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Standardization of nasalance scores in normal Saudi speakers

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Abstract

Objective. The aims of this study were to obtain normative nasalance scores for a normal Saudi population with different ages and genders, to develop nasometric Arabic speech materials, and to make cross-linguistic comparison.

Subjects. Participants included 219 normal Saudi native monolingual Arabic speakers of different ages. Subjects were classified into four groups according to age and gender. Subjects did not have any history of oral, nasal, or velopharyngeal abnormality.

Methods. Arabic speech samples were developed to evaluate nasalance scores, which included syllables repetition, three oral sentences, three oro-nasal sentences, and three nasal sentences. Nasalance data were obtained using Nasometer II–6400.

Results. Normative nasalance values were determined. Significant differences between the male and female children groups were noticed in many parameters. Nasalance scores were higher in adults, with significant differences between all groups.

Conclusion. Normative nasalance scores for Saudi Arabic speakers have been developed for both adults and children. The Arabic speech materials developed in this study appear to be easy to use and applicable for different age groups.

Key words: Nasality, nasometer, normative data, velopharyngeal valve

Introduction

The nasometer is a non-invasive objective tool for evaluating resonance (nasality) disorders of speech. It measures the nasal acoustic energy by a microcomputer-based apparatus. The nasometer provides a nasalance score that corresponds to the ratio of nasal acoustic energy to the sum of oral and nasal acoustic energy expressed as a percentage (1).

Nasalance may vary among different languages. According to Leeper et al. (2), within-subject significant differences in nasalance scores were found in bilingual Canadian French–American English speakers across the two languages, even when care was taken to match the phonetic content of the reading material.

It is well documented that a major prerequisite for assessing resonance in a clinical population is to compare the patient scores with normative data (3). For that reason, normative nasalance scores were originally determined for several languages such as Greek (3), English (4), Spanish (5), Puerto Rican Spanish (6), Finnish (7), Flemish (8), Hungarian (9), French (2), Dutch (10), Canadian French (11), Arabic languages (12), Danish (13), Thai (14), and Japanese (15). These previous studies considered their own language characteristics. Therefore, adaptation of their results cannot be used for Arabic speakers.

Regarding Arabic language, Abou-Elsaad et al. (12) developed normative values for the nasalance scores among Egyptian Arabic speakers. Although
speaking Arabic, the Egyptian Arabic dialect is considered unique, and there are differences between it and other dialects spoken by other Arab countries. This makes the normative nasalance scores developed for the Egyptian dialect difficult to be applied for the Saudi population and other Arabs. This concept was reported in other studies, which mentioned that the nasalance score is not only affected by the tongue language, it even depends on the presence of a particular spoken dialect. This may be attributed to the speaking style leading to cultural-linguistic differences in resonance (4,12). Moreover, Okalidou et al. (3) mentioned that nasalance is affected by subtle differences in articulatory posturing or even articulatory timing of the velopharyngeal port opening during speech.

The same conclusion was reached by a study that examined the racial difference in nasalance scores (16). In this study, white American speakers yielded higher nasalance scores for nasal sentences than their African counterparts in spite of absent differences in nasal cross-sectional area.

Saudi Arabic dialect has a lot in common with most of the dialects spoken by almost all the Arabian Gulf countries, which adds more rationale for developing normative nasalance score for a Saudi population that can be generalized for other countries in the Gulf area. In Saudi Arabia, no previous study has been published to document normative nasalance score for a Saudi population. The aims of this study were to obtain normative nasalance scores for a normal Saudi population with different ages and genders, to develop nasometric Arabic speech materials, and to make cross-linguistic comparisons.

Materials and methods

Subjects

The study was approved by the Institutional Review Board of the College of Medicine, King Saud University, Riyadh, Saudi Arabia. The study was conducted at the Communication and Swallowing Disorders Division, Prince Sultan Military Medical City and Research Chair of Voice, Swallowing, and Communication Disorders, King Abdul Aziz University Hospital, King Saud University, Riyadh, Saudi Arabia. Two hundred nineteen monolingual Saudi native Arabic subjects with normal hearing, voice, speech, and language participated in the study after giving their informed consent. In addition, subjects had no history of craniofacial anomalies, velopharyngeal impairment, or affected mental abilities. The participants were from different urban and suburban locations of Riyadh city, and originally coming from different areas of the Kingdom of Saudi Arabia. Speech was evaluated by two experienced phoniatricians and a qualified speech-language pathologist. The speech screening consisted of an oral-motor examination and 5 minutes of conversational speech, where articulation, language, fluency, and resonance were perceptually evaluated. Subjects were excluded if they reported a common cold in the last 10 days, active nasal obstruction, or history of oro-pharyngeal/nasal surgery in the last 6 months.

Subjects were divided into four groups. Group I consisted of 71 adult females (32.4%) with an age range of 17 – 55 years and a mean age of 32.08 ± 10.10 years. Group II consisted of 73 adult males (33.3%) with an age range of 18 – 54 years and a mean age of 34.37 ± 9.27 years. Group III consisted of 34 female children (15.5%) with an age range of 4 – 14 years and a mean age of 8.71 ± 3.37 years, whereas group IV consisted of 41 male children (18.7%) with an age range of 4 – 12 years and a mean age of 7.39 ± 2.56 years (Table I). The degree of matching of the ages between groups I and II and groups III and IV was statistically tested and revealed non-significant differences (P>0.05).

