calculated for each landmark. Lower incisor, upper incisor, and nasion had the lowest values of SD; gonion, sub-orbital, and rhinion the highest; the other landmarks had an intermediate value of SD. So, measurements are strictly similar among them if a low value of SD is obtained. In this study, SD values (minimum value of 1.2, maximum value of 4.1) are satisfactory: considering that all measurements are expressed in millimeters, there is a minimal variability.

Table 2. Comparison of the facial soft tissue thicknesses [mm] between Italian males and Italian females.

Landmarks	Males						Females					
	N	Mean	SD	Min	Max	IQ range	N	Mean	SD	Min	Max	IQ range
Sub-orbital	50	8.6	2.8	3.7	17.7	6.8-10	50	7.4	3.0	3.6	14.6	4.9-10.3
Nasion	50	8.3	2.0	4	13.14	7.2-9.3	50	7.3	1.7	3.5	12.8	6.1-8.2
Rhinion	47	4.9	2.9	2.8	19.5	3.7-4.8	47	4.2	1.9	2.4	11	3.2-4.4
Zygion	50	7.6	2.1	4.1	12.5	5.9-9.7	50	8.2	2.6	3.7	16.2	6.4-10
Zygomaxillary	50	8.9	2.4	4	12.6	6.8-11	50	9.5	3.5	4.8	19.8	6.5-11.4
Para-zygomaxillary	49	8.4	1.4	4.9	11.7	7.5-9.3	50	9.5	2.3	4.6	14.8	7.5-11.2
Para-midphiltrum	29	13.4	2.1	7.6	17.9	12.3-14.4	23	12.3	1.6	9.1	15.4	11.2-13.2
Upper incisor	27	10.9	1.9	7.3	14.9	9.7-11.7	21	10.3	1.9	7.8	14.3	9.1-11.8
Lower incisor	12	10.4	1.2	9.2	12.4	9.4-11.6	9	10.5	1.3	8.8	12.9	9.4-11.2
Gonion	11	9.7	3.7	6.4	17.1	7-10.9	9	10.4	4.8	6.3	17.1	7.1-16.3
Pogonion	13	10.3	1.6	7.8	14.1	9.4-10.8	8	9.9	2.5	7.1	14	8.4-11.7
Menton	13	9.6	2.8	5.3	15.6	8.7-11.5	8	9.4	1.3	7.7	12.1	8.8-9.7

N: number of measurements; SD= standard deviation; Min: minimum value; Max: maximum value; IQ range = interquartile range

Sexual differences

All the median values of facial soft tissue thicknesses were larger in males when compared to females except for zygion, zygomaxillary, para-zygomaxillary, lower incisor, and gonion (Table 2). The results of the bivariate analyses were reported in Table 3. The results obtained from the multivariate logistic regression model showed that only one landmark was statistically significant associated with the sex. Females showed significantly higher value of para-zygomaxillary; the other measurements did not present significantly differences between females and males (Table 4).

Age differences

The comparison of the facial STT with the age analyzed by multiple linear regression analysis revealed that STT differed significantly for upper incisor and pogonion (Table 5).

Table 3. Basic descriptive statistics of facial soft tissue thicknesses [mm].

Landmarks	N	Mean	SD	Min	Max	Sex	Age
Sub-orbital	100	8	3	3.6	17.7	**0.0573***	**0.007***
Nasion	100	7.8	1.9	3.5	13.1	**0.0122***	**0.037***
Rhinion	94	4.6	2.4	2.4	19.5	**0.1548***	0.411
Zygion	100	7.9	2.3	3.7	16.2	**0.2150***	**0.136***
Zygomaxilla	100	9.1	3	4	19.8	0.3260	0.427
Para-zygomaxillary	99	8.9	2	4.6	14.8	**0.0094***	0.720
Para-midphiltrum	52	12.9	2	7.6	17.9	**0.0603***	0.574
Upper incisor	48	10.6	1.9	7.3	14.9	0.2686	**0.157***
Lower incisor	21	10.5	1.2	8.8	12.9	0.8284	0.342
Gonion	20	10	4.1	6.3	17.1	0.7056	0.456
Pogonion	21	10.2	2	7.1	14.1	0.6438	**0.018***
Menton	21	9.5	2.3	5.3	15.6	0.8835	**0.212***

*Student's-t test ($p < 0.25$) for statistical differences related to genders and age.
N: number of measurements; SD= standard deviation; Min: minimum value; Max: maximum value.

Table 4. Multivariate analysis results for sex.

Landmark	Odds Ratio	Standard Error	P value	95% Confident interval
Suborbital	1.412714	.2551653	0.056	.991539 - 2.012792
Nasion	1.776511	.5514621	0.064	.9668051 - 3.26435
Rhinion	1.262562	.1799544	0.102	.9548388 - 1.669458
Zygion	.6661141	.1733119	0.118	.4000185 - 1.109219
Parazygomaxillary	**.5408493**	**.1668579**	**0.046**	**.2954414 - .990105**
Para-midphiltrum	1.306336	.2636784	0.186	.8795158 - 1.940289

Table 5. Multivariate analysis results for age.

