# Acoustic analysis of normal Saudi adult voices

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## ABSTRACT

**الأهداف:** تحديد الاختلافات في التحليل الصوتي ما بين الذكور والإناث السعوديون، ومقارنة متغيرات قاعدة بيانات برنامج التحليل الصوتي (MDVP) متعدد الاتجاهات المدمجة والتي تم الحصول عليها من بالغي شمال أمريكا بمجموعة من الذكور والإناث السعوديين.

**الطريقة:** تم إجراء دراسة مسحية قطعية لأصوات الذكور والإناث السعوديين الأصحاء خلال الفترة ما بين مارس 2007م حتى ديسمبر 2008م – مستشفى الملك عبدالعزيز الجامعي – الرياض. حيث قام 95 شخص سعودي بنطق صوت /a/ ست مرات وتم تحليل نسبة الحالة الثابتة لثلاث عينات، ومقارنتها بتلك المدمجة بقاعدة بيانات البرنامج.

**النتائج:** وجدت اختلافات إحصائية ذات دلالة هامة بين قاعدة بيانات البرنامج لمجموعة السعوديون و مجموعة شمال أمريكا. حيث أظهرت الاختلافات الإحصائية لقاعدة البرنامج 15 متغيراً من 33 متغير بمجموعة الذكور و 10 متغيرات من 33 متغير بمجموعة الإناث.

**خاتمة:** افترضنا أن الاختلافات الإحصائية تعكس الاختلافات التشريحية للأنسجة بين الشعوب.

**Objectives:** To determine the acoustic differences between Saudi adult male and female voices, and to compare the acoustic variables of the Multidimensional Voice Program (MDVP) obtained from North American adults to a group of Saudi males and females.

**Methods:** A cross-sectional survey of normal adult male and female voices was conducted at King Abdulaziz University Hospital, Riyadh, Kingdom of Saudi Arabia between March 2007 and December 2008. Ninety-five Saudi subjects sustained the vowel /a/ 6 times, and the steady state portion of 3 samples was analyzed and compared with the samples of the KayPentax normative voice database.

**Results:** Significant differences were found between Saudi and North American KayPentax database groups. In the male subjects, 15 of 33 MDVP variables, and 10 of 33 variables in the female subjects were found to be significantly different from the KayPentax database.

**Conclusion:** We conclude that the acoustical differences may reflect laryngeal anatomical or tissue differences between the Saudi and the KayPentax database.

