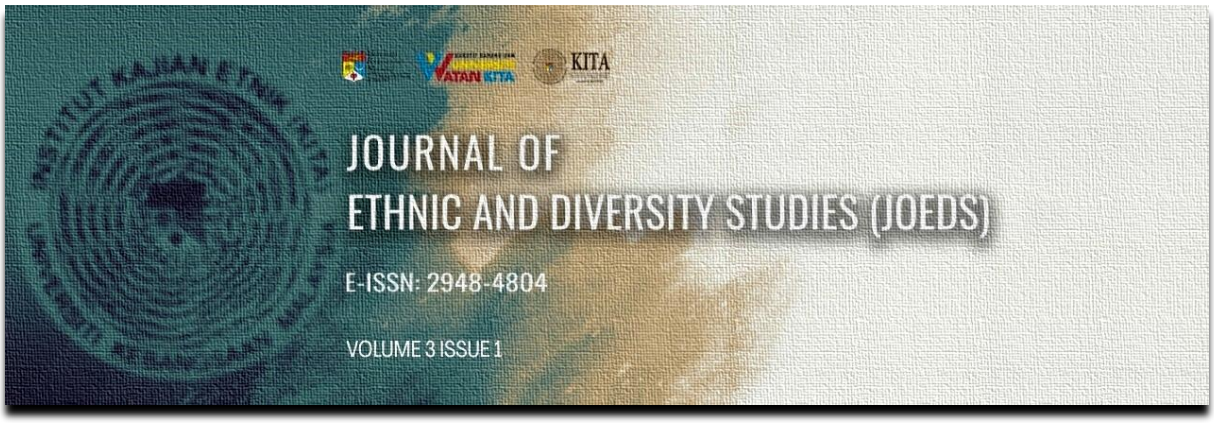

Frontal Sinus Morphology in the Malaysian Population: Patterns of Pneumatization and Gender Differences (Pilot Study)

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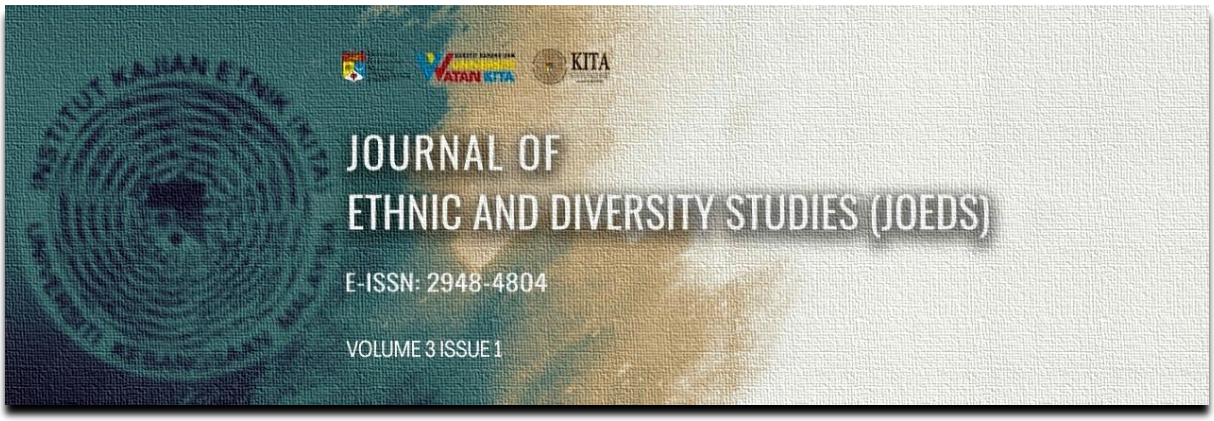
ABSTRACT

The study of various bones has been utilized across different populations for purposes such as gender, racial, and individual identification. This research focuses on examining the pneumatization and dimensions of the frontal sinus (FS) within the Malaysian population. The study analysed 60 multidetector computed tomography (MDCT) scans of bilateral frontal sinuses from Malaysian subjects aged over 25 years, all without any pathological conditions or prior surgeries involving the FS. Findings revealed that 26.66% of the sample exhibited variations in FS development. For individuals with pneumatization on both sides, the average frontal depth (FD) measured 10.54 ± 3.39 mm. In cases where the right frontal sinus was not pneumatized, the FD averaged 8.32 ± 2.23 mm, and the left width (LW) was 30.78 ± 6.50 mm. Among those with bilateral pneumatization, significant gender differences were observed in FD ($P = 0.042$), right width (RW) ($P = 0.033$), and LW ($P = 0.033$). However, no significant racial differences were found in FD ($P = 0.819$), RW ($P = 0.718$), or LW ($P = 0.270$). The study concludes that about one-quarter of Malaysians show variations in frontal sinus development, more frequently on the right side. Despite notable gender-related differences in FS measurements, racial variations were not significant. The authors recommend further research with a larger and ethnically balanced sample to validate these findings.