Landmark	Standard Error	P value	95% Confident interval
Suborbital	1,843026	0,184	-6.494208 – 1.362426
Nasion	3.495582	0.233	-3.107105 – 11.79421
Zygion	3.05681	0.318	-3.355256 – 9.675616
Upper incisor	**1.859748**	**0.019**	**-8.855647 – -.9277276**
Pogonion	**2.52065**	**0.009**	**-12.9089 – -2.163626**

DISCUSSION

Facial approximation is a technique used in forensic anthropology to create a facial appearance based on the skull morphology of an unidentified body. The usefulness of this technique is related to the human ability to identify a known face even if it is not identical with the given one.[42] For this reason, population studies on soft tissue thickness are important to verify the association between facial approximation and biological data (such as race, sex, and age).[18] In this study, data on facial soft tissue thickness measured on 100 CT scans of Italian males and females were collected. The landmarks taken into consideration were the easiest to identify due to correspondence to well-defined anatomical structures.[33] The reduced sample size for some landmarks resulted from the scanning technique used for head CT, in which the primary concern is the lowest possible level of radiation to patients. Nevertheless, this sample represent the largest data set reported in the literature on STTs for an Italian adult population. Because of the lack of information on patients' BMI, along with STTs' mean values, values are reported in common with other studies.[7-9] In this way it is possible to fit the resulting facial approximation to body constitution. For this reason, in Table 1 the ranges of values are reported along with the means and standard deviations, separately for gender groups. This could be an important element in forensic approximation as it is known in the literature that even if the STTs' changing had minimal effect on the facial form, this affected the subjective recognition significantly.[6]

Sexual differences

In this study, all the landmarks were larger in males than in females except for zygion, zygomaxillary, para-zygomaxillary, lower incisor, and gonion. Nevertheless, only para-zygomaxillary was statistically significant associated with the sex. The higher values of males were reported by other authors in different studies [9, 13, 14, 22, 23, 28, 41-43] even if some differences were found.

For example, comparing our data with a population of a different ancestry [22], like an Asian population, the mean values of the present study were higher for the nasal and mental area and lower for the oral area. In addition, they reported lower values in males than in females only for the pogonion landmark.

Comparing our data with other Caucasian populations [9, 41] the mean values of the present study were overall higher for the landmark related to the nasal and orbital area and lower for the oral and zygomatic area. In the Slovak study they reported all the values higher in males than in females, on the contrary, in the present study and in the Czech study some landmarks are higher in females than in males. Furthermore, both Slovak and Czech studies described a gender statistical difference in most of the landmarks in contrast to the present results.

Age differences

Considering different ages, in this study the statistical analysis showed a statistical relevance of STTs for only two landmarks: upper incisor and pogonion. This evidence should be further investigated in future studies with a broader sample in order to assess age differences.

In this case, the comparisons with other Caucasian populations are variable in different studies. The statistical analysis in the Slovak population [41] is completely different compared with the present results: a significant difference was found for other landmarks such as midphiltrum and orbital landmarks. In a Turkish population [39] the differences were found especially for landmarks of the nasal area and even of the oral area, according to the present study and to Wilkinson [5] and De Greef [44] studies. Therefore, the present results revealed that even in the same racial group, the STTs differ from one population to another. For this reason, in the facial approximation process population differences should be taken into consideration and different population data sets of STTs should be considered even for gender and age differences.

CONCLUSIONS

This study aimed to bring a valuable contribution to the European values of STTs for facial approximation, since there were only a few previous data sets on the average soft tissue values for the Italian population. Facial approximation is a valuable tool in the identification process, especially in the early stages and in cases where very little information is available on the identity of the deceased. So, even in the absence of evidence useful for personal identification of skeletal remains, a possible face should be generated taking into account only sex and population data, facial approximation could be successful in the identification process.[9]

Statistical analysis was performed in order to assess the differences considering sex and age of the individuals. Considering sex and age differences, this study provides preliminary data about the impact of sex and ageing on the evaluation of STTs for facial approximation. The statistical results obtained in this study have an ancillary statistical role in the STTs' evaluation, however, more data should be collected in further studies with larger samples. Likewise, there are also population differences comparing the results of the present study with other studies also carried out on a Caucasian population.

The STTs' measurements obtained in this study can be collected with other data sets [18, 33] in a single database for craniofacial reconstruction of an Italian population in forensic cases or in future research studies. We believe that further studies are needed in order to enlarge the population sample, to provide additional information on the variability of STTs according to different variables. This will be useful to calculate a mathematical formula that would quickly calculate mean values for the facial reconstruction process. This could increase the reliability of facial approximation according to specific geographical context and anthropological data.

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