

Formant Frequencies of Normal Malaysian Indian Young Adults in Sustained Vowels

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Abstract – This paper investigates the first four formant frequencies of 60 normal Malaysian Indian young adults in sustained vowels using acoustical analysis. The F_1 , F_2 , F_3 and F_4 of Malaysian Indian males were reported at 359 ± 87 Hz, 1457 ± 630 Hz, 2799 ± 336 Hz and 3777 ± 299 Hz respectively. The F_1 , F_2 , F_3 and F_4 of Malaysian Indian females were reported at 485 ± 172 Hz, 1707 ± 746 Hz, 3081 ± 330 Hz and 4305 ± 288 Hz respectively. Malaysian Indian females had significant higher formant frequencies in all vowels than those of Indian males except F_2 and F_3 in /u/. Besides that, significant differences in all the formant frequencies were observed across all the vowels for both Indian males and females. Significant interactions between vowels and gender were found in F_1 , F_2 and F_3 but not in F_4 .

Keywords— Formant Frequency, Sustained Vowels, Malaysian Indian, Young Adults

I. INTRODUCTION

Formant characteristic of sustained vowel have been examined over past 40 years. Formant frequencies differ across gender [1-5], age groups [3, 5-8] and ethnic groups [1, 9-11]. Peterson & Barney [3] reported that each of the American vowels has its own acoustic characteristic and can be differentiated through formant frequencies. The study also revealed that children had the higher formant frequencies than those of adult.

Formant frequencies of males were lower than those of females [1-6, 12]. Peterson and Barney [3] found that female had the higher formant frequencies than those of male. Fant [12] demonstrated that the formants frequencies of male were about 20% lower than those of female in average. Andrianopoulos *et al.* [1] reported the same formant differences in four ethnic groups of Caucasian, African American, native Hindi Indian and native Chinese.

Mayo & Grunt [9] found that formant frequencies of African American males were significant lower than those of White American males in /a/. Nevertheless, Walton & Orlikoff [13] reported that no significant differences in formant frequencies were observed in /a/, /i/ and /u/ among African American males and White American males. Mayo & Manning [10] discovered that F_1 and F_3 of African

American male were significant lower than that of Caucasian-American male.

Andrianopoulos *et al.* [1] found that the native Hindi Indian males had a lower F_1 for /a/ and /i/ compared to that of Caucasian, African American, native Chinese. Indian females had significantly higher F_3 in /i/ compared to that of the other three ethnic groups. Olagbaju *et al.* [11] concluded that ethnic difference had much effect on F_2 while Torre Iii *et al.* [5] found that F_2 was much affected by the age factor. The formant frequencies of normal adults are well documented for different ethnic groups. However, formant frequencies data of Malaysian Indian young adults is not established.

Malaysia is a multi-cultural country, which is comprised of three major ethnic groups: Malay, Chinese and Indian. The purpose of this study is to investigate the formant frequencies in sustained Malay vowels among Malaysian Indian young adults between 18 and 23 years old. The Malay vowels consist of /a/, /e/, /ə/, /i/, /o/, /u/ [14, 15]. The list of the vowels is shown in Table 1 according to tongue height and tongue position. The study determines the significant differences in the formant frequencies across the gender and all the six Malay sustained vowels.

Table 1 List of Malay vowels.

Position Height	Front	Centre	Back
High	/i/		/u/
Mid-high	/e/		/o/
Mid-low		/ə/	
Low	/a/		

II. METHODS

A. Subjects

The study involved 30 normal Malaysian Indian males and 30 normal Malaysian Indian females between 18 and 23 years old. The subjects were undergraduate students of University of Malaya, Kuala Lumpur, Malaysia. The mean age, height and weight of the subjects were reported at 20.5

± 1.1 years old, 167.2 ± 9.8 cm and 59.3 ± 12.9 kg respectively. During the time of recording, none of the subject was reported to have cold, allergy, flu, history of professional singing, neurologic, respiratory, pulmonary, cardiovascular disease, articulation and voice disorder. All the subjects were non-smoker.

B. Equipment and Procedure

The subjects were requested to pronounce each of six sustained Malay vowel with duration of five seconds each at their comfortable pitch and loudness. The speech signals were recorded using Shure SM58 condenser microphone which was connected to a laptop. During the speech recording, the microphone was positioned approximately 2 to 3cm from the mouth of the subjects with an angle of 45° . The speech sounds were sampled at 20 kHz with 16 bit resolution. All the recordings were carried out in normal room environment with sound pressure level below 50dB (A). GoldWave [16] sound editor software was used to perform the speech recording. At least 3 seconds signal was extracted from the midpoint of the recorded vowel sounds for the analysis of formant frequencies.