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Voice assessment consists of both the auditory-perceptual assessment of voice and the acoustic and aerodynamic analysis. Both provide an indication of the severity of the dysphonia and may also be used to assess changes that occur with time and/or treatment. The voice assessment measures provide unique and complementary information to the medical diagnosis, all of which becomes a part of the treatment plan for the patient. Moreover, a comprehensive assessment of the voice helps to understand the impact of the disease on voice production and to evaluate the factors that contribute to the ongoing abnormal voice. Tantamount to the study and interpretation of the measures found in the abnormal voice is the knowledge of normal vocal function. Many factors such as age,[1] gender,[2] pulmonary status,[3] and diseases,[4] have been shown to contribute to the acoustic measures of the voice and to help define the normal voice population. Race has been suggested to contribute to the perception of voice. Walton and Orlikoff[5] have shown that measures of amplitude and frequency perturbation in African American adult males are not equal to those of white adult males. Also, Sapienza[6] analyzed the vowel /a/ in a group of 20 African Americans and 20 white Americans. She found that African American males and females had higher mean fundamental frequencies and lower sound pressure levels for the voice samples, but the differences were not significant.[6] She did find significant differences for both males and females between the African American group and the white American group for maximum flow declination rate (MFDR). This difference was partially attributed to the larger ratio of the membranous to cartilaginous portion of the vocal folds and increased thickness, a finding previously reported by Boshoff.[7] Sapienza[6] did not examine other acoustic parameters for gender or racial differences. Walton and Orlikoff[5] found through acoustical analysis that black speakers had significantly greater amplitude perturbation measures, and significantly lower harmonics-to-noise ratios than did white adult males. Although the black males had a lower mean speaking fundamental frequency than the white males, the differences were not significant in their group of 50 subjects. In 1996, Mayo et al[8] measured the cross-sectional area of the nose and found that there were no differences in the cross-sectional areas between whites and African-Americans, the nasalance scores obtained from a reading passage were higher in the white individuals.[8] The authors suggested that the nasalance differences may be due to both adapted speech patterns as well as tissue characteristics of the speakers, not the nasal volume itself. A recent study by Xue et al[9] further supported the contention that speakers from different races may not reflect normal standards as provided by the KayPentax database. Those authors quantified vocal tract dimensional parameters such as oral length, oral volume, pharyngeal length, pharyngeal volume, total vocal tract length, and total vocal tract volume in adult male speakers from 3 divergent populations; white Americans, African Americans, and Chinese. In addition, they examined the acoustic characteristics from each group of speakers. They found significant differences in the volumetric differences of the vocal tract, and those volumetric differences were partially responsible for the differences in the acoustic characteristics of vowels. Since vocal assessment involves more than just an auditory perceptual assessment of voice, measures related to the acoustic parameters of phonation can help the treating voice team to understand the impact of the disease on voice production, to evaluate the degree of vocal fold dysfunction, and to monitor changes in the patient's vocal performance. The multi-dimensional voice program (MDVP) is a computerized voice analysis system. It provides objective, non-invasive, and reproducible acoustic vocal information. The MDVP extracts up to 33 acoustic variables for each voice analysis (***Appendix**). It then compares them, graphically or numerically, to a built-in normative database.[10] Currently, there are no objective data to identify the normal values of Saudi adult voices. While there is clinical anecdotal evidence that Saudi adults may sound different from North American males and females, there are no data to support those contentions. Based on the findings of Walton and Orlikoff,[5] and those of Sapienza,[6] there is reason to believe that Saudi adults may not reflect the normative values provided by large scale databases used in the United States. The clinical experience of one of the present authors suggests that many normal Saudi adults show abnormal MDVP findings based on the built-in KayPentax MDVP normative data. However, that data are primarily taken from American white adults. The aims of this study were thus 3-fold: first, to determine the differences between normal Saudi adult males and females, second, to establish normative data for acoustic analysis of adult Saudi normal voices using MDVP; and third, to compare Saudi normative data of males and females with built-in normative data in the KayPentax MDVP software.

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**Methods.** The study was conducted at King Abdulaziz University Hospital, Riyadh, Kingdom of Saudi Arabia between March 2007 and December 2008. It was approved by the Research Center, Medical College, King Saud University, and its Ethical Committee. The sample size of 100 normal Saudi subjects was obtained through biostatistical power analysis. The subjects consisted of 95 out of 100 subjects. Five subjects were excluded because the recordings contained excessive background noise. Inclusion criteria were age between 18 and 60 years, Saudi nationality, and informed consent was obtained. Exclusion criteria were a history of any of the following: recent voice problems or symptoms suggesting reflux laryngitis (within the last year), laryngeal operation, prolonged laryngeal intubation, hearing impairment, and history of smoking. The acoustic analysis was performed using a Computerized Speech Lab (CSL, model 4300, Kay Elemetrics Corp., Lincoln Park, New Jersey, USA). The MDVP software (Model 4305, Kay Elemetrics Corp., Lincoln Park, New Jersey, USA) was used to analyze the acoustic signals. The sampling rate was set to 50,000 Hz. The examination was performed in an acoustically treated room. The subject held the microphone (Shure, Chicago, USA) at a fixed distance of 15 cm and at a 45° angle off-position. Subjects were trained to produce a steady vowel /a/ for 6 seconds, multiple times before commencing the test. Following the training, subjects were then instructed to vocalize and sustain the vowel /a/ for 6 seconds at a comfortable pitch and loudness after they were instructed to clear their throat. The middle 3 seconds were used for analysis because they are the most regular and are less affected

*The full text including Appendix is available in PDF format on Saudi Medical Journal website (www.smj.org.sa) by signal perturbations after excluding the onset and offset of phonation.[11-15] The voice signal was considered acceptable for analysis if it were sustained for the proper length of time, free of overload on the volume unit monitor and with no audible variation in pitch and loudness as observed by the experimenter.

