Forensic Science International 293 (2018) 102.e1–102.e11

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Forensic Anthropology Population Data

Facial soft tissue thickness trends for selected age groups of Sri Lankan adult population

Himashi Sandamini[a,*], Aparni Jayawardena[a], Lochana Batuwitage[a], Roshan Rajapakse[a], Damitha Karunaratna[a], Muditha Vidanapathirana[b], Aruna Pallewatte[c]

[a] University of Colombo School of Computing, 35 Reid Ave, Colombo 00700, Sri Lanka
[b] Faculty of Medical Sciences, University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka
[c] Neuroradiology and MRI Unit, The National Hospital of Sri Lanka, Colombo 10, Sri Lanka

ARTICLE INFO

Article history:
Received 3 April 2018
Received in revised form 26 September 2018
Accepted 2 October 2018
Available online 9 October 2018

Keywords:
Facial reconstruction
Facial soft tissue thickness
Magnetic resonance imaging
Sri Lanka

ABSTRACT

Facial soft tissue thickness (FSTT), together with the osteological characteristics of the skull, is one of the important factors for facial reconstruction in both forensic anthropology and plastic surgeries. Even though a number of countries around the world have analysed the FSTT data of their own populations and are having a FSTT database, no such dataset or analysis is available in Sri Lanka.

In this study, FSTT was measured at 23 standard anthropological landmarks using magnetic resonance images (MRIs) of 243 adult individuals (male — 121, female — 122) of the Sri Lankan population, which were collected from clinical data from the National Hospital of Sri Lanka. For each landmark, basic descriptive statistics were calculated. The FSTT values which were classified according to the gender and age, were analysed to assess the variation of FSTT with those categories.

The results of this study indicate that there are certain FSTT attributes which are related to specific landmarks and age groups. For example, data in this study depict that men have higher FSTT than women, in the area along the midline. However, the area around the cheeks shows comparatively large tissue thickness in young women (within 20–39 age range) than in men. Some landmarks indicate a significant variation in values with aging. Finally the results of this study were compared with that of a North West Indian study to evaluate whether a significant difference is present among the two geographically close countries.

1. Introduction

With the occurrence of natural disasters like tsunami or terrorist bombings, a country will be bestowed with piles of unidentified dead bodies. In all such tragic events which result in skeletonized, decomposed or badly mutilated human body remains, it is of utmost importance to uncover the identity of the deceased due to a number of reasons. In such instances the process of forensic facial reconstruction (FFR) comes into action. FFR is the process by which facial approximations are generated by using the skeletal remains of an individual. It is particularly utilized when other methods of identifications have failed, in order to aid in the identification process of forensic cases or to provide tangible impression of individuals in archeological cases. [1]

In today's context, the reconstruction of the face is done using computer based 3D graphic methods [2]. In this regard, the important fact to note is that, producing a face from the skull using facial reconstruction techniques relies on the relationship with the soft tissues covering the skull [3]. Prevalence of adequate facial soft tissue thickness (FSTT) data is essential to the accuracy of outputs of facial reconstruction. Such data forms one of the main basis of the computerized reconstruction process.

In the global context (especially in developed countries) studies have been conducted to establish FSTT measurements (databases) for different population groups [4–12]. These studies have mainly utilized ultrasound technology, computed tomography (CT) or magnetic resonance imaging (MRI) data to obtain the skin tissue thickness values.

When considering the Sri Lankan context, currently there is no repository at the national level which contains tissue thickness values for all age groups in Sri Lanka. Only a single pilot study has analyzed the skin tissue thickness patterns, pertaining to the Sri

* Corresponding author.
E-mail addresses: sandaminihimashi@gmail.com (H. Sandamini), uajaya8@gmail.com (A. Jayawardena), lthathsaranee@gmail.com (L. Batuwitage), rnr@ucsc.cmb.ac.lk (R. Rajapakse), ddk@ucsc.cmb.ac.lk (D. Karunaratna), mudithavidana@sjp.ac.lk (M. Vidanapathirana), m09714@pgim.cmb.ac.lk (A. Pallewatte).

https://doi.org/10.1016/j.forsciint.2018.10.001
0379-0738/

Lankan population of the 20–30 age category [13]. That is the only known study that has been done in relation to the collection and analysis of skin tissue thickness in the Sri Lankan context to the best of our knowledge. As the above study has only focused on a single tissue thickness category, many local medical officers have highlighted the national importance of a comprehensive set of data (FSTT) covering all age groups of Sri Lankan population.

The current study has considered adult age groups of the age range 20–59. Further, it aims at establishing a FSTT database from MRIs, and to form tissue thickness trends to be used in the context of local forensic reconstruction activities.

2. Materials and methods

The study consists of a sample of 223 MRIs and 20 volume MRIs of Sri Lankan adults within the age category 20–59 years. The sample was divided into 4 age groups: 20–29, 30–39, 40–49, and 50–59 as there is no substantial variation of FSTT within these age ranges having an interval of 10 years. Each age group consists of a minimum sample size of 30. MRI scans were obtained from the National Hospital of Sri Lanka (MRI hardware specifications: 3T MRI-Philips Ingenia (Best-Netherlands), slice thickness 1.5 mm Digital Imaging and Communications in Medicine (DICOM) parameters are TR/TE, FOV, Matrix) with the approval of the ethical committee of the National Hospital of Sri Lanka and with the provision that all the patient information obtained during the course of this study will be treated as strictly confidential. Patients with head trauma, fractures, swellings, asymmetries, distortions, malformations or any abnormality that could influence the shape of the face or thickness of the soft tissues and musculature, were eliminated from the sample [14]. Since there was a difficulty in obtaining FSTT measurements of most of the landmarks around the jaw area, a sample of 20 volume MRIs were also obtained from the National Hospital Colombo.

Table 1
Descriptions of the anatomical landmarks of the skull used for the current study [1,18,19].

Landmark name	Description
1. Bregma	The point where the coronal and sagittal sutures intersect
2. Glabella	Cross point between midline and supraorbital line
3. Nasion	Midpoint of the fronto nasal suture
4. End of nasal bone	Passage between bone and cartilage of the nose
5. Mid philtrum	Centered between nose and mouth on midline
6. Upper lip	Midline on the upper lip
7. Lower lip	Midline on the lower lip
8. Chin lip fold	Midline centered in fold chin, below lips
9. Mental eminence	Centered on forward most projecting point of chin
10. Beneath chin	The vertical measure of the soft tissue on the lower edge of the chin
11. Supra Orbital	A point above the orbit, centered on the uppermost margin or border of the orbit
12. Infra orbital	A point below the orbit, centered on the lowermost margin or border of the orbit
13. Ectoconchion	The intersection of the most anterior surface of the lateral border of the orbit and a line bisecting the orbit along its long axis.
14. Inferior malar	The lowest point on the suture between the zygomatic and maxillary bones
15. Supra-canine	Upper lip lined up superiorly/inferiorly with lateral edge of the nostril.
16. Infra-canine	Also known as sub canine. Lower lip lined up superiorly/inferiorly with lateral edge of the nostril.
17. Jugale	The point in the notch between the temporal and frontal process of the zygomatic bone
18. Zygomatic arch	A point on the maximum lateral outer curvature of the zygomatic bone.
19. Supra-glenoid	A point above and slightly forward of the external auditory meatus.
20. Mastoidale	A paired point at the inferior tip of the mastoid process.
21. Euryon	The most laterally positioned point on the side of the braincase
22. Supra M2	A landmark above the second maxillary molar
23. Sub M2	A landmark below the second mandibular molar