A discrimination test was carried out by 10 Malaysian Malay undergraduate students of University of Malaya, Kuala Lumpur, Malaysia to evaluate the correct pronunciation of the vowels by the Malaysian Indian young adults. The pronunciation of the vowel as considered correct if agreement was made by at least 7 out of the 10 listeners.

Praat software [17] was used to determine the first four formant frequencies of the vowels. SPSS statistical analysis software [18] was used to determine the significant differences in formant frequencies across the gender and the vowels. Independent samples t-test ($\alpha = 0.05$) was used to compare the mean differences in formant frequencies across the gender while one-way analysis of variance (ANOVA) was used to determine the mean differences in formant frequencies across the vowels. The significance level, α was set at 0.05 for the statistical analysis.

III. RESULTS

A. Male subjectss

Table 2 shows the first four formant frequencies of Malaysian Indian males in six vowels. The mean F_1 of Malaysian Indian male was 359.09 ± 86.56 Hz. /a/ had the highest F_1 value while /i/ had the lowest F_1 value. The mean F_2 , F_3

and F_4 were reported at 1457.40 ± 630.33 Hz, 2798.70 ± 335.50 Hz and 3776.90 ± 298.90 Hz respectively. /i/ was reported to have the highest F_2 , F_3 and F_4 while /o/ had the lowest F_2 and F_4 and /e/ had the lowest F_3 .

Table 2 Formant frequencies (Mean \pm SD) of Malaysian Indian males.

Vowel	Formant frequencies (Hz)			
	F_1	F_2	F_3	F_4
/a/	445 \pm 112	1155 \pm 121	2703 \pm 302	3836 \pm 287
/e/	390 \pm 64	1416 \pm 277	2682 \pm 334	3763 \pm 277
/ə/	360 \pm 67	2107 \pm 2597	2750 \pm 393	3825 \pm 299
/i/	263 \pm 21	2376 \pm 188	3193 \pm 267	3901 \pm 398
/o/	377 \pm 61	838 \pm 103	2701 \pm 161	3606 \pm 244
/u/	320 \pm 28	853 \pm 261	2763 \pm 204	3733 \pm 179
Mean	359 \pm 87	1457 \pm 630	2799 \pm 336	3777 \pm 299

B. Female subjects

Table 3 shows the first four formant frequencies of Malaysian Indian females in six vowels. The mean F_1 of Malaysian Indian female was 484.61 ± 171.74 Hz. /a/ and /i/ were reported to have the highest and lowest F_1 value. The mean F_2 , F_3 and F_4 were reported at 1707.00 ± 746.20 Hz, 3080.90 ± 329.86 Hz and 4304.50 ± 287.73 Hz respectively. /i/ and /u/ were found to have the highest and lowest F_2 , F_3 and F_4 value.

Table 3 Formant frequencies (Mean \pm SD) of Malaysian Indian females.

Vowel	Formant frequencies (Hz)			
	F_1	F_2	F_3	F_4
/a/	769 \pm 148	1458 \pm 127	3045 \pm 237	4248 \pm 221
/e/	487 \pm 78	1632 \pm 155	2989 \pm 271	4410 \pm 327
/ə/	528 \pm 112	2545 \pm 222	3160 \pm 208	4404 \pm 266
/i/	324 \pm 55	2763 \pm 291	3521 \pm 192	4445 \pm 207
/o/	431 \pm 86	973 \pm 105	2917 \pm 318	4165 \pm 284
/u/	369 \pm 43	872 \pm 153	2853 \pm 250	4156 \pm 276
Mean	485 \pm 172	1707 \pm 746	3081 \pm 330	4305 \pm 288

C. Significant difference in gender

In overall, Indian females have 1.18 times higher formant frequencies than those of Indian males. The independent samples t-test revealed that Indian female had significant higher formant frequencies than those of Indian males in all six vowels except F_2 and F_3 of /u/. Table 4 shows the summary of the significant level in formant frequencies across the gender.

Table 4 Significant level across the gender in six vowels.

Formant	Significant Level					
	/a/	/e/	/ə/	/i/	/o/	/u/
F ₁	<0.001	<0.001	<0.001	<0.001	0.007	<0.001
F ₂	<0.001	<0.001	<0.001	<0.001	<0.001	0.732
F ₃	<0.001	<0.001	<0.001	<0.001	0.002	0.135
F ₄	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

D. Significant difference in vowels

One-way ANOVA test analysis showed that there were significant differences in formant frequencies across the vowels among Malaysian Indian males ((F_{F1} (5,174)=26.734; p<0.001), (F_{F2} (5,174) = 278.051; p<0.001), (F_{F3} (5,174) =13.888; p<0.001) and (F_{F4} (5,174) =3.772; p<0.003)). The post hoc test analysis showed that significant differences in F₁ were observed in all vowel pairs except /ə/-/e/, /ə/-/o/, /ə/-/u/ and /e/-/o/. As for F₂, significant differences were observed across the vowel pairs except /o/-/u/.

