

FACIAL SOFT TISSUE THICKNESS (FSTT) AND ITS SEXUAL DIMORPHISM IN A MALAYSIAN SAMPLE: A CT-BASED APPROACH

KETEBALAN TISU LEMBUT WAJAH (FSTT) DAN DIMORFISME SEKSUAL DALAM SAMPEL POPULASI MALAYSIA: PENDEKATAN BERASASKAN IMBASAN CT

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ABSTRAK

Facial soft tissue thickness (FSTT) is a crucial element in forensic identification and facial reconstruction. Exploring its variations according to different sexes provides valuable information that is needed for an accurate identification. This study aimed to investigate FSTT variations between males and females of adult Malaysian populations. A total of 413 head and neck computed tomography (CT) scans (208 males, 205 females) of patients aged 18–65 years were selected. Four mid-sagittal landmarks; nasion, mid-philtrum, subnasale, and upper lip were involved in the measurement, using 3D-Slicer software. The effect of sex on FSTT was analysed using multivariate analysis of variance (MANOVA). MANOVA showed a statistically significant difference in FSTT between sexes (Wilks' Lambda = 0.020, $p < 0.001$). All four landmarks demonstrated significant variations between males and females (all $p < 0.001$). Males have greater FSTT compared to females at all landmarks. In conclusion, there were significant FSTT variations between the sexes of adult Malaysian population. This population-specific data could be applied as forensic reference that tailored to Malaysian population.

Keywords: Sex, Facial soft tissue thickness, CT, Variations

ABSTRAK

Ketebalan tisu lembut wajah (Facial Soft Tissue Thickness, FSTT) merupakan elemen penting dalam proses identifikasi forensik dan pembinaan semula wajah. Penelitian terhadap variasinya mengikut jantina memberikan maklumat kritikal yang diperlukan bagi memastikan ketepatan identifikasi. Kajian ini bertujuan menyiasat perbezaan FSTT antara lelaki dan perempuan dalam kalangan populasi dewasa di Malaysia. Sebanyak 413 imbasan tomografi berkomputer (CT) kepala dan leher (208 lelaki, 205 perempuan) melibatkan pesakit berumur 18–65 tahun telah dipilih. Empat titik penanda mid-sagital—nasion, mid-philtrum, subnasale dan bibir atas—digunakan dalam pengukuran melalui perisian 3D-Slicer. Kesan jantina terhadap FSTT dianalisis menggunakan analisis varians multivariat (MANOVA). Keputusan MANOVA menunjukkan perbezaan statistik yang signifikan dalam FSTT antara jantina (Wilks' Lambda = 0.020, $p < 0.001$). Keempat-empat titik penanda menunjukkan variasi yang signifikan antara lelaki dan perempuan (semua $p < 0.001$). Lelaki mempunyai nilai FSTT yang lebih besar berbanding perempuan pada semua titik penanda. Kesimpulannya, terdapat variasi FSTT yang signifikan antara jantina bagi populasi dewasa Malaysia. Data khusus populasi ini boleh digunakan sebagai rujukan forensik yang disesuaikan dengan populasi Malaysia.

Kata kunci: *Jantina, ketebalan tisu lembut wajah, CT, variasi*

Background

Facial soft tissue thickness (FSTT) is a crucial parameter in forensic anthropology and facial reconstruction (Bulut et al. 2014). It is measured perpendicularly from the outer skin surface towards the facial bone border (Domaracki and Stephan 2006; Nilendu and Johnson 2023). FSTT serves as an important bridge between the two (Saadeh et al., 2020), and this connection provides a valuable information that can be applied for human identification (Domaracki and Stephan 2006; Torres Muñoz et al. 2011). Sex is the most critical biological profile that must be established in forensic investigations (Lundy 1998; Spradley and Jantz 2011). By exploring the relationship between sex and FSTT variation, the process of human identification could be facilitated smoothly (Agbolade et al. 2020; Miller 2018).