**Table 1** - Comparison of multidimensional voice program parameters between male and female Saudi subjects.

| Variables | Saudi males Mean ± SD | Saudi females Mean ± SD | *P*-value |
|---|---|---|---|
| Fo | 126.5962 ± 16.23941 | 230.7292 ± 24.48728 | 0.000* |
| MFo | 126.57290 ± 16.235100 | 230.64796 ± 24.442473 | 0.000* |
| To | 8.043 ± 1.1578 | 4.384 ± 0.4697 | 0.000* |
| Fhi | 130.51728 ± 16.629121 | 239.72593 ± 26.002762 | 0.000* |
| Flo | 122.98390 ± 15.780497 | 217.41960 ± 27.665197 | 0.000* |
| STD | 1.24488 ± 0.412103 | 2.2065 ± 0.678147 | 0.000* |
| PFR | 2.10 ± 0.552 | 2.37 ± 1.029 | 0.197 |
| Fftr | 4.20593 ± 1.976020 | 3.34421 ± 1.775188 | 0.029* |
| Fatr | 3.79889 ± 2.035378 | 3.39426 ± 1.580804 | 0.172 |
| Jita | 50.86417 ± 31.159641 | 33.68248 ± 16.797729 | 0.001* |
| Jitt | 0.69922 ± 0.614722 | 0.77240 ± 0.379457 | 0.055 |
| RAP | 0.37067 ± 0.240998 | 0.48122 ± 0.280045 | 0.13* |
| PPQ | 0.36534 ± 0.224573 | 0.45050 ± 0.222458 | 0.023* |
| sPPQ | 0.66172 ± 0.479185 | 0.55782 ± 0.191682 | 0.157 |
| vFO | 0.98383 ± 0.307960 | 1.01664 ± 0.477842 | 0.788 |
| ShdB | 0.28455 ± 0.133882 | 0.23894 ± 0.078221 | 0.087 |
| Shim | 3.12234 ± 1.196133 | 2.73068 ± 0.877076 | 0.102 |
| APQ | 2.4964 ± 0.98460 | 1.8948 ± 0.59432 | 0.000* |
| sAPQ | 3.941 ± 1.2420 | 3.283 ± 1.2044 | 0.000* |
| vAm | 9.69802 ± 3.341229 | 10.57320 ± 4.080466 | 0.288 |
| NHR | 0.13083 ± 0.014528 | 0.11269 ± 0.018697 | 0.000* |
| VTI | 0.04416 ± 0.046139 | 0.03890 ± 0.012951 | 0.759 |
| SPI | 16.14321 ± 8.637701 | 15.03661 ± 8.429572 | 0.528 |
| FTRI | 0.2892 ± 0.15438 | 0.3256 ± 0.70700 | 0.005* |
| ATRI | 3.40282 ± 1.675845 | 2.31195 ± 1.494291 | 0.013* |
| DVB | 0.00 ± 0.000 | 0.11 ± 0.639 | 0.122 |
| DSH | 0.07 ± 0.322 | 0.15 ± 0.476 | 0.210 |
| DUV | 0.04 ± 0.227 | 0.03 ± 0.150 | 0.894 |
| NVB | 0.00 ± 0.000 | 0.02 ± 0.143 | 0.277 |
| NSH | 0.09 ± 0.388 | 0.18 ± 0.565 | 0.201 |
| NUV | 0.05 ± 0.292 | 0.04 ± 0.200 | 0.679 |
| SEG | 110.98 ± 19.917 | 125.29 ± 8.473 | 0.000* |
| PER | 420.48 ± 89.261 | 868.22 ± 107.446 | 0.000* |