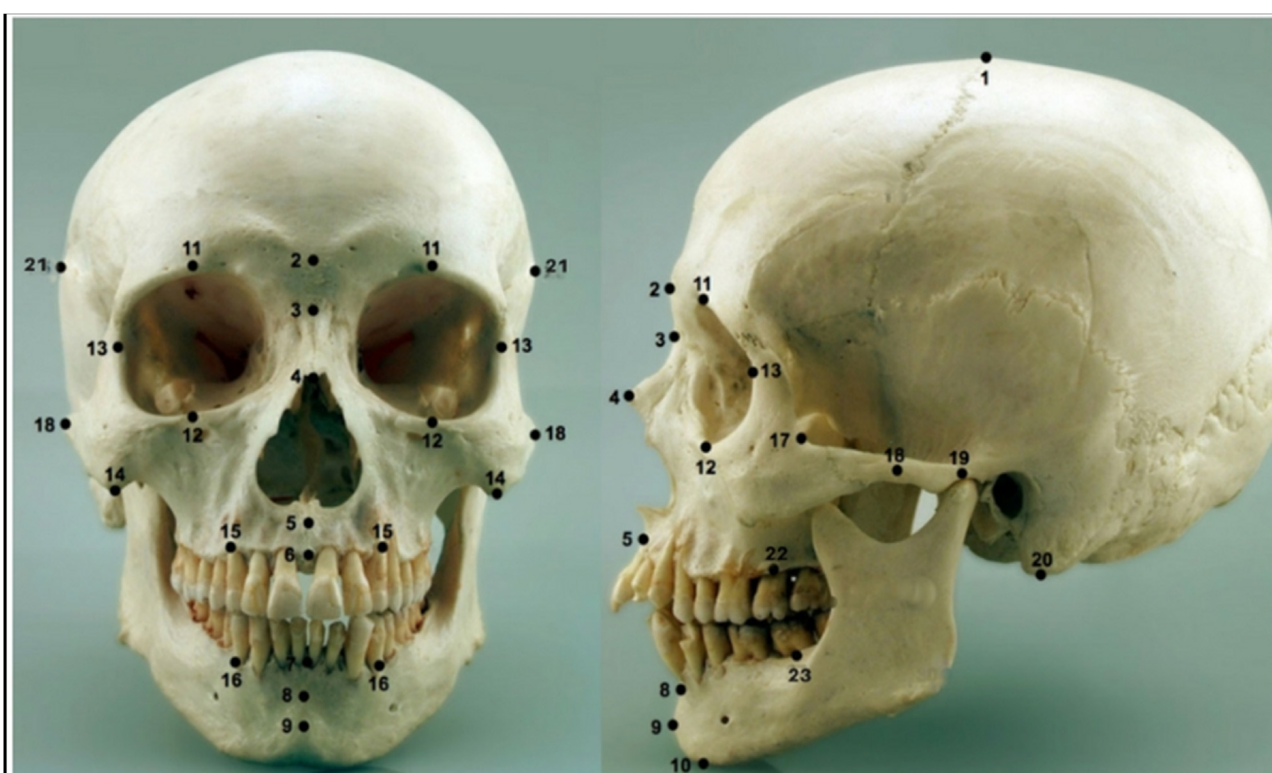

Fig. 1. Frontal and lateral view landmarks for markers measurements or locations of tissue depths.

All the MRI scans obtained for this study are of subjects taken from supine position. However Bulut et al. [15] has noted that it is in the upright position that an accurate representative of the FSTT can be obtained of anatomical landmarks using CT and MRI data. They further noted 7 landmarks in which the deviation of FSTT is high between upright and supine position measurements. This effect is to be analyzed in the local data sets in future studies.

After acquiring the DICOM images and prior to measuring, it was vital to perform image preprocessing as the clarity of bony and soft tissue regions of certain images was poor. Therefore Canny edge detection was performed on selected images using MATLAB R2013b [16] software, to improve clarity of the regions. After the edge detection, the boundary between the bone and soft tissue was made clear, in the selected images.

For this study tissue thickness of 23 facial landmarks were measured. These landmarks were defined and used traditionally in the area of facial soft tissue thickness measurement [17]. Here, an assumption was made that the face is bilaterally symmetrical. Therefore, when measuring the same landmark, only one side was selected from the lateral sides, depending on the level of clarity of the tissue thickness at the particular landmark (Fig. 1).

For the process of identifying facial landmarks from 2D MRI images and for tissue thickness measuring purposes, the domain knowledge was obtained from the experts in field of anatomy and forensic medical science and neuroradiology from University of Sri Jayewardenepura and National Hospital of Sri Lanka (Table 1).

Measurements were taken from the sagittal (Fig. 2), coronal and axial planes of MRIs using the Radiant DICOM Viewer software. In order to obtain clear measurements, both T1 and T2 views of the aforementioned plains were used. The required bony landmark was located on the hard tissue and then a tangent was created from the curve of the outer surface of the bony landmark (Line "A" in Fig. 3). A line was drawn perpendicular (measuring 90° from the bony landmark) to the tangent at the bony landmark and extended outwards to meet the facial skin surface (Line "B" in Fig. 3). The length of the perpendicular line from the bone to the junction with the skin surface was regarded as the equivalent FSTT of that landmark (as shown in Fig. 3). The FSTT recorded is the Euclidean distance between the bony landmark and its soft tissue [8].

Inter observer variability of the measurement of the three observers were calculated, in order to evaluate the measurement precision (reproducibility). To assess the inter observer variability, MRI scans from 10 subjects were selected randomly, and the measurements were repeated thrice by the three observers. Then then ANOVA F test was performed for these measurements using IBM SPSS 20 software (Table 2).

The results of the analysis indicated that for all the measurements, the level of significance (p value) [20] corresponding to ANOVA F test was greater than 0.05. Hence, the conclusion was made

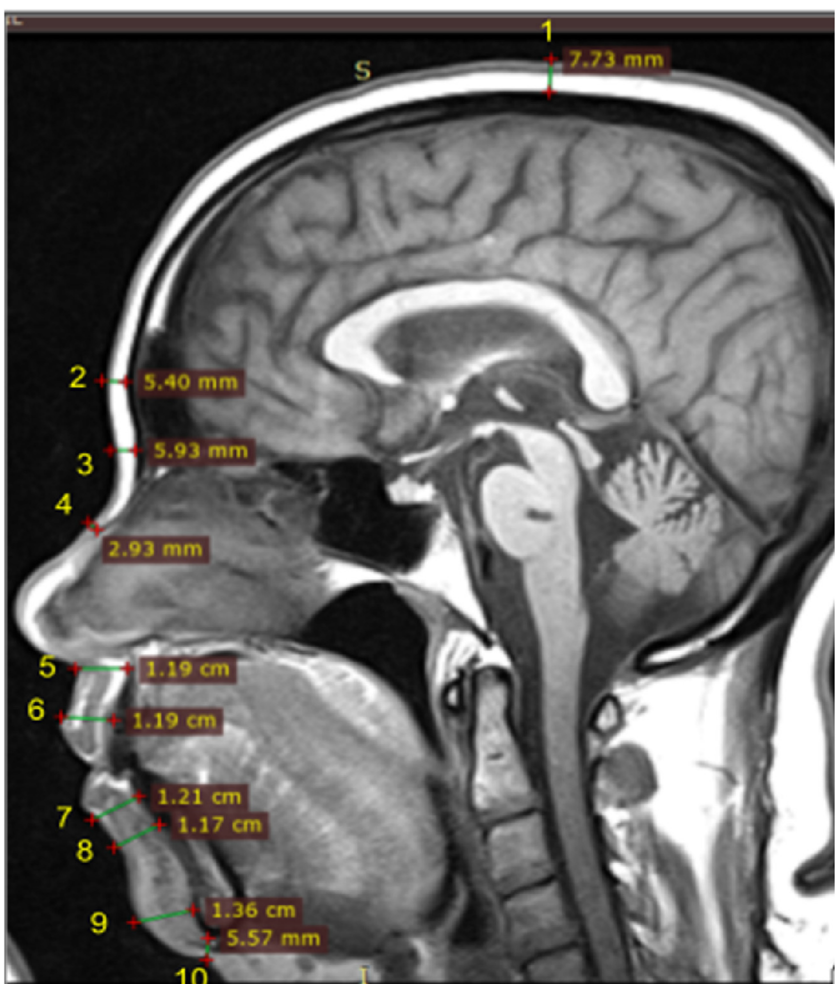

Fig. 2. Measurements taken from sagittal plane of MRI.