Keywords: Forensic science, Frontal sinuses, multidetector computed tomography (MDCT), human identification.



ABSTRAK

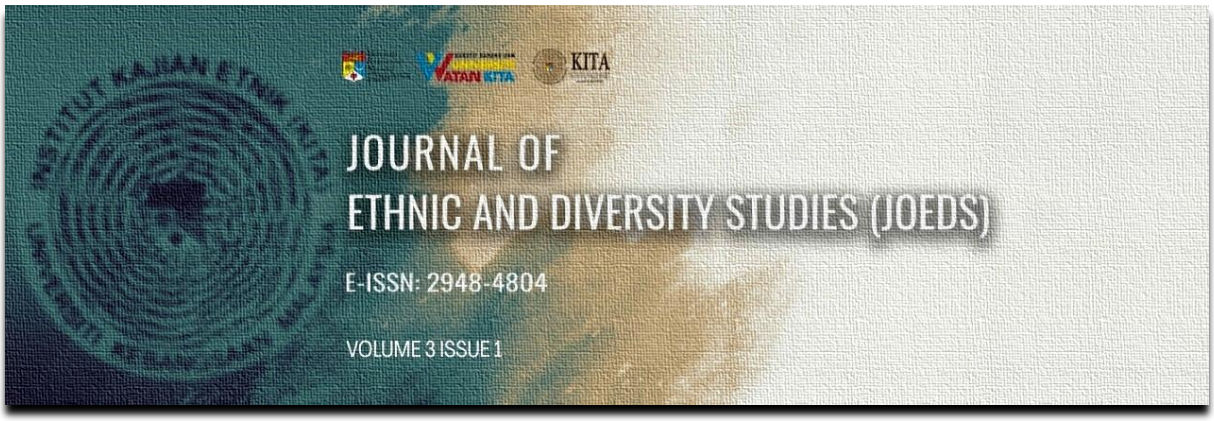
Kajian pelbagai tulang telah digunakan merentas populasi yang berbeza untuk tujuan seperti jantina, kaum dan pengenalan individu. Penyelidikan ini memberi tumpuan kepada mengkaji pneumatisasi dan dimensi sinus frontal (FS) dalam populasi Malaysia. Kajian ini menganalisis 60 imbasan tomografi berkomputer (MDCT) multidetector sinus frontal dua hala daripada subjek Malaysia berumur lebih 25 tahun, semuanya tanpa sebarang keadaan patologi atau pembedahan terdahulu yang melibatkan FS. Penemuan mendedahkan bahawa 26.66% daripada sampel mempamerkan variasi dalam pembangunan FS. Bagi individu dengan pneumatisasi pada kedua-dua belah, purata kedalaman hadapan (FD) diukur 10.54 ± 3.39 mm. Dalam kes di mana sinus hadapan kanan tidak dipneumatik, FD purata 8.32 ± 2.23 mm, dan lebar kiri (LW) ialah 30.78 ± 6.50 mm. Antara mereka yang mengalami pneumatisasi dua hala, perbezaan jantina yang ketara diperhatikan dalam FD (P = 0.042), lebar kanan (RW) (P = 0.033), dan LW (P = 0.033). Walau bagaimanapun, tiada perbezaan kaum yang ketara ditemui dalam FD (P = 0.819), RW (P = 0.718), atau LW (P = 0.270). Kajian itu menyimpulkan bahawa kira-kira satu perempat rakyat Malaysia menunjukkan variasi dalam perkembangan sinus frontal, lebih kerap di sebelah kanan. Walaupun terdapat perbezaan yang ketara berkaitan jantina dalam pengukuran FS, variasi kaum tidak ketara. Penulis mengesyorkan penyelidikan lanjut dengan sampel yang lebih besar dan seimbang dari segi etnik untuk mengesahkan penemuan ini.

Kata kunci: Sains forensik, Sinus hadapan, tomografi berkomputer pelbagai pengesan (MDCT), pengenalan manusia.

INTRODUCTION

The frontal sinuses are a pair of an air-filled cavities located within the frontal bone, superior to the orbits and posterior to the glabella(1). The two frontal sinuses are separated by a septum which is rarely found in midline (2). This sinus is not apparent at birth, develops by the second year of life and is visible radiographically by the age of five years. It is widely accepted that the frontal sinus is developed by 20 years of age and remains stable until further enlargement of the chambers occurs as a result of bone resorption during advanced age (3). The frontal sinuses develop individually and are rarely symmetrical (4).