In the forensic field, accurate sex estimation reduces the potential matches of a case by half (Moore 2012; Spradley and Jantz 2011; Wang et al. 2024). Previous studies have investigated the sexual dimorphism that manifested in various FSTT landmarks and reported several findings (Alhumadi et al. 2022; Ayoub et al. 2019; Nilendu and Johnson 2023; Saadeh et al. 2020; Torres Muñoz et al. 2011). Generally, males exhibit thicker, soft tissue compared to females at most facial landmarks (Agbolade et al. 2020; Alhumadi et al. 2022; Nilendu and Johnson 2023). However, the thickness might demonstrate some level of inconsistency as it is highly dependent on the methods that are used and the population background (Ismail et al. 2019; Musilová et al. 2019; Rozendaal et al. 2020; Wang et al. 2023). It was also suggested that FSTT is influenced by genetics, environmental and nutritional factors (Ichikawa-Seki et al. 2022; Iqbal et al. 2020; Ismail et al. 2019; Randolph-Quinney et al. 2011) Thus, establishing a population-specific data is essential to avoid any inaccurate identification.

Various methods have been used to measure FSTT. The methods are generally categorized into two-dimensional (2D) and three-dimensional (3D) (Agbolade et al. 2020; Stavrianos et al. 2007). One of the methods that is used to measure FSTT is needle puncture (Gupta et al. 2015; Torres Muñoz et al. 2011). This is a direct and invasive technique as the fine needle is inserted perpendicularly through the skin until it touches the facial bone of the cadavers (Gupta et al. 2015). In addition, ultrasound is also preferred as being non-invasive and affordable (Gupta et al. 2015; Stephan and Preisler 2018). On the other hand, 3D methods such as CT scans, cone-beam CT (CBCT), and magnetic resonance imaging (MRI) are more precise for FSTT analysis (Berar et al. 2005; Gupta et al. 2015; Stavrianos et al. 2007). These methods can visualize both bone and soft tissue simultaneously and comprehensively (Yadav and Aggarwal 2010; Zhang 2022).

Malaysia is a multi-ethnic country comprises various facial features (Alazzawi et al. 2012; Chan et al. 2020; Tan et al. 2021). Although previous studies have investigated FSTT variations, most were conducted on populations outside Malaysia. Due to that, a population-specific data is required to facilitate the identification process of the remains within Malaysian context (Chan et al. 2020; Chin et

al. 2013; Miller 2018). Hence, the method is more reliable and reproducible as the differences within the population are addressed (Agbolade et al. 2020; Chin et al. 2013)

Therefore, this study aims to investigate FSTT variations between different sexes among the Malaysian population, by using CT scan data. It is hoped that the findings could establish sex-specific FSTT data that is tailored to Malaysian population.

Methodology

Study design

This was a cross-sectional design that was conducted at the Department of Biomedical Imaging, Pusat Perubatan Universiti Malaya (PPUM). A total of 413 samples were selected, composed of both sexes; males (n=208) and females (n=205), aged between 25-45 years old. The mean ages were 37.4 and 35.9 (SD +1.2 and +0.8) years old for males and females respectively. Head and neck CT scans were viewed using the Picture Archiving and Communication System (PACS) to ensure that only high-quality CT scans were selected. The data were imported into the 3D Slicer software for landmark identification (Fedorov et al. 2012). Four mid-sagittal landmarks were selected: nasion, subnasale, mid-philtrum, and upper lip. The definition of each landmark was presented in Table 1 and Figure 1. These landmarks were adapted from a few studies that were conducted previously (Ayoub et al. 2019; Bulut et al. 2014; Chung et al. 2015).

Table 1. Definition of the landmarks

No.	Landmark	Definition
1	Nasion	The skin surface point over the bony nasion.
2	Subnasale	The midline soft tissue point where the nasal septum meets the upper lip
3	Mid-philtrum	The central point of the philtrum, located between the subnasale and the upper lip margin
4	Upper Lip	The most anterior midline point on the vermilion border of the upper lip



Figure 1. Four FSTT landmarks; 1) Nasion, 2) Subnasale, 3) Mid-philtrum 4) Upper lip

FSTT Measurement

Distances from the selected FSTT landmarks to their underlying bone structures were obtained using measuring tools in the 3D-Slicer software (Figure 2). These distances were recorded in the Microsoft Excel software. The data was imported into SPSS version 25 for analysis. Multivariate analysis of variance (MANOVA) was applied to investigate the effect of sex on FSTT landmarks.