As for Indian females, the one-way ANOVA test analysis showed that significant differences in formant frequencies were observed across the vowels ((F_{F1} (5,174)=84.686; p<0.001), (F_{F2} (5,174) = 538.269; p<0.001), (F_{F3} (5,174) =27.887; p<0.001), (F_{F4} (5,174) =7.221; p<0.003). The post hoc test showed that significant differences in F₁ were observed in all vowel pairs except /ə/-/e/, /e/-/o/, /i/-/u/ and /o/-/u/ pairs. Significant differences across all vowels pair were reported in F₂ except /o/-/u/.

E. Interaction between gender and vowels

Two-way ANOVA test analysis showed that the interaction between vowel and gender was significant for F₁ (F_(5,348)=25.941; p<0.001), F₂ (F_(5,348) = 9.333; p<0.001) and F₃(F_(5,348) =2.661; p<0.03). However, there was no significant interaction between vowel and gender for F₄ (F_(5,348) =1.657; p>0.10).

IV. DISCUSSIONS

F₁ is associated to the tongue height articulation of vowel relative to the roof of the mouth. Low F₁ value indicates that the tongue has moved to higher articulatory posture [19, 20]. F₂ is associated with the horizontal tongue position relative to the back of the mouth. High F₂ value indicates that the tongue has moved in a more anterior position [19, 20]. Apart from that, lip rounding will lower the formant frequencies especially for back vowel [20].

Malaysian Indian had the lowest F₁ value in /i/ followed by /u/ and /a/ while the highest F₂ value in /i/ followed by /a/ and /u/. The study agreed with the finding of Andrianopoulos *et al.* [1] and Olagbaju *et al.* [11] where /i/ and /u/ had the lowest F₁ and F₂ values respectively. However, the study disagreed with the study of Olagbaju *et al.* [11] that /a/ had lower F₁ value than /u/ and /i/ had lower F₂ value than that of /a/.

In comparison with the study of Andrianopoulos *et al.* [1], Malaysia Indian males had lower F₁ but higher F₂ than that of native Hindi Indian males for /a/ and /i/. As for /u/, Malaysia Indian males had higher F₁ but lower F₂ than that of native Hindi Indian males. Malaysia Indian females showed higher F₁ and F₂ for /i/ but lower for /u/ than that of native Hindi Indian females. For /a/, Native Hindi Indian females had higher F₁ but lower F₂ than that of Malaysia Indian females. Compared to the study of Olagbaju *et al.* [11], Malaysian male Indians had lower F₁ and F₂ than those of native male Hindi in the vowels of /a/, /e/, /i/, /o/ and /u/ except F₂ of /i/. The comparison is shown in Table 5.

Table 5 Formant frequencies of native Hindi Indian.

Study	Vowel	Gender	Formant Frequency (Hz)		
			F1	F2	F3
Andrianopoulos <i>et al.</i> [1]	/a/	Male	570.20	1107.30	2609.63
	/i/		267.97	2210.40	3007.07
	/u/	Female	313.43	901.33	2436.50
	/a/		817.67	1430.17	2055.07
Olagbaju <i>et al.</i> [11]	/i/	Female	315.10	2353.90	3172.50
	/u/		382.17	894.92	2922.21
	/a/	Male	701	2083	-
	/e/		534	1803	-
	/i/		473	1921	-
	/o/		718.00	1673	-
/u/	739.00	1611.	-		

V. CONCLUSIONS

The study has investigated the first four formant frequencies of six vowels in normal Malaysian Indian young adults. The mean F₁, F₂, F₃ and F₄ of Malaysian Indian males were reported at 359.09 ± 86.56 Hz, 1457.40 ± 630.33 Hz, 2798.70 ± 335.50 Hz and 3776.90 ± 298.90 Hz respectively. The F₁, F₂, F₃ and F₄ of Malaysian Indian females were reported at 484.61 ± 171.74 Hz, 1707.00 ± 746.20 Hz, 3080.90 ± 329.86 Hz and 4304.50 ± 287.73 Hz respectively. Malaysian Indian females had significant higher formant frequencies in all vowels than those of Indian males except F₂ and F₃ in /u/. Besides that, significant differences in all the formant frequencies were observed across all the vowels

for both Indian males and females. Significant interactions between vowels and gender were found in F_1 , F_2 and F_3 but not in F_4 .

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