Pneumatization refers to the extension of this sinus into adjacent structures, resulting in a range of morphological patterns. Frontal sinus pneumatization occurs in approximately 90% of the population, but the degree of pneumatization varies widely among individuals as well as within the same individual (5). These morphological variations has surgical, radiological as well as forensic significance (6). Variations in pneumatization of frontal sinuses may affect the outcomes of endoscopic sinus surgery, maxillofacial and skull base surgery(7). Knowledge of



frontal sinus pneumatization aids in the interpretation of radiological imaging, particularly computed tomography (CT) scans, which are commonly used in clinical practice (8). On the other hand, the unique morphology of the frontal sinuses and the possibility of preserving its intact structure have helped in forensic identification of human skeletal remains (9). Recognition of frontal sinus pneumatization patterns contributes to the understanding of evolutionary biology and comparative anatomy. Comparative studies help in gender and racial identification (10-12). Consequently, it's morphology among different populations has been widely studied and reported worldwide (2). Yet, the distribution and variability of frontal sinus morphology among Malaysian adult population has been rarely studied (13). Therefore, aim of the present research is to study the frontal sinus pneumatization and measurements among the Malaysian population.

MATERIALS AND METHODS

The study sample consisted of 43 Malay, 10 Indians, 7 Chinese patients with 26 males and 34 females. The inclusion criteria for the study considered were age of 25 years and above, have no pathological condition related to the frontal sinus or prior surgery.

A total of 60 multidetector computed tomography (MDCT) scans of bilateral frontal sinus images were retrieved retrospectively from database of radiology department, Hospital Shah Alam from 2017-2020. The institutional review board approval was exempted as the study included only retrospective anonymous patients' data with no intervention on the patients. Further, these scans were of patients not having any disease or surgery related to the paranasal sinuses. subsequently the patients' consent was waived.

The scan measurements were performed by an experienced radiologist and repeated twice for quality assurance. For obtaining the scans, a Multidetector Computed Tomography (MDCT) scanner (SOMATOM Definition AS, 64 slice, Siemens), employing volumeteric acquisition and multiplanar reconstruction with high resolution bone window alogrithm in axial plane was utilized. The images were viewed and measurements obtained on Prime DICOM viewer software using its inbuilt electronic caliper. The measurements included the width and depth of the frontal sinus, measured in the axial section and the height, measured in the coronal section. The frontal depth (FD) or anteroposterior diameter was defined as the longest distance from the most anterior point of the anterior wall to the most posterior point of the posterior wall of the largest pneumatized compartment of the frontal sinus in the axial view. The frontal width was defined as the longest transverse distance from the most medial point of the medial wall to the most lateral point of the lateral wall in the axial view. It was measured on both sides to have the Left (LW) and Right (RW) transverse diameter (Width) of the frontal sinus. In the largest pneumatized compartment, the anteroposterior (FD) and transverse (FW) dimensions were oriented perpendicularly (14) (Figure 1).

JOURNAL OF
ETHNIC AND DIVERSITY STUDIES (JOEDS)
E-ISSN: 2948-4804
VOLUME 3 ISSUE 1

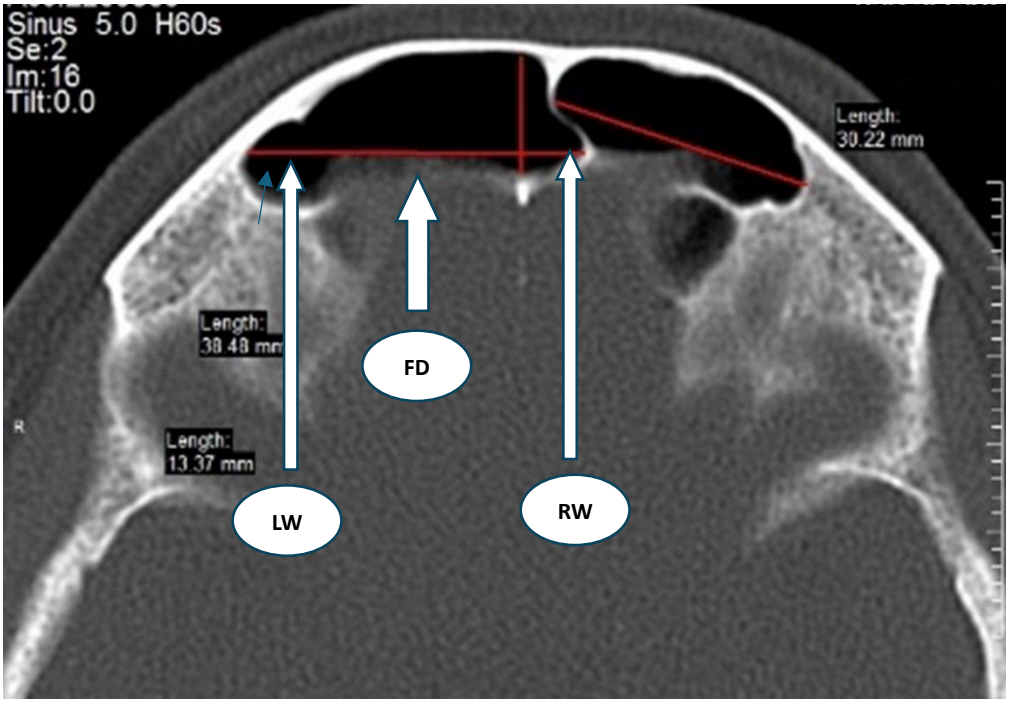


FIGURE 1. Measurements of the frontal sinus depth (FD), right width (RW) and left width (LW)

The collected data were statistically analysed by SPSS (version 26) to identify the prevalence of frontal sinus pneumatization according to side, race and gender, the average measurements of width and depth of frontal sinus in relation to gender and race of the sample.