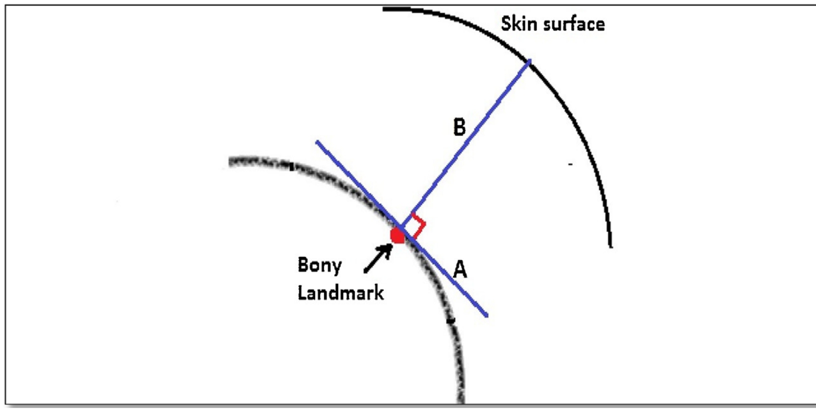

Fig. 3. Diagrammatic representation of establishing tissue thickness measurements.

that the differences between the mean values of the 3 observers were minimal and all the measurements were reproducible.

2.1. Statistical Analysis

The resulting measurement data were recorded and statistical analysis was done by IBM SPSS 20 software. Basic descriptive statistics such as the mean, standard deviation, range, maximum and minimum FSTT of males and females were calculated separately for each age group. Males and females were classified according to their age and variations in tissue thickness were compared against these 2 parameters (age and gender).

Prior to performing statistical tests the normality of the measured data was tested using, four normality tests namely Jarque–Bera test, Anderson–Darling test, Shapiro–Wilk's and Q–Q plot tests [21]. All the tests were performed from R x64 3.4.1 statistical software.

Graphical representations were created to illustrate the variation of FSTT between gender groups. For this purpose graphs were drawn by 'pchip' curve drawing technique using MATLAB R2013b software [22]. However, these graphical representations were performed only for the purpose of visualization and no calculations were solely on the graphs. Further analysis was performed statistically from independent t-test and one way ANOVA test using IBM SPSS Statistics 20 software. For the ANOVA test, the p value of 0.05 was considered as the level of significance. (The analysis was done for only 17 landmarks out of 23 for certain age groups due to data availability.)

A comparison of mean values of males and females at facial tissue depth landmarks was done in order to investigate any correlation existing between gender and tissue thickness groups. Also, graphical illustrations were created to compare the FSTT values within the four selected age groups (separately for 2 gender groups) in order to analyse the pattern of variation of the tissue thickness with aging.

3. Results

3.1. Normality

The four normality tests noted above were conducted separately for the data samples of 17 landmarks. Majority of the landmarks passed all the 4 normality tests while others passed more than 2 normality tests. This concluded that all the samples employed in this study are normally distributed.

3.2. Inter-observer variability

Table 2
Inter-observer variability of 10 selected subjects.

Landmarks	Observer 01			Observer 02			Observer 03			ANOVA p Value
	Mean ± S.D			Mean ± S.D			Mean ± S.D			
	Mean	S.D	Std. error	Mean	S.D	Std. error	Mean	S.D	Std. error	
Bregma	6.7875	0.4511	0.22555	6.83	1.04243	0.52122	6.93	0.92617	0.46309	0.971
Glabella	7.1917	0.42668	0.17419	7.0883	0.8652	0.35322	6.9883	1.03733	0.42349	0.912
Nasion	6.2633	0.88769	0.3624	6.415	1.16732	0.47656	6.535	0.93921	0.38343	0.897
End of nasal bone	4.8333	0.83392	0.34045	4.5933	1.15419	0.47119	4.3033	1.0275	0.41947	0.67
Mid-philtrum	12.1333	1.85867	0.7588	10.575	1.75052	0.71465	11.55	1.71901	0.70178	0.335
Upper lip margin	10.055	1.42284	0.58087	9.6117	1.41587	0.57803	10.74	2.04817	0.83616	0.509
Lower lip margin	12.0517	1.4893	0.608	12.05	1.6171	0.66018	10.8117	1.19232	0.48676	0.261
Chin-lip fold	11.62	2.09876	0.85682	12.0567	2.0498	0.83683	13	1.75385	0.71601	0.482
Mental eminence	13.1	2.91719	1.30461	12.9	2.88357	1.28957	13.76	2.86409	1.28086	0.887
Beneath chin	5.508	3.87106	1.73119	5.876	4.10352	1.83515	5.758	4.04968	1.81107	0.989
Supra orbital	9.8717	1.05876	0.43224	9.7033	1.84012	0.75122	9.2067	1.54554	0.63097	0.737
Infra orbital	9.035	1.04186	0.42534	9.7917	1.33056	0.5432	9.3833	1.20409	0.49157	0.562
Ectoconchion	5.392	0.7111	0.31802	5.528	1.95715	0.87526	5.664	1.37298	0.61402	0.957
Supra canine	12	1.66433	0.9609	11.9667	1.43643	0.82932	12	1.92873	1.11355	1
Jugale	11.5167	1.17884	0.48126	11.3033	1.69712	0.69285	12.5833	1.37756	0.56239	0.284
Zygomatic arch	11.855	2.45551	1.00246	12.0867	2.89862	1.18336	12.9183	3.06164	1.24991	0.792
Supra glenoid	15.5667	4.62284	1.88727	14.9667	3.86919	1.57959	16.8833	4.32084	1.76398	0.735
Euryon	6.0017	0.7295	0.29789	5.7267	0.72737	0.29695	5.515	0.68225	0.27853	0.511

3.3. Results of basic descriptive statistics

See Table 3.

3.4. Gender based differences

Below graphical representations (Figs. 4–7) show the variation of the FSTT between the 2 gender groups of the selected 4 age groups.

3.5. Age based differences

Below graphical representations (Figs. 8–9) show how FSTT differs with aging in the 2 gender groups.

3.6. Comparison with North West Indian population

Results of this study were compared with a North West Indian study [14] to evaluate the difference in related skin tissue thickness categories. An Indian study was selected due to the reason that it is a country geographically close to Sri Lanka and the availability of descriptive statistics in similar age groups.

When comparing the results of the Sri Lankan population and the North West Indian population, it demonstrated some differences between the FSTT values of the 2 populations. A Z-test analysis was performed to measure the level of deviation of North West Indian study with the Sri Lankan study. The result is significant at $p < 0.05$.

4. Discussion

The current study measured the facial soft tissue thickness of 23 standard anthropological landmarks through MRI images of a sample of Sri Lankan adult population with 243 individuals. The measured data analysis was done based on the categories of age, gender and country. What follows are some notable differences in the categories.

4.1. Gender based differences

With regard to the comparisons performed in gender groups, typically, men have higher FSTT than women. The area along the midline of males shows a higher FSTT than female (Table 4). However the area around the cheeks (represented by Jugale, Zygomatic Arch and Supra Glenoid) shows comparatively large tissue thickness in young women (within 20–39 age range) than in men (Table 4). The reason for men having a higher FSTT than women, as stated in other studies is the presence of larger skulls and larger muscle attachments in men than women [23]. Researchers have recognized that fundamental differences which exist in facial tissue depths between the gender groups are due to the differences in skull morphology.

4.2. Age based differences

The analysis of the variation of the FSTT between the age groups shows variable patterns among the age groups. (E.g. Highest FSTTs

Table 3
Statistical analysis of facial tissue thickness (mm) for all age groups.