*statistically significan ($p<0.05$). Fo - average fundamental frequency, MFo - mean fundamental frequency, To - average pitch period), Fhi - highest fundamental frequency, Flo - lowest fundamental frequency, STD - standard deviation of Fo, PFR - phonatory fo-range in semi-tones, Fftr - fo-tremor frequency, Fatr - amplitude tremor frequency, Jita - absolute jitter, Jitt - jitter percent, RAP - relative average perturbation, PPQ - pitch perturbation quotient, sPPQ - smoothed pitch perturbation quotient, vFo - fundamental frequency variation, ShdB - shimmer in dB, Shim - shimmer percent, APQ - amplitude perturbation quotient, sAPQ - smoothed ampl. perturbation quotient, vAm - peak-to-peak amplitude variation, NHR - noise to harmonic ratio, VTI - voice turbulence index, SPI - soft phonation index, FTRI - fo-tremor intensity index, ATRI - amplitude tremor intensity index, DVB - degree of voice breaks, DSH - degree of sub-harmonics, DUV - degree of voiceless, NVB - number of voice breaks, NSH - number of sub-harmonic segments, NUV - number of unvoiced segments, SEG - number of segments computed, PER - total number detected pitch periods

The SPSS (Statistical Package for Social Science) software version 15 was used for statistical analysis. Mann-Whitney test was used to compare normal Saudi males with normal Saudi females. Student's t-test was used to compare the normative Saudi data with the built-in normative data in the MDVP software for males and females. P-values of <0.001515 were considered as statistically significant. Probability values were adjusted using the Bonferroni technique to correct any possibility of inflated Type I error. Multivariate analysis of variance was not used as only the means and standard deviations of the built-in MDVP normative data were available.

**Results.** The final group of subjects consisted of 45 Saudi males (mean age 29.0 ± 8.7 years) and 50 Saudi females (mean age 30.0 ± 10.2 years). The comparison between normal male and female Saudi subjects is presented in **Table 1**. The MDVP parameters with statistically significant differences between normal Saudi males and females are presented in **Table 2**. Seventeen of 33 MDVP variables showed significant differences

**Table 2** - The 17 multidimensional voice program parameters with statistically significant differences between Saudi males and females (refer to Appendix for abbreviations).

| Variable | Males (N=45) | Females (N=50 ) | *P*-value |
|---|---|---|---|
| Fo | 126.5962 | 230.7292 | 0.000* |
| MFo | 126.57290 | 230.64796 | 0.000* |
| To | 8.043 | 4.384 | 0.000* |
| Fhi | 130.51728 | 239.72593 | 0.000* |
| Flo | 122.98390 | 217.41960 | 0.000* |
| STD | 1.24488 | 2.2065 | 0.000* |
| Fftr | 4.20593 | 3.34421 | 0.029* |
| Jita | 50.86417 | 33.7 | 0.001* |
| RAP | 0.37067 | 0.48122 | 0.013* |
| PPQ | 0.36534 | 0.45050 | 0.023* |
| APQ | 2.4964 | 1.8948 | 0.000* |
| sAPQ | 3.941 | 3.283 | 0.000* |
| NHR | 0.13083 | 0.11269 | 0.000* |
| FTRI | 0.2892 | 0.3256 | 0.005* |
| ATRI | 3.40282 | 2.31195 | 0.013* |
| SEG | 110.98 | 125.29 | 0.000* |
| PER | 420.48 | 868.22 | 0.000* |

*statistically significant ($p<0.05$). Fo - average fundamental frequency, MFo - mean fundamental frequency, To - average pitch period, Fhi - highest fundamental frequency, Flo - lowest fundamental frequency, STD - standard deviation of Fo, Fftr - fo-tremor frequency, Jita - absolute jitter, RAP - relative average perturbation, PPQ - pitch perturbation quotient, sPPQ - smoothed pitch perturbation quotient, APQ - amplitude perturbation quotient, sAPQ - smoothed ampl. perturbation quotient, vAm - peak-to-peak amplitude variation, NHR - noise to harmonic ratio, FTRI - fo-tremor intensity index, ATRI - amplitude tremor intensity index, SEG - number of segments computed, PER - total number detected pitch periods

**Table 3** - Multidimensional voice program (MDVP) parameters with statistically significant differences between Saudi males and built-in MDVP male data.