RESULTS

The demographic profile of the study population is depicted in Table 1. It included 60 Malaysian individuals (7 Chinese, 10 Indian, 43 Malay) which roughly correlates with the racial distribution among the Malaysian population (15).

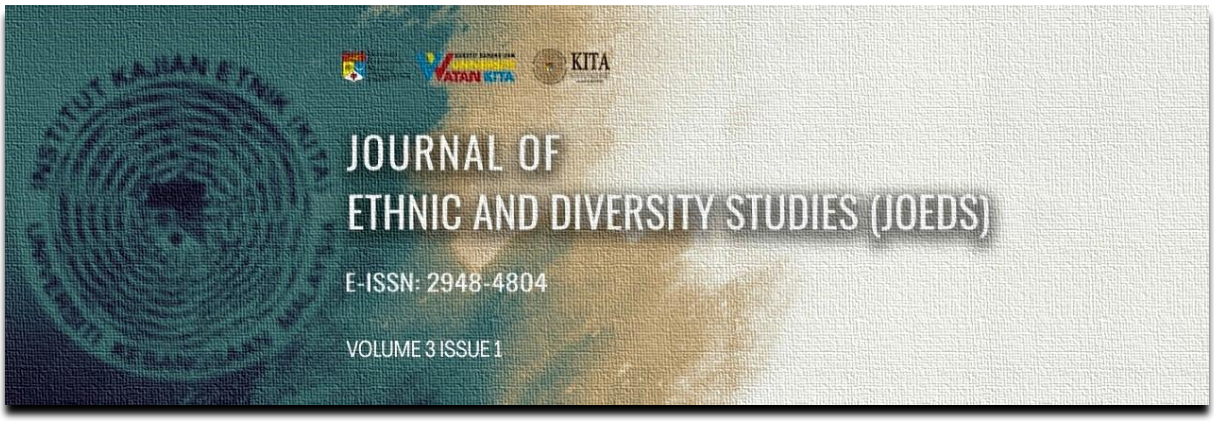


TABLE 1. Demographic data of the study participants.

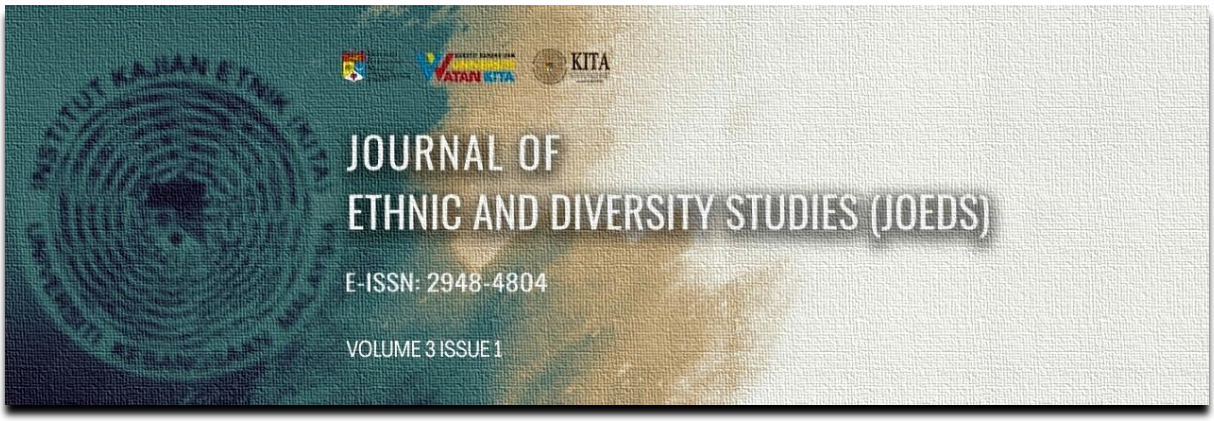
		RACE			Total
		CHINESE	INDIAN	MALAY	
GENDER	FEMALE	0	3	23	26
	MALE	7	7	20	34
Total		7	10	43	60

Among the sample studied, 73.3% had bilateral frontal sinus pneumatization. While 26.66% revealed variations in frontal sinus pneumatization, 9 (15%) have no frontal sinus on both sides, 6 (10%) have no right-side frontal sinus, and 1 (1.66%) has no left side frontal sinus. The variation (absence of both frontal sinus) was common among Malay (20%) when compared to Chinese (3.33%) and Indians (3.33%). With respect to gender, bilateral absence of frontal sinus was seen more often in females among Malays and more commonly among males among Indians. However, right sided non -pneumatization of frontal sinus was seen more commonly among males in all racial groups. (Table 2).