Landmark	Sex	20–29 M (n = 17) F (n = 19)		30–39 M (n = 22) F (n = 29)		40–49 M (n = 28) F (n = 27)		50–59 M (n = 39) F (n = 37)	
		Mean	Std. deviation	Mean	Std. deviation	Mean	Std. deviation	Mean	Std. deviation
Bregma	M	6.25	1.08	6.27	1.76	6.41	1.65	6.02	0.97
	F	7.07	1.04	6.57	1.28	6.44	1.18	6.78	1.34
Glabella	M	5.83	0.82	5.97	0.55	6.58	1.53	6.31	0.90
	F	5.55	0.78	5.90	1.50	5.61	0.87	6.35	1.19
Nasion	M	7.00	1.59	7.09	1.11	7.53	1.54	6.83	1.40
	F	5.88	0.98	6.12	1.36	5.8	0.99	6.22	1.47
End of nasal bone	M	3.39	0.45	3.34	0.51	3.30	0.66	3.26	0.47
	F	2.77	0.30	2.89	0.75	2.78	0.54	3.49	0.91
Mid philtrum	M	15.17	1.98	14.54	1.88	13.72	1.53	12.85	1.35
	F	13.30	1.43	11.54	2.81	11.81	1.56	10.93	1.39
Upper lip margin	M	12.97	1.18	12.29	1.22	11.64	1.48	10.85	1.55
	F	11.37	1.311	10.38	1.67	9.06	1.26	8.94	0.99
Lower lip margin	M	11.49	1.54	12.078	0.96	12.72	2.16	11.62	1.56
	F	11.35	1.22	10.33	1.78	9.09	2.32	10.42	1.08
Chin-lip fold	M	12.34	1.64	13.02	1.24	13.61	2.05	12.54	1.64
	F	11.49	2.08	12.01	1.70	12.04	1.79	11.94	1.45
Mental eminence	M	12.04	2.56	13.13	1.80	13.15	1.84	11.71	1.67
	F	11.75	2.38	11.70	2.46	10.35	1.92	11.37	3.34
Beneath chin	M	7.56	2.50	7.68	2.49	7.37	1.54	7.42	1.54
	F	5.41	0.99	6.64	2.31	5.86	1.30	5.96	1.32
Supra orbital	M	7.65	1.23	8.67	2.18	9.45	1.40	7.91	1.33
	F	7.80	1.03	7.80	2.057	8.63	1.17	8.36	1.38
Infra orbital	M	6.19	1.09	6.75	1.00	7.59	2.27	6.44	1.10
	F	6.84	1.64	6.63	2.10	7.40	1.51	7.48	1.38
Ectoconchion	M	4.27	0.53	4.64	1.05	5.21	1.11	4.82	0.76
	F	4.83	1.15	5.05	1.28	4.81	1.14	5.21	0.83
Jugale	M	7.18	0.99	8.21	1.71	8.99	2.45	8.34	1.78
	F	9.00	3.99	10.27	2.43	9.25	1.94	10.27	2.41
Zygomatic arch	M	7.62	1.51	8.94	2.10	10.32	3.51	9.14	2.21
	F	9.49	4.76	10.65	2.14	9.53	2.60	11.03	3.03
Supra glenoid	M	11.60	2.40	11.62	1.50	12.60	2.24	12.49	2.06
	F	13.20	3.48	12.85	4.22	11.61	2.82	12.97	2.82
Euryon	M	4.99	0.83	5.25	1.08	5.12	0.99	5.15	1.11
	F	5.09	0.96	4.92	0.70	4.95	0.91	5.41	0.60

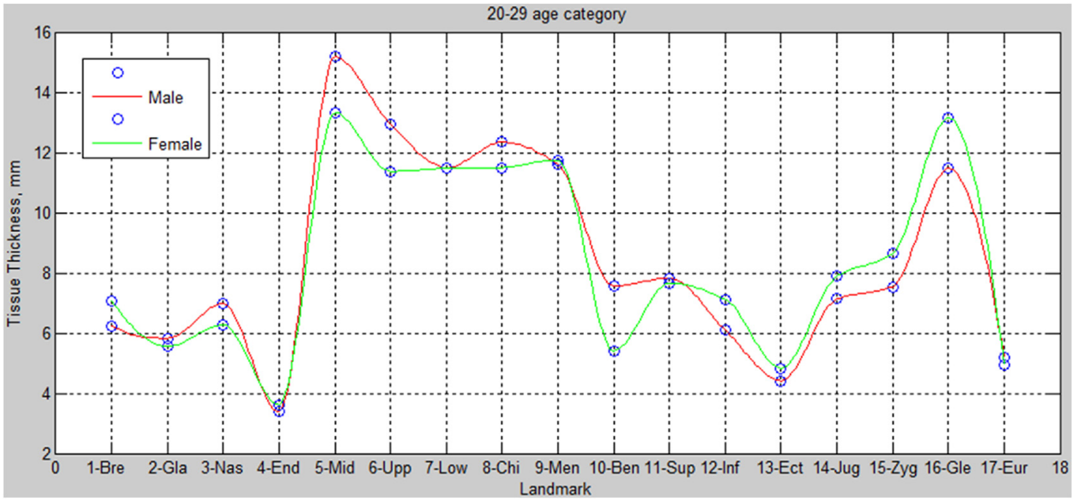

Fig. 4. Variation of FSTT of both genders for 20–29 age range.

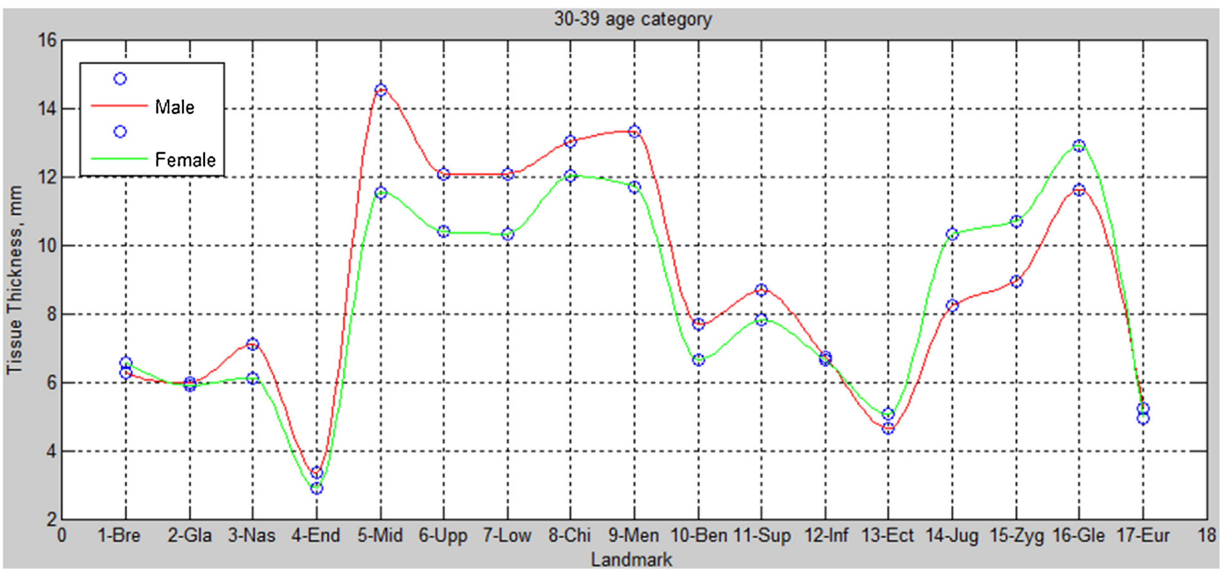

Fig. 5. Variation of FSTT of both genders for 30–39 age range.

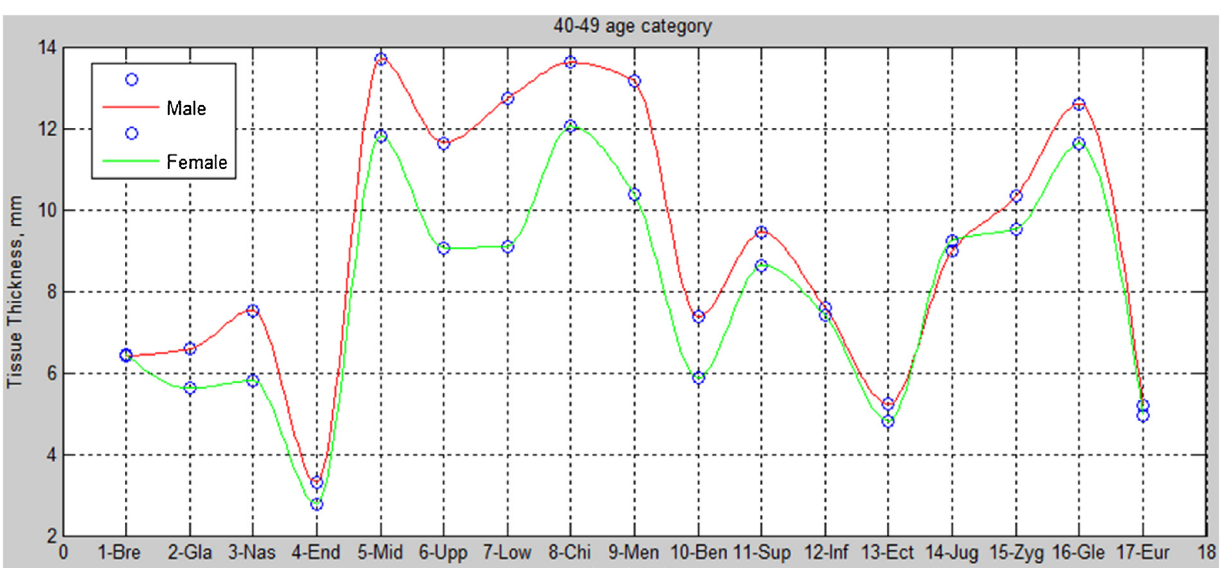

Fig. 6. Variation of FSTT of both genders for 40–49 age range.