| Variable | Saudi males | Built-in normal males | P-value (t-test) (p<0.05) | Corrected p-value (Benferroni) ( 0.001515) |
|---|---|---|---|---|
| Fo | 126.5962 | 145.223 | 0.0000000 | Significant |
| MFo | 126.57290 | 141.743 | 0.0000000 | Significant |
| To | 8.043 | 7.055 | 0.0000881 | Significant |
| Fhi | 130.51728 | 150.08 | 0.0000000 | Significant |
| Flo | 122.98390 | 140.418 | 0.0000000 | Significant |
| STD | 1.24488 | 1.349 | 0.4308286 | - |
| PFR | 2.10 | 2.095 | 0.1705499 | - |
| Fftr | 4.20593 | 3.655 | 0.0245402 | - |
| Fatr | 3.79889 | 2.728 | 0.0628324 | - |
| Jita | 50.86417 | 41.663 | 0.0000000 | Significant |
| Jitt | 0.69922 | 0.589 | 0.3132347 | - |
| RAP | 0.37067 | 0.345 | 0.6421983 | - |
| PPQ | 0.36534 | 0.338 | 0.5790344 | - |
| sPPQ | 0.66172 | 0.561 | 0.1834541 | - |
| vFO | 0.98383 | 0.939 | 0.5312499 | - |
| ShdB | 0.28455 | 0.219 | 0.0028949 | - |
| Shim | 3.12234 | 2.523 | 0.0890813 | - |
| APQ | 2.4964 | 1.986 | 0.2425544 | - |
| sAPQ | 3.941 | 3.055 | 0.0291171 | - |
| vAm | 9.69802 | 7.712 | 0.0000262 | Significant |
| NHR | 0.13083 | 0.122 | 0.0017843 | - |
| VTI | 0.04416 | 0.052 | 0.2282082 | - |
| SPI | 16.14321 | 6.77 | 0.0000036 | Significant |
| FTRI | 0.2892 | 0.311 | 0.4332665 | - |
| ATRI | 3.40282 | 2.133 | 0.0000974 | Significant |
| DVB | 0.00 | 0.2 | 0.0000000 | Significant |
| DSH | 0.07 | 0.2 | 0.0049998 | - |
| DUV | 0.04 | 0.2 | 0.0000097 | Significant |
| NVB | 0.00 | 0.2 | 0.0000000 | Significant |
| NSH | 0.09 | 0.2 | 0.0416905 | - |
| NUV | 0.05 | 0.2 | 0.0002623 | Significant |
| SEG | 110.98 | 95.0 | 0.0000000 | Significant |
| PER | 420.48 | 433.143 | 0.0000000 | Significant |

Fo - average fundamental frequency, MFo - mean fundamental frequency, To - average pitch period, Fhi - highest fundamental frequency, Flo - lowest fundamental frequency, STD - standard deviation of Fo, PFR - phonatory fo-range in semi-tones, Fftr - fo-tremor frequency, Fatr - amplitude tremor frequency, Jita - absolute jitter, Jitt - jitter percent, RAP - relative average perturbation, PPQ - pitch perturbation quotient, sPPQ - smoothed pitch perturbation quotient, vFo - fundamental frequency variation, ShdB - shimmer in dB, Shim - shimmer percent, APQ - amplitude perturbation quotient, sAPQ - smoothed ampl. perturbation quotient, vAm - peak-to-peak amplitude variation, NHR - noise to harmonic ratio, VTI - voice turbulence index, SPI - soft phonation index, FTRI - fo-tremor intensity index, ATRI - amplitude tremor intensity index, DVB - degree of voice breaks, DSH - degree of sub-harmonics, DUV - degree of voiceless, NVB - number of voice breaks, NSH - number of sub-harmonic segments, NUV - number of unvoiced segments, SEG - number of segments computed, PER - total number detected pitch periods

**Table 4** - Multidimensional voice program (MDVP) parameters with statistically significant differences between Saudi females and built-in MDVP female data.