TABLE 2. Frontal sinus pneumatization pattern among the studied sample distributed according to race and gender.

		Those having both sides pneumatization of the frontal sinuses		Those having Non pneumatization of the frontal sinuses						
				Both sides non pneumatization		Right side non pneumatization		Left side non pneumatization		Total
Total No. (%)		44 (73.33%)		9 (15%)		6 (10%)		1 (1.66%)		16 (26.66%)
Gender		Male	Female	Male	Female	Male	Female	Male	Female	
Race	Malay	14 (23.3%)	17 (28.33%)	2 (3.33)	5 (8.3%)	3 (4.98%)	1 (1.66%)	1 (1.66%)	0	12 (20%)
	Chinese	5 (8.3%)	0	1 (1.66%)	0	1 (1.66%)	0	0	0	2 (3.33%)
	Indian	5 (8.3%)	3 (4.98%)	1 (1.66%)	0	1 (1.66%)	0	0	0	2 (3.33%)

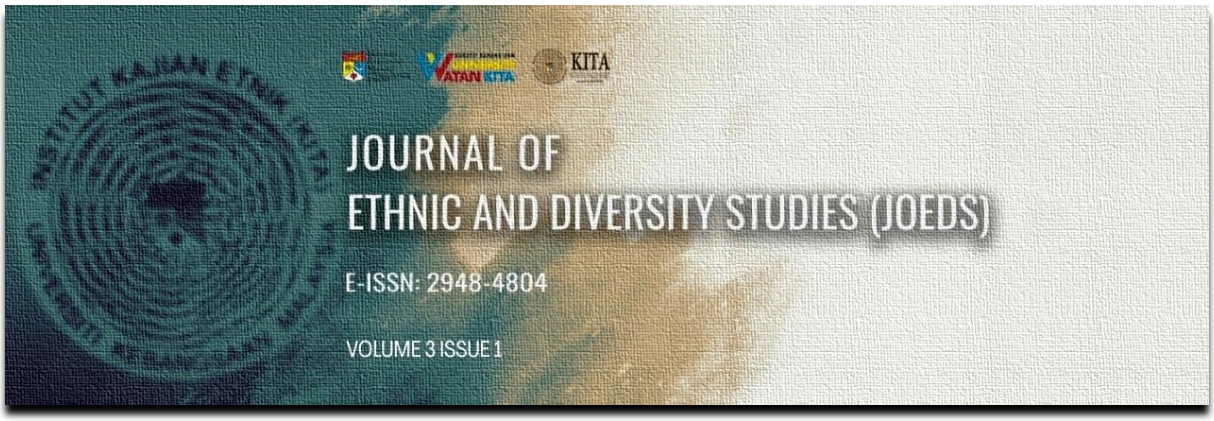
Among those who had bilateral pneumatization of the frontal sinus, the anteroposterior diameter of the frontal sinus (FD) among females was 6.93 ± 1.44 mm among Indian and 9.84



± 3.91 mm among Malay. While among males, FD was 9.89 ± 3.73 mm among Chinese, 13.62 ± 2.43 mm among Indians and 11.28 ± 2.18 mm among Malay. The right transverse diameter (width) (RW) among females was 20.86 ± 6.05mm among Indian and 26.32 ± 9.15 mm among Malay. While among males, RW was 30.93 ± 10.13 mm among Chinese, 34.37 ± 9.04 mm among Indians and 29.63 ± 5.84 mm among Malay. The left transverse diameter (LW) among females was 23.50 ± 5.60 mm among Indian and 27.28 ± 9.78 mm among Malay. While among males, LW was 26.54 ± 10.18 mm among Chinese, 41.11 ± 7.75 mm among Indians and 32.21 ± 5.90 mm among Malay (Table 3). Hence, when both the frontal sinuses are pneumatized, RW (28.44 ± 8.44mm) was found to be smaller than the LW (30.08 ± 9.27). But, this difference was not statistically significant (Table 3).Further, on comparing the mean measurements using ANOVA, there was a significant gender variation in the measurements of FD (p= 0.042), RW (p= 0.033) and LW (p= 0.033). Meanwhile there was no significant racial variations in the measurements of FD (p= 0.819), RW (p= 0.718) and LW (p= 0.270).

TABLE 3. Comparison of racial and gender variations in the frontal sinus measurements among those having both side pneumatization of the frontal sinuses.