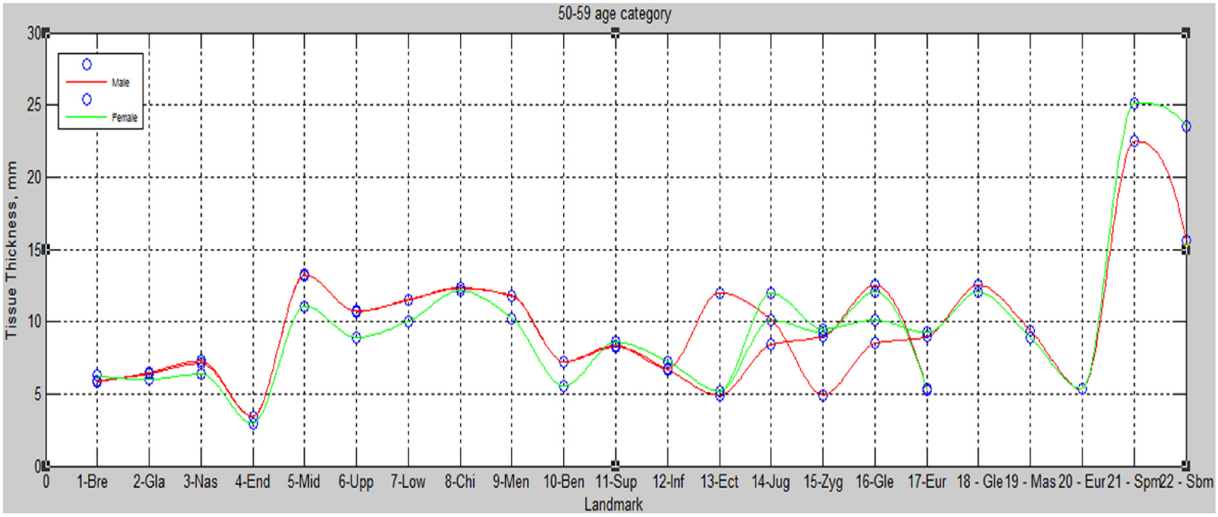

Fig. 7. Variation of FSTT of both genders for 50–59 age range.

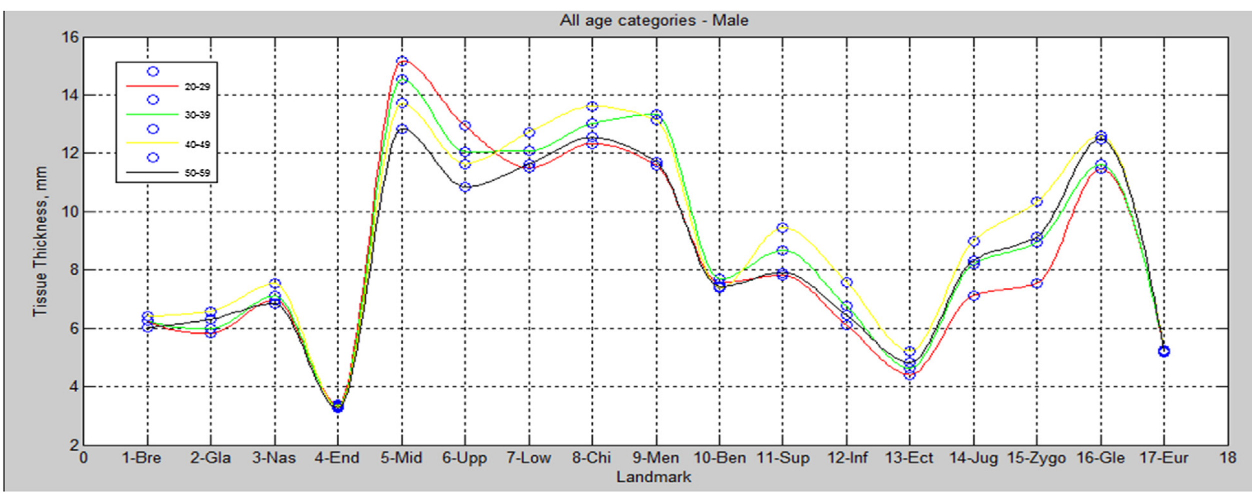

Fig. 8. Variation of FSTT with aging — male population.

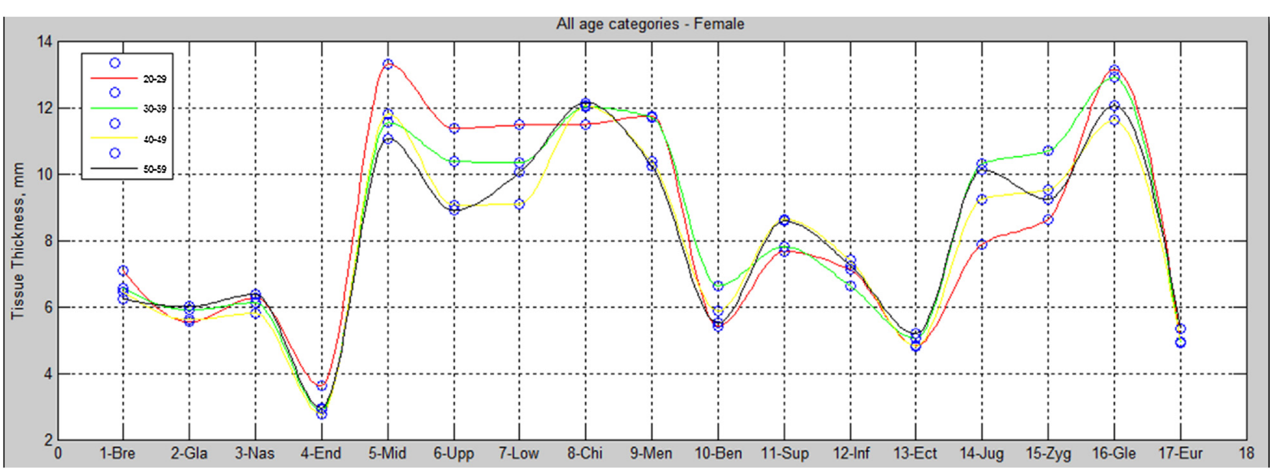

Fig. 9. Variation of FSTT with aging — female population.

Table 4
Results of the statistical analysis (Independent t-test) of FSTT (mm) variation between two gender groups.