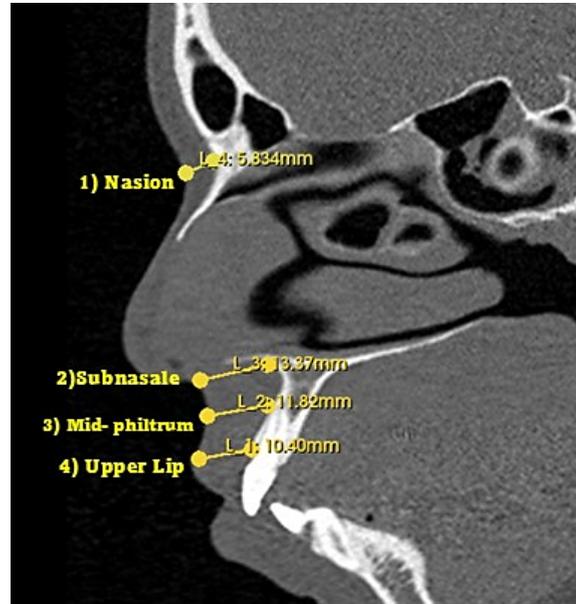


Figure 2. FSTT landmarks measurement

Results

Table 2 showed a significant multivariate effect of sex (Wilks' Lambda =0.020, F=48.11, $p < 0.001$ and partial Eta squared= 0.980) on FSTT.

Table 2. MANOVA of sex factor on FSTT

Effect	Test	Value	F	df	p-value	Partial Eta Squared
Sex	Pillai Trace	0.980	48.11	4	<0.001**	0.980
	Wilks' Lambda	0.020	48.11	4	<0.001**	0.980
	Hotelling's Trace	49.50	48.11	4	<0.001**	0.980
	Roy's Largest Root	49.50	48.11	4	<0.001**	0.980

** $p < 0.001$, significant different

Further analysis revealed that sex factor has significant effects on all four FSTT landmarks (Table 3). The highest F-value was demonstrated at the subnasale landmark (F=81.32, $p < 0.001$). This indicated that there was a high FSTT variation between males and females at this landmark.

Table 3. Sex effect on all FSTT landmarks

Factor	FSTT landmarks	F	df	Mean squares (MF)	p-value
Sex	Nasion	35.77	1	130.43	<0.001**
	Subnasale	81.32	1	241.58	<0.001**
	Mid-philtrum	20.56	1	472.15	<0.001**
	Upper lip	36.76	1	393.7146	<0.001**

** $p < 0.001$, significant different

Table 4 showed mean value of all FSTT landmarks in each sex. Generally, male demonstrated higher FSTT values compared to female, in all four landmarks.

Table 4. Mean FSTT value (mm) of male and female groups in all landmarks

Landmarks	Sex	Mean (+SD) (mm)
Nasion	Male	5.45 (0.32)
	Female	5.21 (0.41)
Subnasale	Male	14.67 (0.13)
	Female	13.34 (0.26)
Mid-philtrum	Male	12.95 (0.15)
	Female	11.48 (0.11)
Upper Lip	Male	12.53 (0.33)
	Female	10.26 (0.51)

Discussion

Facial soft tissue thickness (FSTT) plays a vital role in forensic identification and facial reconstruction (Bulut et al. 2014; Torres Muñoz et al. 2011). Accurate facial recognition in human identification relies on FSTT data that originated from reliable measuring methods (Agbolade et al. 2020; Domaracki and Stephan 2006). Among methods that are used, CT scan has become a preferred modality for FSTT measurement (Agbolade et al. 2020; Yadav and Aggarwal 2010). This method is promising due to its ability to capture both bone and soft tissue in high resolution and provides a clear FSTT distance between two (Leth 2007). In addition, measurement errors could be reduced as the tissue is being presented clearly as compared to 2D modalities i.e. ultrasound (Kumar and Vijai 2012). However, there is still a lack of FSTT data that are specific for Malaysian population. Previous studies were based on Western or West Asian populations and might not reflect the Malaysian population (Alhumadi et al. 2022; Ayoub et al. 2019; Bulut et al. 2014; Domaracki and Stephan 2006; Hamid and Abuaffan 2016; Nilendu and Johnson 2023; Saadeh et al. 2020; Stephan and Preisler 2018). Thus, this study was conducted to address the gap.