		Anteroposterior diameter (Depth) of the frontal sinus (FD)			Right transverse diameter (Width) of the frontal sinus (RW)		Left transverse diameter (Width) of the frontal sinus (LW)	
GENDER	RACE	N	Mean (mm)	Std. Dev	Mean (mm)	Std. Dev	Mean (mm)	Std. Dev
FEMALE	CHINESE	0						
	INDIAN	3	6.93	1.44	20.86	6.05	23.50	5.60
	MALAY	17	9.84	3.91	26.32	9.15	27.28	9.78
	Total	20	9.41	3.77	25.50	8.85	26.71	9.26
MALE	CHINESE	5	9.89	3.73	30.93	10.13	26.54	10.18
	INDIAN	5	13.62	2.43	34.37	9.04	41.11	7.75
	MALAY	14	11.28	2.18	29.63	5.84	32.21	5.90
	Total	24	11.48	2.77	30.89	7.41	32.89	8.48
Total	CHINESE	5	9.89	3.73	30.93	10.13	26.54	10.18
	INDIAN	8	11.11	3.99	29.30	10.29	34.51	11.24
	MALAY	31	10.49	3.27	27.81	7.88	29.51	8.51
	Total	44	10.54	3.39	28.44	8.44	30.08	9.27
Anova test	Racial variations	.819			.718		.270	
	Gender variations	.042			.033		.026	



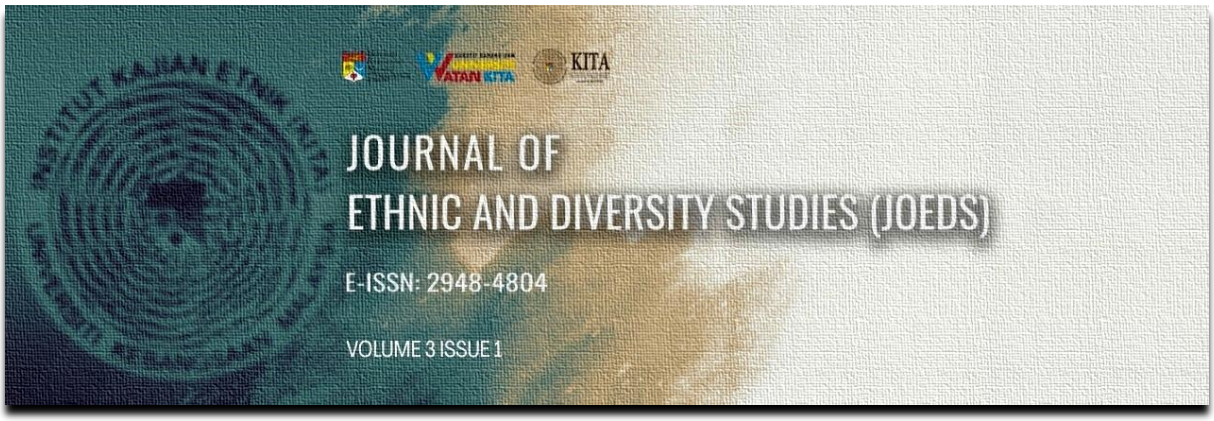
Among those with non-pneumatization of the right frontal sinus, the FD is 8.32 ± 2.23 mm (5.52 mm among females and 8.89 ± 1.96 among males) and the LW is 30.78 ± 6.50 mm (38.4 m among females and 29.26 ± 5.96 mm among males) (Table 4).LW among those with both sides pneumatization is 30.08 ± 9.27 mm (Table 3) and 30.78 ± 6.5 among those with Right side non pneumatization (Table 4). FD among those with both sides pneumatization 10.54 ± 3.39 mm (Table 3) and 8.32 ± 2.23 mm among those with Right side non pneumatization (Table 4).

TABLE 4. Left frontal sinus measurements in those having Right side non pneumatization.

		Anteroposterior diameter (Depth) of the frontal sinus (FD)			Left transverse diameter (Width) of the frontal sinus (LW)	
GENDER	RACE	N	Mean	Std. Dev	Mean	Std. Dev
FEMALE	CHINESE					
	INDIAN					
	MALAY	1	5.52		38.4	
	Total	1	5.52		38.4	
MALE	CHINESE	1	8.14		30.26	
	INDIAN	1	7.32		24.65	
	MALAY	3	9.66	2.30	30.47	7.59
	Total	5	8.89	1.96	29.26	5.96
Total	CHINESE	1	8.14		30.26	
	INDIAN	1	7.32		24.65	
	MALAY	4	8.62	2.79	32.45	7.362
	Total	6	8.32	2.23	30.78	6.50