Landmark	p Value			
	20–29 Age group	30–39 Age group	40–49 Age group	50–59 Age group
Bregma	0.070	0.482	0.482	0.224
Glabella	0.725	0.919	0.932	0.122
Nasion	0.048	0.032	0.032	0.061
End of nasal bone	0.008	0.534	0.534	0.025
Mid philtrum	0.008	0.001	0.001	0.000
Upper lip margin	0.006	0.001	0.001	0.000
Lower lip margin	0.668	0.002	0.002	0.000
Chin-lip fold	0.205	0.075	0.075	0.719
Mental eminence	0.738	0.107	0.107	0.067
Beneath chin	0.114	0.281	0.281	0.000
Supra orbital	0.870	0.201	0.201	0.608
Infra orbital	0.238	0.820	0.820	0.252
Ectoconchion	0.221	0.288	0.288	0.165
Supra canine	–	0.028	0.028	0.988
Jugale	0.205	0.067	0.028	0.002
Zygomatic arch	0.236	0.302	0.302	0.713
Supra Glenoid	0.234	–	–	0.425
Euryon	0.849	0.273	0.273	0.892

at landmarks are shown by the males within the age range 40–49; this is not the case in females) (Fig. 7, Table 5). Also, it shows that FSTTs at Mid Philtrum and Upper Lip margin landmarks gradually decrease with aging in both genders (Figs. 7, 8, Table 5).

The FSTT at some landmarks increase or decrease with aging while some do not show any significant pattern. These differences of the tissue thickness may be attributed to the variation of the deposition of fat with aging (Tables 6–9).

Also in a study by Kaur et al. [24], the researchers have explained several causes for the variation of FSTT with aging. Among them they have showed that skin related deformations associated with the introduction of wrinkles and the reduction of muscle strength with aging, affects the decrease of FSTT.

4.3. Comparison with the North West Indian population

According to the Z test analysis and the p value calculation, it showed that all male age groups of North West Indian population have less significant difference in Lower Lip margin and beneath Chin areas when compared with the Sri Lankan population.

When comparing the female population of North West Indians with the Sri Lankan females, the Nasion area showed less significant difference across all age groups. The difference in the Lower Lip margin gets increased with the age of the female population. Yet the difference is significant when compared with other landmarks. In 40–49 and 50–59 age groups of female population, beneath Chin area showed less significant difference.

Even difference of the Ectoconchion area is less significant in both male and female populations of both Sri Lankan and North West Indian populations, when compared with other landmarks, with the age it showed an increase.

Therefore, it can be said that the North West Indian population shows minimal variations of the tissue thickness values in some landmarks when compared with the Sri Lankan population, which

Table 5
Results of the statistical analysis (one way ANOVA) of FSTT (mm) variation between two gender groups within four age groups.

Landmark		p Value											
		20–29			30–39			40–49			50–59		
		30–39	40–49	50–59	20–29	40–49	50–59	20–29	30–39	50–59	20–29	30–39	40–49
Bregma	M	0.988	1.000	0.627	0.988	0.988	0.314	1.000	0.988	0.418	0.627	0.314	0.418
	F	0.674	0.397	0.124	0.674	0.942	0.532	0.397	0.942	0.870	0.124	0.532	0.870
Glabella	M	0.999	0.353	0.400	0.999	0.374	0.422	0.353	0.374	0.995	0.400	0.422	0.995
	F	0.638	0.998	0.631	0.638	0.616	1.000	0.998	0.616	0.609	0.631	1.000	0.609
Nasion	M	0.997	0.844	0.985	0.997	0.916	0.913	0.844	0.916	0.433	0.985	0.913	0.433
	F	0.825	0.998	0.729	0.825	0.591	0.996	0.998	0.591	0.464	0.729	0.996	0.464
End of nasal bone	M	0.774	0.982	0.775	0.774	0.893	0.999	0.982	0.893	0.901	0.775	0.999	0.901
	F	0.534	1.000	0.745	0.534	0.382	0.977	1.000	0.382	0.635	0.745	0.977	0.635
Mid-philtrum	M	0.600	0.086	0.002	0.600	0.659	0.054	0.086	0.659	0.443	0.002	0.054	0.443
	F	0.069	0.139	0.003	0.069	0.986	0.540	0.139	0.986	0.353	0.003	0.540	0.353
Upper lip	M	0.770	0.041	0.001	0.770	0.274	0.010	0.041	0.274	0.519	0.001	0.010	0.519
	F	0.193	0.000	0.000	0.193	0.002	0.001	0.000	0.002	0.997	0.000	0.001	0.997
Lower lip	M	0.847	0.112	0.720	0.847	0.430	0.999	0.112	0.430	0.333	0.720	0.999	0.333
	F	0.412	0.001	0.099	0.412	0.028	0.769	0.001	0.028	0.249	0.099	0.769	0.249
Chin-lip-fold	M	0.996	0.198	0.983	0.996	0.231	0.999	0.198	0.231	0.140	0.983	0.999	0.140
	F	0.840	0.811	0.431	0.840	1.000	0.833	0.811	1.000	0.878	0.431	0.833	0.878
Mental eminence	M	0.215	0.285	0.824	0.215	0.988	0.006	0.285	0.998	0.005	0.824	0.006	0.005
	F	1.000	0.222	0.805	1.000	0.102	0.711	0.222	0.102	0.595	0.805	0.711	0.595
Beneath chin	M	0.219	0.561	0.187	0.219	0.838	0.997	0.561	0.838	0.865	0.187	0.997	0.865
	F	0.095	0.834	0.674	0.095	0.283	0.459	0.834	0.283	0.987	0.674	0.459	0.987
Supra orbital	M	0.224	0.005	0.615	0.224	0.428	0.703	0.005	0.428	0.016	0.615	0.703	0.016
	F	1.000	0.464	0.512	1.000	0.282	0.326	0.464	0.282	1.000	0.512	0.326	1.000
Infra orbital	M	0.771	0.042	0.900	0.771	0.280	0.970	0.042	0.280	0.043	0.900	0.970	0.043
	F	1.000	0.816	0.914	1.000	0.731	0.872	0.816	0.731	0.993	0.914	0.872	0.993
Ectoconchion	M	0.611	0.021	0.025	0.611	0.289	0.372	0.021	0.289	0.986	0.025	0.372	0.986
	F	0.943	1.000	0.798	0.943	0.877	0.973	1.000	0.877	0.650	0.798	0.973	0.650
Jugale	M	0.238	0.035	0.178	0.238	0.855	0.999	0.035	0.855	0.688	0.178	0.999	0.688
	F	0.148	0.945	0.373	0.148	0.236	0.925	0.945	0.236	0.583	0.373	0.925	0.583
Zygomatic arch	M	0.291	0.018	0.087	0.291	0.631	0.980	0.018	0.631	0.743	0.087	0.980	0.743
	F	0.586	0.986	1.000	0.586	0.686	0.370	0.986	0.686	0.960	1.000	0.370	0.960
Supra glenoid	M	1.000	0.596	0.669	1.000	0.548	0.620	0.596	0.548	0.995	0.669	0.620	0.995
	F	0.979	0.616	0.863	0.979	0.743	0.964	0.616	0.743	0.950	0.863	0.964	0.950
Euryon	M	0.949	0.957	0.970	0.949	1.000	0.998	0.957	1.000	0.999	0.970	0.998	0.999
	F	0.934	0.968	0.703	0.934	0.999	0.183	0.968	0.999	0.260	0.703	0.183	0.260

Table 6
Results of the Z- test analysis of tissue thickness comparison of Sri Lankan and North West Indian sample groups (20–29 age group).

Landmark	20–29 Male					20–29 Female				
	Sri Lankan	North West Indian	Difference	Z statistic	p Value	Sri Lankan	North West Indian	Difference	Z statistic	p Value
Bregma	6.25	3.52	2.73	N/A	N/A	7.07	3.67	3.40	11.32775511	<0.00001
Glabella	5.83	4.97	0.86	3.44941896	0.000562	5.54	5	0.54	2.26450827	0.023543
Nasion	6.97	5.75	1.22	2.611808757	0.009007	5.88	5.58	0.30	1.511730115	0.13061
End of nasal bone	3.39	2.1	1.29	9.757154026	<0.00001	2.70	2.01	0.69	3.707465636	0.000209
Mid philtrum	15.17	12.02	3.15	5.076726326	<0.00001	13.30	11.01	2.29	4.921176791	<0.00001
Upper lip margin	12.92	10.41	2.51	6.376754676	<0.00001	11.08	10.04	1.04	3.201363296	0.001368
Lower lip margin	11.49	11.4	0.09	0.2053835293	0.837338	11.46	11.42	0.04	0.1227812527	0.902345
Chin-lip fold	12.34	8.13	4.21	8.155277397	<0.00001	11.49	8.65	2.84	4.753892944	<0.00001
Mental eminence	11.60	8.6	3.00	3.071637869	0.002129	11.75	8.9	2.85	3.676214612	0.000237
Beneath chin	7.56	7.02	0.54	0.5270682642	0.598194	5.41	6.55	−1.14	−3.279509186	0.001042
Supra orbital	7.82	7.17	0.65	1.888192898	0.059013	7.66	6.38	1.28	4.14598543	3.40E-05
Infra orbital	6.09	4.56	1.53	5.724173626	<0.00001	7.11	4.51	2.60	5.704213026	<0.00001
Ectoconchion	4.41	4.58	−0.17	−1.170564585	0.242001	4.83	4.54	0.29	0.8992493132	0.368546
Jugale	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zygomatic arch	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Supra glenoid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 7
Results of the Z-test analysis of tissue thickness comparison of Sri Lankan and North West Indian sample groups (30–39 age group).