| Variable | Saudi females | Built-in normal females | *P*-value of t-test (0.05) | Corrected p-value (Benferroni) (0.001515) |
|---|---|---|---|---|
| Fo | 230.7292 | 243.973 | 0.0103333 | - |
| MFo | 230.64796 | 241.08 | 0.0334030 | - |
| To | 4.384 | 4.148 | 0.0087855 | - |
| Fhi | 239.72593 | 252.724 | 0.0128607 | - |
| Flo | 217.41960 | 234.861 | 0.0021055 | - |
| STD | 2.2065 | 2.722 | 0.0896648 | - |
| PFR | 2.37 | 2.25 | 0.5576143 | - |
| Fftr | 3.34421 | 3.078 | 0.5307270 | - |
| Fatr | 3.39426 | 2.375 | 0.0069883 | - |
| Jita | 33.68248 | 26.927 | 0.0412849 | - |
| Jitt | 0.77240 | 0.633 | 0.0541102 | - |
| RAP | 0.48122 | 0.378 | 0.0375940 | - |
| PPQ | 0.45050 | 0.366 | 0.0462207 | - |
| sPPQ | 0.55782 | 0.532 | 0.5219586 | - |
| vFO | 1.01664 | 1.149 | 0.3841120 | - |
| ShdB | 0.23894 | 0.176 | 0.0000385 | Significant |
| Shim | 2.73068 | 1.997 | 0.0000190 | Significant |
| APQ | 1.8948 | 1.397 | 0.0000163 | Significant |
| sAPQ | 3.283 | 2.371 | 0.0000421 | Significant |
| vAm | 10.57320 | 10.743 | 0.8605930 | - |
| NHR | 0.11269 | 0.112 | 0.8145306 | - |
| VTI | 0.03890 | 0.046 | 0.0047255 | - |
| SPI | 15.03661 | 7.534 | 0.0000001 | Significant |
| FTRI | 0.3256 | 0.304 | 0.8411287 | - |
| ATRI | 2.31195 | 2.658 | 0.4166338 | - |
| DVB | 0.11 | 0.2 | 0.3317028 | - |
| DSH | 0.15 | 0.2 | 0.4724052 | - |
| DUV | 0.03 | 0.2 | 0.0000000 | Significant |
| NVB | 0.02 | 0.2 | 0.0000000 | Significant |
| NSH | 0.18 | 0.2 | 0.8074115 | - |
| NUV | 0.04 | 0.2 | 0.0000018 | Significant |
| SEG | 125.29 | 92.594 | 0.0000000 | Significant |
| PER | 868.22 | 713.188 | 0.0000000 | Significant |

Fo - average fundamental frequency, MFo - mean fundamental frequency, To - average pitch period, Fhi - highest fundamental frequency, Flo - lowest fundamental frequency, STD - standard deviation of Fo, PFR - phonatory fo-range in semi-tones, Fftr - fo-tremor frequency, Fatr - amplitude tremor frequency, Jita - absolute jitter, Jitt - jitter percent, RAP - relative average perturbation, PPQ - pitch perturbation quotient, sPPQ - smoothed pitch perturbation quotient, vFo - fundamental frequency variation, ShdB - shimmer in dB, Shim - shimmer percent, APQ - amplitude perturbation quotient, sAPQ - smoothed ampl. perturbation quotient, vAm - peak-to-peak amplitude variation, NHR - noise to harmonic ratio, VTI - voice turbulence index, SPI - soft phonation index, FTRI - fo-tremor intensity index, ATRI - amplitude tremor intensity index, DVB - degree of voice breaks, DSH - degree of sub-harmonics, DUV - degree of voiceless, NVB - number of voice breaks, NSH - number of sub-harmonic segments, NUV - number of unvoiced segments, SEG - number of segments computed, PER - total number detected pitch periods between Saudi males and Saudi females. While it was expected that fundamental frequency and standard deviation would be different between males and females, the results also suggested that measures of frequency perturbation are also significantly different. In essence, males show lower fundamental frequency measures, but demonstrated higher frequency perturbation, noise, and tremor measures. The MDVP parameters for Saudi males and Saudi females compared to built-in MDVP male and female data are presented in **Tables 3 & 4**. Although not all MDVP variables were found to be statistically significant, the data indicated that 15 of the 33 variables in the male group were statistically significantly different from the Kay database, and 10 of the 33 variables in the female group were statistically significantly different from the Kay database. Compared to male built-in Kay data, normal Saudi males showed lower frequency measures, higher frequency and amplitude perturbations, and higher noise, tremor, and irregularity measures. On the other hand, normal Saudi females demonstrated higher amplitude perturbations and soft phonation index, lower break, and irregularity measures compared to female built-in Kay data.