DISCUSSION

The unique morphology of frontal sinuses was first reported by Zuckerkandl in 1895(13). Since then, researchers have concluded that the appearance of the radiographic image of the frontal sinus is unique for each individual(2). As the left and right frontal sinuses develop independently, a significant asymmetry between these sinuses can arise in the same individual (16). On this evidence, it is proposed that frontal sinus pattern matching be used for personal identification when other methods have failed (14) making it crucial for forensic investigations. Ct Scans have been identified as a reliable method for the measurement of different dimensions of the frontal sinus (17). This study unveils the frontal sinus pneumatization patterns and measurements among Malaysian population. The findings reveal that 15% of the studied sample had bilateral absence of frontal sinus, 10% had no right-side frontal sinus, and 1.66% had absence of left side frontal sinus. Similar studies conducted in other populations show varied results. The Turkish population were detected to have bilateral and unilateral absence



of frontal sinus in 3.8% and 4.8% respectively (12). Another study among 147 male and 142 female Indians, 4 individuals showed unilateral/bilateral absence of frontal sinuses (18). Thereby, the unilateral/bilateral absence of frontal sinus varies across populations. Climate, environmental factors and individual health are believed to be responsible for these variations (13).

The variation (absence of both frontal sinus) is common among Malay (20%) more than Chinese (3.33%) and Indians (3.33%) The variations among Chinese and Indians are commoner among males than females. But this conclusion regarding the gender cannot be generalized and need to be studied on a sample with equal number of male and females from each ethnic group. It is concluded that asymmetry for the frontal sinus of both sides is a rule because of the unequal sinus development (3,19). In this research, among those who are having both side pneumatization of the frontal sinus, RW (28.44 ± 8.44mm) is non-significantly smaller than the LW (30.08 ± 9.27). In contrast to other researches, a study among Indians detected that the mean measurement of right-side frontal sinus is greater than the left side in both males and females (18) which is in contrast to other studies (20,21).

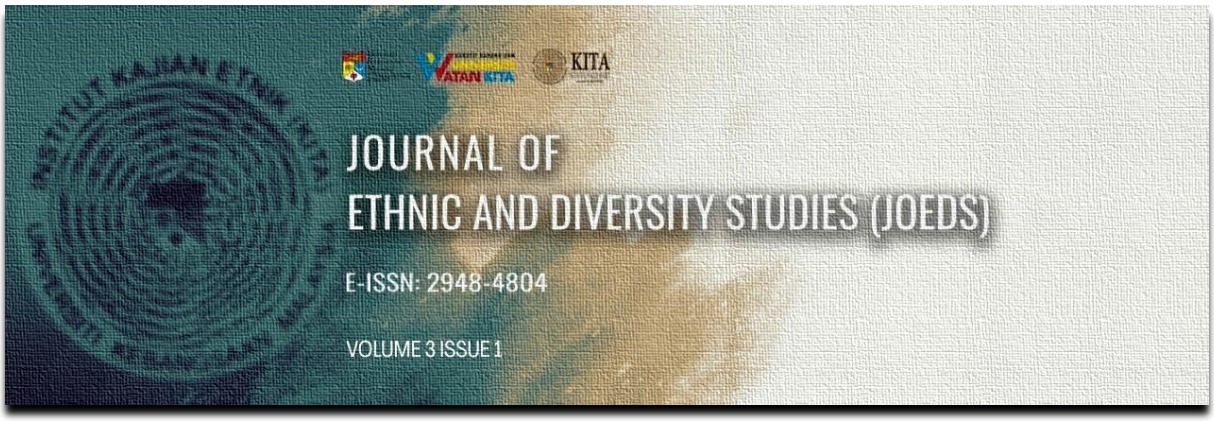
Morphologic evaluation of frontal sinus is a useful technique to determine gender (22, 23), which is confirmed by the results of the current study among Malaysians. Based on the Arabian-Caucasian and Han-Chinese sub-population findings, the frontal sinus is an effective tool for determining gender and appears to have potential in ethnicity identification (23) in comparison to the current study findings where there is a significant gender variation in the measurements of FD, RW and LW. Nevertheless, there is no significant racial variations in these measurements.

LIMITATIONS OF THE STUDY

The authors would like to acknowledge the presence of some limitations. There were no females among the Chinese ethnic group in the sample. This could be attributed to the scans being taken from a single hospital in Malaysia. Further, it was a retrospective study on Ct Scans of individuals with no prior sinus pathology/ surgery. Hence, a similar study on a larger sample of Malaysian population with equal number of participants based on gender and race is suggested.

CONCLUSION

The findings of the study reveal that the morphology of the frontal sinus varies among individuals across gender and race. As population specific variations have been observed, this study helps to build the database on frontal sinus morphology among the Malaysian adult population. This data maybe helpful for forensic identifications as well as for surgical planning in the field of otorhinolaryngology and neurosurgery.