In the present study, multivariate analysis of variance (MANOVA) was applied to investigate the overall effect of sex on FSTT. Four FSTT landmarks were dependent variables that were involved in the analysis (Brobbe et al. 2022). This approach was chosen to ensure a more comprehensive FSTT analysis among multiple dependent variables (Ayoub et al. 2019; Brobby et al. 2022). The results revealed statistically significant sex effects at all four landmarks: nasion, subnasale, mid-philtrum, and upper lip. Males exhibited thicker soft tissue compared to females at all landmarks. These findings were in accordance with few studies conducted before. For instance, a study conducted on Taiwanese populations showed significant differences on FSTT landmarks between different sex as measured from CT scan images (Chung et al. 2015). The differences at the selected landmarks including mid-philtrum and upper lip were assessed statistically. It was revealed that males generally have greater FSTT than females. Other study conducted on Lebanese adult populations revealed significant effect of sex on FSTT landmarks that were measured on lateral cephalograms. The tissue was found to be thicker at several landmarks including nasion, subnasale and upper lip in males as compared to females by MANOVA test (Ayoub et al. 2019). Similarly, another study that involved adult Caucasians reported significant larger FSTT in males compared to females. This large-scale study assessed multiple landmarks by ultrasound, including upper lip and mid-philtrum, which were found to be larger in males as compared to females (De Greef et al. 2006). In contrast, a study that involved FSTT measurement in cadavers showed no significant differences between males and females (Torres Muñoz et al., 2011).

The contrary finding might be attributed to its different method, as the study employed needle puncture measurements into cadavers (Pasca and Ulasan 2014).

Differences in facial soft tissue thickness (FSTT) between males and females are influenced by several factors. Males typically have more prominent facial bones and greater muscle bulk which contribute to a thicker connective tissue (Lefevre et al. 2013; Saadeh et al. 2020). Males demonstrated stronger facial expression activities such as during smiling and pouting (Schutte et al. 2023). This different pattern of exertion mechanism lead into FSTT variations between males and females (Schumann et al. 2021; Schutte et al. 2023). Apart from that, sex hormone such as testosterone promotes a collagen production in skin which result in a denser connective tissue in males than females (Lefevre et al. 2013; Tunheim et al. 2023). On the other hand, estrogen in females involves in hyaluronic acid production that allow the skin to become more flexible and moister than males (Emmanuelle et al. 2021; Perović and Blažej 2018). Additionally, aging process affects FSTT differently based on different sexes due to these hormonal shifts (Cheng et al., 2022; McDuff et al., 2017; Mohamad et al., 2016; Yang et al., 2024). These combined influences help explain why males consistently present with greater FSTT, as also seen in the present Malaysian population.

The present study analysed four mid-sagittal landmarks; nasion, subnasale, mid-philtrum, and upper lip. All landmarks demonstrated significantly greater soft tissue thickness in males compared to females. Among these, the subnasale landmark showed the highest degree of sexual dimorphism. This finding might be related to its underlying skeletal structures (Chen et al. 2021; Ulinuha et al. 2022). Variations in nasal aperture shape and maxillary prominence could contribute to the FSTT variation as the subnasale lies on these structures (Eggerstedt et al. 2020; Shamaei-Tousi et al. 2022). Males tend to have greater size of nasal aperture as compared to females (Chen et al., 2021; Eggerstedt et al., 2020; Marianetti et al., 2016). The FSTT at the mid-philtrum and upper lip also revealed substantial differences. These areas are influenced by muscle volume and fat distribution in the perioral region which are influenced by the sex hormones (Khosla et al. 2012; Lefevre et al. 2013; Narla and Ott 2018). These findings emphasize that FSTT variations are attributed to sex differences.

Conclusion

The present study highlighted the FSTT relationship with different sexes among Malaysians, based on CT-scan imaging. The results showed sex has a significant effect on FSTT variations. Males have a thicker soft tissue compared to females, with the greatest variations were demonstrated at the subnasale landmark. Our study provide insight on FSTT variations between males and females of the Malaysian population. These findings have potential applications in forensic identification and could serve as a foundation for the development of a large-scale software that integrates both soft tissue and bone structures in the future.

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