**Discussion.** Acoustic analysis is one of the important assessment tools for voice analysis.[15,16] It is user-friendly for the patient and the clinician. The MDVP is a well-known acoustic analysis program frequently used in voice clinics and as a research tool. The MDVP has its own built-in normative data that were collected in 1997 from 55 normal white American subjects, as described by KayPentax, the manufacturing company of CSL and MDVP.[17] However, the data presented in this report suggest that each racial group may have a distinct set of normative data. Data from Walton and Orlikoff[5] and from Xue et al,[9] are in general agreement to the extent that they studied acoustic parameters.

Comparing the male and female results (**Table 2**), the Fo (average fundamental frequency) was higher for females than for males. This is expected, and in general agreement with common findings.[18] Both Saudi males and females had significantly lower mean fundamental frequency measures compared to the KayPentax database. This finding agrees with the data from Walton and Orlikoff[5] who found that black speakers had significantly greater amplitude perturbation measures, and significantly lower harmonics-to-noise ratios than did white adult males. In the Walton and Orlikoff study[5] as well as the Xu et al study,[9] African American subjects had lower speaking fundamental frequencies than the white American group. This finding may relate to the structure of the African vocal tract and larynx as pointed out by Boshoff.[7] African males have longer and thicker true vocal folds than females (longer and thicker vibrating objects produce lower frequencies). The frequency and amplitude perturbation variables were higher for males than for females and suggests that this effect might arise from training because females use their voices more frequently than males.[19] The training effects of Saudi normal adults have not been studied. In the present study, normal Saudi males showed statistically significant differences for 15 of the 33 MDVP variables studied, and females showed significant differences for 10 of the 33 variables studied (**Tables 3 & 4**). This can be most likely explained by possible racial differences since the protocol in this study was the same as that used to acquire the KayPentax data, the manufacturing company of CSL and MDVP. The vowel /a/ was used in the KayPentax data and in the Saudi data. Thus, racial differences are a more likely explanation for the differences between our normative data and the built-in data in MDVP. Increased tissue thickness may account for these differences. Further studies of racial differences in voice should include measures of tissue characteristics. Given the scant amount of data relating to African and Asian individuals, we can only hypothesize that tissue thickness,[8] or overall vocal tract volume,[6,7] may contribute to the differences found in the present data. Further investigation with additional vowels and a more homogeneous sample (such as age controls) may shed light into the racial differences in voice production. As yet, it is not known if the differences in the adult population are also seen in children. Although acoustic analysis using MDVP is important and valuable, it still has deficiencies including lack of standardization for a wide range of speech tasks and many of the MDVP variables have a wide range of normal values, low sensitivity, and specificity. Thus, even when the same protocol and same analysis software are used, acoustic voice analysis variables such as race must be considered in the interpretation in addition to the normal variables of gender and age.

In conclusion, acoustic analysis of voice using MDVP is an important voice assessment tool. The fundamental frequency and many of the frequency and amplitude perturbation variables showed statistically significant differences between normal Saudi males and females. In addition, the groups of Saudi males and females show significant differences in perturbation parameters compared to a standard North American database. The data from this study support the hypothesis that these differences are most likely due to racial differences. We therefore offer the following recommendations: first, the normative data in MDVP software should take racial differences into account. Second, international standardization of assessment protocols should be specified for acoustic analysis of voice. Finally, because of the variations seen in the MDVP database, data sets should be interpreted to include the salient factors such as gender, age, voice sample in addition to race in order to better understand the differences between normal and abnormal voices.

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