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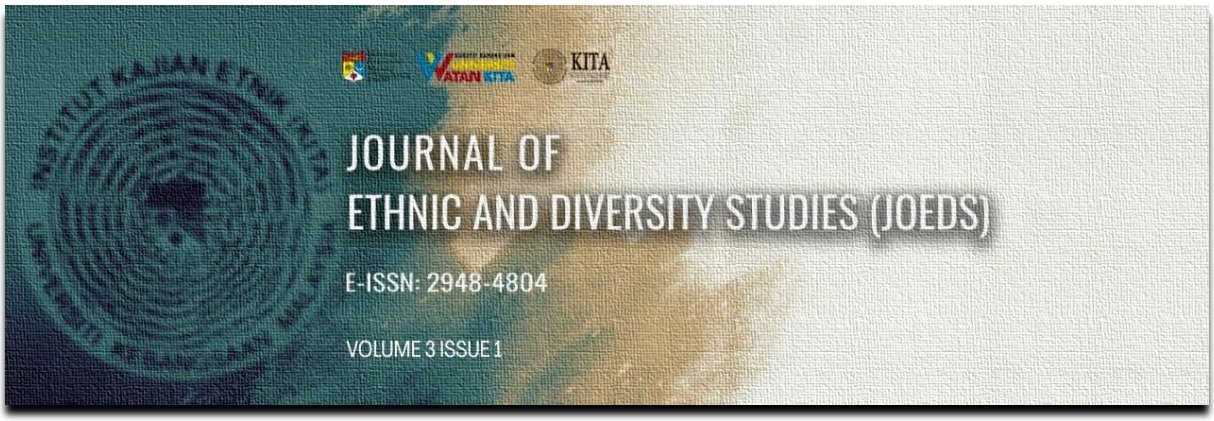

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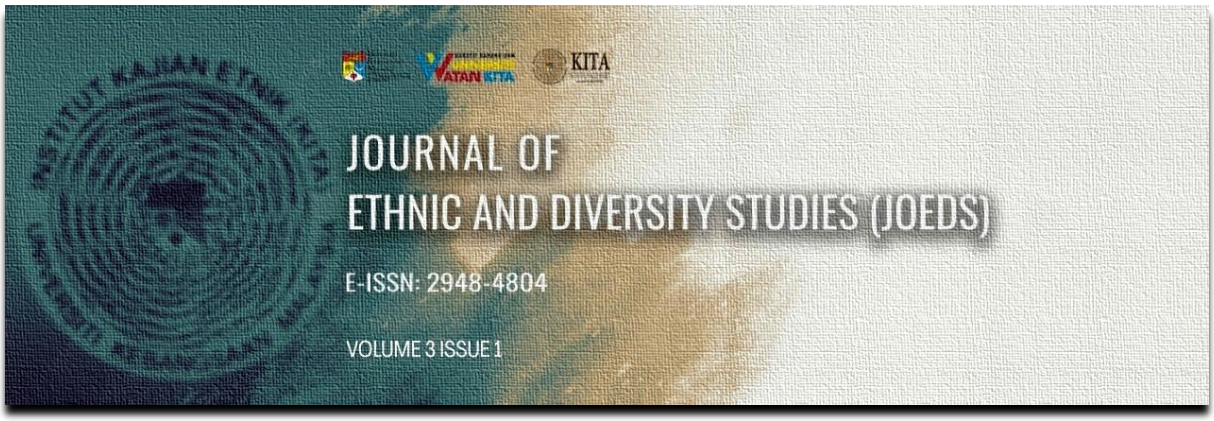

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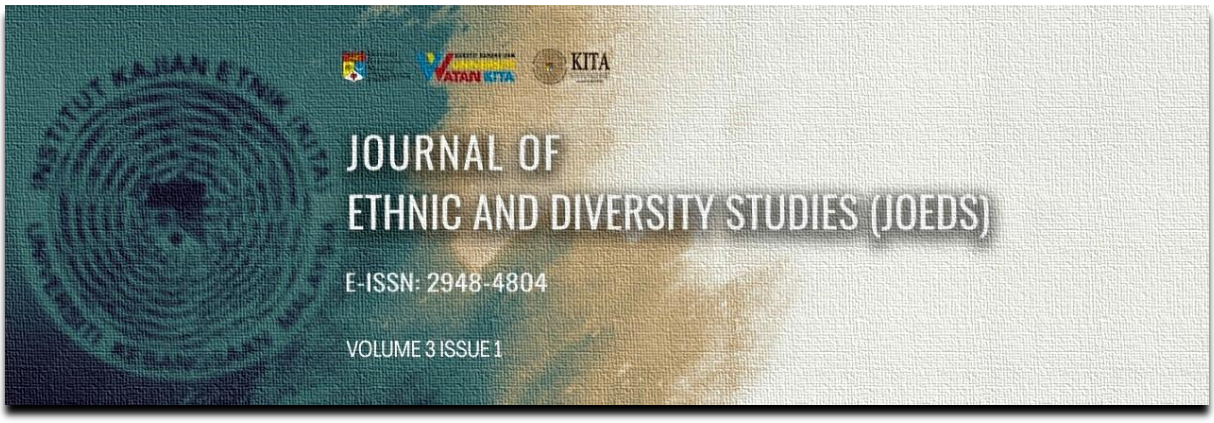

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