Landmark	30–39 Male					30–39 Female				
	Sri Lankan	North West Indian	Difference	Z statistic	p Value	Sri Lankan	North West Indian	Difference	Z statistic	p Value
Bregma	6.27	3.6	2.67	5.795296104	<0.00001	6.56	3.67	2.89	11.24305094	<0.00001
Glabella	5.97	5.35	0.62	3.149167588	0.001638	5.90	5.66	0.24	0.7628617537	0.445583
Nasion	7.09	5.87	1.22	3.887158955	0.000101	6.12	5.9	0.22	0.7552843913	0.450129
End of nasal bone	3.34	2.11	1.23	9.450084915	<0.00001	2.89	2.04	0.85	5.690934915	<0.00001
Mid philtrum	14.54	12.14	2.40	4.451397632	<0.00001	11.54	10.82	0.72	1.157374782	0.24715
Upper lip margin	12.29	10.57	1.72	3.751959075	0.000175	10.38	10.11	0.27	0.7494631656	0.453616
Lower lip margin	12.078	11.7	0.378	1.199364519	0.230411	10.33	10.84	−0.51	−1.19453862	0.232478
Chin-lip fold	13.02	9.03	3.99	10.78152021	<0.00001	12.01	8.76	3.25	8.323117066	<0.00001
Mental eminence	13.13	9.65	3.48	7.334316652	<0.00001	11.70	8.59	3.11	5.917654332	<0.00001
Beneath chin	7.68	7.97	−0.29	−0.4220086032	0.673025	6.64	6.64	0	0	1
Supra orbital	8.67	7.13	1.54	2.779573985	0.005444	7.80	6.79	1.01	2.390607519	0.016821
Infra orbital	6.75	4.71	2.04	7.851400469	<0.00001	6.63	4.49	2.14	5.157754359	<0.00001
Ectoconchion	4.64	4.54	0.10	0.3366423895	0.736418	5.05	4.59	0.46	1.756493263	0.07902
Jugale	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zygomatic arch	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Supra glenoid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 8
Results of the Z-test analysis of tissue thickness comparison of Sri Lankan and North West Indian sample groups (40–49 age group).

Landmark	40–49 Male					40–49 Female				
	Sri Lankan	North West Indian	Difference	Z statistic	p Value	Sri Lankan	North West Indian	Difference	Z statistic	p Value
Bregma	6.41	3.57	2.84	3.704486576	0.000212	6.44	3.65	2.79	10.86881001	<0.00001
Glabella	6.58	5.33	1.25	5.359961824	<0.00001	5.61	5.45	0.16	0.6424102643	0.520613
Nasion	7.53	5.75	1.78	8.741583611	<0.00001	5.8	5.92	−0.12	−0.4803696854	0.631227
End of nasal bone	3.30	2.04	1.26	4.741908476	<0.00001	2.78	2.07	0.71	6.078796876	<0.00001
Mid philtrum	13.72	11.89	1.83	2.384402476	0.017107	11.81	10.37	1.44	3.196846074	0.00139
Upper lip margin	11.64	10.64	1.00	2.188077484	0.02867	9.06	10.01	−0.95	−2.661581177	0.007791
Lower lip margin	12.72	11.55	1.17	8.460303595	<0.00001	9.09	10.63	−1.54	−2.604800978	0.009214
Chin-lip fold	13.61	9.32	4.29	8.061350085	<0.00001	12.04	8.88	3.16	7.048615244	<0.00001
Mental eminence	13.15	9.22	3.93	−1.425694074	0.142921	10.35	9	1.35	2.830643143	0.004646
Beneath chin	7.37	8.04	−0.67	7.552015074	<0.00001	5.86	6.73	−0.87	−2.367043408	0.017933
Supra orbital	9.45	7.15	2.30	6.316076542	<0.00001	8.63	6.68	1.95	6.860126136	<0.00001
Infra orbital	7.59	4.63	2.96	2.745999411	0.006033	7.40	4.67	2.73	8.533561716	<0.00001
Ectoconchion	5.21	4.5	0.71	0.3366	0.736418	4.81	4.6	0.21	0.8232811987	0.410394
Jugale	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zygomatic arch	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Supra glenoid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 9
Results of the Z- test analysis of tissue thickness comparison of Sri Lankan and North West Indian sample groups (50–59 age group).

Landmark	50–59 Male					50–59 Female				
	Sri Lankan	North West Indian	Difference	Z statistic	p Value	Sri Lankan	North West Indian	Difference	Z statistic	p Value
Bregma	6.02	3.51	2.51	13.10843053	<0.00001	6.78	3.68	3.10	10.29353084	<0.00001
Glabella	6.31	5.19	1.12	5.803768442	<0.00001	6.35	4.94	1.41	5.162327118	<0.00001
Nasion	6.83	5.99	0.84	3.091947942	0.001989	6.22	5.76	0.46	1.438680878	0.150264
End of nasal bone	3.26	2.08	1.18	15.65368378	<0.00001	3.49	1.99	1.50	7.676246418	<0.00001
Mid philtrum	12.85	11.19	1.66	5.243240679	<0.00001	10.93	9.05	1.88	3.52641037	0.000421
Upper lip margin	10.85	9.88	0.97	3.000459185	0.002696	8.94	9.75	−0.81	−2.156961619	0.031084
Lower lip margin	11.62	11.51	0.11	0.3508114721	0.725738	10.42	10.83	−0.41	−1.302694513	0.192916
Chin-lip fold	12.54	9.01	3.53	10.60621765	<0.00001	11.94	8.24	3.70	7.804058428	<0.00001
Mental eminence	11.71	8.97	2.74	6.997212093	<0.00001	11.37	8.83	2.54	5.325846125	<0.00001
Beneath chin	7.42	7.39	0.03	0.07400880022	0.94101	5.96	6.49	−0.53	0.06860258316	0.945308
Supra orbital	7.91	6.83	1.08	3.849252503	0.000119	8.36	6.69	1.67	8.913335256	<0.00001
Infra orbital	6.44	4.63	1.81	8.513861954	<0.00001	7.48	4.45	3.03	13.87369492	<0.00001
Ectoconchion	4.82	4.35	0.47	2.922327694	0.003475	5.21	4.51	0.70	5.319156474	<0.00001
Jugale	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zygomatic arch	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Supra glenoid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

can be used for the further analysis of the tissue thickness patterns among these countries.

5. Conclusion

In conclusion, facial skin tissue thickness trends for male and female populations of the 20–59 age group in Sri Lanka were explored by this research. The study presented the basic descriptive statistics for each age group and evaluated the statistical significance of FSTT measurements within age and gender groups of the Sri Lankan adult population.

From the analysis conducted in the study, it was found that men generally have higher FSTT than women in certain landmarks. For example the area along the midline of males always shows higher FSTT than females. However, this trend is not true to all landmarks and age groups. One instance is the area around the cheeks which show comparatively large tissue thickness in young women (within 20–39 age range) than in men. The reason for the observation above (men having higher FSTT), may be due to the presence of larger skulls and larger muscles attachment in males than females.

With aging some landmarks show a regular pattern of variation while some do not show this trend. In both males and females FSTTs at points like Mid Philtrum and Upper Lip Margin gradually decrease with the age. In females the FSTTs at Supra Orbital, Jugale, Zygomatic Arch and Supra Glenoid landmark increase with age.

Finally the comparison of the data collected in this project, with that of a north west Indian study did not result in significant variations in the FSTT values.

With the FSTT values established through this study, the intention is to set up a national level FSTT database to be utilized in forensic facial reconstruction projects. As future work, the authors are currently applying learning methods (regression tree analysis and random forest regression) to devise missing FSTT values within certain age ranges where clinical data is difficult to be obtained. Also, the current research can be extended further toward a full analysis by considering the body mass index (BMI) value of the individuals, which plays an important role in forming the FSTT.

Author contribution statement

Himashi Sandamini—Conceptualization; Data curation; Formal analysis Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing

Aparni Jayawardena—Conceptualization; Data curation; Formal analysis Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing

Lochana Batuwitage—Conceptualization; Data curation; Formal analysis Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing

Roshan Rajapakse—Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Writing – review & editing

Damith Karunaratne—Data curation; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Writing – review & editing

Muditha Vidanapathirana—Data curation; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Writing – review & editing

Aruna Pallewatte—Data curation; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Writing – review & editing

Acknowledgement

The data collection and measurement stages of this project was supported by the University of Sri Jayewardenepura, Sri Lanka. The authors are grateful for Dr. P.H. Dissanayeka and Dr. Sajith Edirisinghe of the Department of Anatomy, Faculty of Medical Sciences, and University of Sri Jayewardenepura for providing guidance in the measuring activities. Further, they are indebted to Dr. Chandima Thilakaratne of Department of Statistics, University of Colombo for providing assistance in relation to the statistical analysis activities.

References

[1] C. Wilkinson, Forensic Facial Reconstruction, first ed., Cambridge University Press, Cambridge, 2008.
[2] S. Decker, J. Ford, Accuracy and reliability of soft tissue depth measurements from CT for forensic facial reconstruction, J. Forensic Radiol. Imaging 1 (2013) 82, doi:http://dx.doi.org/10.1016/j.jofri.2013.03.009.
[3] W.N.J. Chan, G.A. Listi, M.H. Manhein, In vivo facial tissue depth study of Chinese-American adults in New York city, J. Forensic Sci. 56 (2011) 350–358, doi:http://dx.doi.org/10.1111/j.1556-4029.2010.01640.x.
[4] M.H. Manhein, G.A. Listi, E. Barsley, R. Musselman, N. Eileen Barrow, D.H. Ubelaker, In-vivo facial depth measurements for children and adults, J. Forensic Sci. 45 (2000) 48–60, doi:http://dx.doi.org/10.1520/jfs14640j.
[5] O. Bulut, S. Sipahioglu, B. Hekimoglu, Facial soft tissue thickness database for craniofacial reconstruction in the Turkish adult population, Forensic Sci. Int. 242 (2014) 44–61, doi:http://dx.doi.org/10.1016/j.forsciint.2014.06.012.

[6] F. Chen, Y. Chen, Y. Yu, Y. Qiang, M. Liu, D. Fulton, T. Chen, Age and sex related measurement of craniofacial soft tissue thickness and nasal profile in the Chinese population, Forensic Sci. Int. 212 (2011), doi:http://dx.doi.org/10.1016/j.forsciint.2011.05.027 272. e1–272. e6.
[7] D. Cavanagh, M. Steyn, Facial reconstruction: soft tissue thickness values for South African black females, Forensic Sci. Int. 206 (2011), doi:http://dx.doi.org/10.1016/j.forsciint.2011.01.009 215.e1–215.e7.
[8] T.R. Peckmann, M. Harris, M. Huculak, A. Pringle, M. Fournier, In vivo facial tissue depth for Canadian Mi'kmaq adults: a case study from Nova Scotia, Canada, J. Forensic Leg. Med. 29 (2015) 43–53, doi:http://dx.doi.org/10.1016/j.jflm.2014.12.004.
[9] A. Lodha, M. Mehta, M.N. Patel, S.K. Menon, Facial soft tissue thickness database of Gujarati population for forensic craniofacial reconstruction, Egypt J. Forensic Sci. 6 (2016) 126–134, doi:http://dx.doi.org/10.1016/j.ejfs.2016.05.010.
[10] T. Saxena, S.R. Panat, N.C. Sangamesh, A. Choudhary, A. Aggarwal, N. Yadav, Facial soft tissue thickness in North Indian adult population, J. Indian Acad. Oral Med. Radiol. 24 (2012) 121–125, doi:http://dx.doi.org/10.5005/jp-journals-10011-1275.
[11] F. Tilotta, F. Richard, J. Glaunès, M. Berar, S. Gey, S. Verdeille, Y. Rozenholc, J.F. Gaudy, Construction and analysis of a head CT-scan database for craniofacial reconstruction, Forensic Sci. Int. 191 (2009) 1–12, doi:http://dx.doi.org/10.1016/j.forsciint.2009.06.017.
[12] J.H. Chung, H.T. Chen, W.Y. Hsu, G.S. Huang, K.P. Shaw, A CT-scan database for the facial soft tissue thickness of Taiwan adults, Forensic Sci. Int. 253 (2015), doi:http://dx.doi.org/10.1016/j.forsciint.2015.04.028 132.e1–132.e11.
[13] R.N. Rajapakse, A.K. Madugalla, I. Amarasinghe, A.T. Padmathilake, V.H. Dharmaratne, D. Sandaruwan, M. Vidanapathirana, Facial muscle anatomy based approach for forensic facial reconstruction in Sri Lanka, Int. Conf. Adv. ICT Emerg. Reg. (2012) 27–35, doi:http://dx.doi.org/10.1109/icter.2012.6422828.
[14] D. Sahni, Sanjeev, G. Singh, I. Jit, P. Singh, Facial soft tissue thickness in Northwest Indian adults, Forensic Sci. Int. 176 (2008) 137–146, doi:http://dx.doi.org/10.1016/j.forsciint.2007.07.012.
[15] O. Bulut, C. Jessica Liu, F. Koca, C. Wilkinson, Comparison of three-dimensional facial morphology between upright and supine positions employing three-dimensional scanner from live subjects, Leg. Med. 27 (2017) 32–37, doi:http://dx.doi.org/10.1016/j.legalmed.2017.06.002.
[16] Mathworks.Com, Edge Detection-MATLAB & Simulink, http://www.mathworks.com/help/images/edge-detection.html. (Accessed 26 September 2018).
[17] S.N. Byers, Introduction to Forensic Anthropology, fifth ed., Routledge, London, 2017.
[18] N.R. Langley, L.M. Jantz, S.D. Ousley, R.L. Jantz, G. Milner, Data collection procedures for forensic skeletal material 2.0, 2016. https://fac.utk.edu/wp-content/uploads/2016/03/DCP20_webversion.pdf.
[19] N. von Cramon-Taubadel, Revisiting the homoiology hypothesis: the impact of phenotypic plasticity on the reconstruction of human population history from craniometrics data, J. Hum. Evol. 57 (2009) 179–190, doi:http://dx.doi.org/10.1016/j.jhevol.2009.05.009.
[20] M. Ibrahim, The significance of P-value in medical research, J. Allied Health Sci. Pak. 1 (2015) 74–85.
[21] Spider Financial, Normality test — facts and myths. http://www.spider-financial.com/support/documentation/numxl/tips-and-tricks/normality-test-facts-and-myths. (Accessed 20 December 2017)
[22] University of Virginia Library, Understanding Q–Q Plots, (2015) https://data.library.virginia.edu/understanding-q-q-plots/. (Accessed 18 December 2017).
[23] S. Rhine, Tissue Thickness for Southwestern Indians [dissertation], Physical Anthropology Laboratories, University of New Mexico, New Mexico, 1983, pp. 62–63, doi:http://dx.doi.org/10.1086/newmexianthr.2.3.4291169.
[24] M. Kaur, R.K. Garg, S. Singla, Analysis of facial soft tissue changes with aging and their effects on facial morphology: a forensic perspective, Egypt. J. Forensic Sci. 5 (2015) 46–56, doi:http://dx.doi.org/10.1016/j.ejfs.2014.07.006.