Development of Arabic speech material

Subjects were asked to produce the speech material at a normal rate and habitual pitch and loudness. The Arabic testing material constructed and used in this study included:

1. Syllable repetition task (17): This subtest included 14 consonant–vowel syllables of pressure-sensitive consonants (plosives and fricatives, 10 oral and 4 nasal) combined with either the low vowel /a/ or the high vowel /i/. All participants were asked to repeat syllables until the screen was full of relatively even peaks and the first couple of syllables had

Table I. Distribution of the study groups.

| Group I (Adult females) | Number | Percent | Minimum age | Maximum age | Mean age | SD |
|-------------------------|--------|---------|-------------|-------------|----------|----|
| Group II (Adult males)  |        |         |             |             |          |    |
| Group III (Female children) |      |         |             |             |          |    |
| Group IV (Male children) |        |         |             |             |          |    |
| Total                   | 219    | 100%    |             |             |          |    |
disappeared to the left. Approximately 6–10 syllables were expected to be produced during the 2-second period represented on the display screen. The syllable repetition task included repeated /ba.ba.ba…/, /ta.ta.ta…/, /ka.ka.ka…/, /sa.sa.sa…/, ja. ja. ja…/, /bi.bi.bi…/, /ti.ti.ti…/, /ki.ki.ki…/, /si.si.si…/, /ji.ji.ji…/, /mi.mi.mi…/, and /ni.ni.ni…/.

2. Sustained sounds task (17): /a/, /i/, /m/, /s/. This subtest included two sustained vowels and two sustained consonants. All subjects were asked to sustain the tested consonants and vowels until the screen was full.

3. A set of three nasal sentences containing a preponderance of nasal consonants.

4. A set of three oral sentences, which were devoid of any nasal consonants.

5. A set of three oro-nasal sentences, which contained both oral and nasal consonants in representative ratios for spoken Arabic. As a prerequisite for the development of the oro-nasal material, the natural frequencies of oral and nasal phonemes in spoken Arabic were determined. As there were no such previously published data, analysis of frequency of oral and nasal consonants in three representative samples, each sample lasting for 45 minutes, of Arabic conversation between two normal adult Saudi individuals was performed. The three samples of conversation were as follows: the first sample was between two adult females, the second sample was between two adult males, and the third sample was between an adult male and an adult female. The three samples were analyzed and revealed that the average percentage of nasal consonants was about 11.45%. This ratio was used to construct the three oro-nasal sentences.

The sentences used in items 3, 4, and 5 were understandable, readable, and easy to be repeated fluently. Rehearsal was performed before recording. Every speech sample was repeated three times, and then the average was calculated. For children who could not read, nine picture cards, which were illustrative and contained the same phonological characteristics of the needed sentences, were prepared and used: three cards for the oral sentences, three cards for the nasal sentences, and three cards for the oro-nasal sentences. IPA transcriptions of the used sentences as well as their English translations are included in Supplementary Appendix A available online at http://informahealthcare.com/doi/abs/10.3109/14015439.2014.907339.

Instrumentation

Nasalance data were obtained using Nasometer II–6400 (18). Prior to testing, the nasometer was calibrated at the beginning of every day of testing according to the instructions provided in the manufacturer’s manual. Each subject was fitted with the headset, which was adjusted by stabilizing the metal plate perpendicular to the face.

Procedures

Subjects were seated in an acoustically treated room, next to the nasometer, and facing the experimenters. They were verbally given a set of instructions and were asked to follow the examiner in repeating the different speech tasks using a natural speech flow, speaking rate, and vocal loudness. Rehearsal was performed before recording. Every speech sample was repeated three times, and then the average was calculated.

Data analysis and statistical testing

Quantitative variables were presented as mean and SD. Kolmogorov test was done to test normality and revealed that all subtest data were normally distributed. Parametric variables were compared between two groups using independent sample t test, and compared between more than two groups using one way analysis of variance (ANOVA) followed by Scheffé test as post hoc test. The statistical package SPSS (version 20) was used, and the P value of <0.05 is considered as minimal level of significance.

Results

Matching of age among adult males and females revealed insignificant differences between both groups, which indicated matched groups regarding age. Similarly, matching of age among male and female children was evaluated and revealed also matched groups regarding age (P > 0.05).

Nasalance scores for all subtests were obtained and analyzed to evaluate gender-related differences among adults and children; they revealed that adult females showed overall higher nasalance scores compared to adult males. However, these differences were insignificant apart from a few tasks (repeated /ti/, /ki/, and /shi/ syllables) (Table II).

Unlike adult females, female children did not show consistent tendency of higher nasalance in comparison to the male children group. However, differences were significant for some tasks (repeated /pa/, /ta/, /pi/, /ni/, prolonged /a/, /i/, /m/, oral sentences, and oro-nasal sentences). There were significantly higher mean nasalance values for /pa/, /ta/, /pi/, and oral sentences in the female children.
Table II. Comparison of normative nasalance score between Group I and Group II.

|        | Group I (n = 71) |        | Group II (n = 73) |        |
|--------|------------------|--------|------------------|--------|
|        | Mean  SD |        | Mean  SD |        | P   |
| pa     | 6.93  1.32  | 7.29  2.29  | N.S. |
| ta     | 8.15  3.03  | 8.32  3.05  | N.S. |
| ka     | 9.86  3.35  | 9.99  3.70  | N.S. |
| sa     | 8.15  2.86  | 8.70  3.47  | N.S. |
| ja     | 8.20  2.94  | 8.86  3.70  | N.S. |
| pi     | 14.77  6.15  | 13.52  5.24  | N.S. |
| ti     | 21.20  8.46  | 17.77  8.19  | < 0.05 |
| ki     | 23.86  6.97  | 19.85  7.47  | < 0.001 |
| si     | 19.63  8.16  | 17.12  7.74  | N.S. |
| jí     | 21.45  7.97  | 18.52  7.34  | < 0.05 |
| ma     | 58.77  9.57  | 58.90  7.72  | N.S. |
| na     | 65.79 14.49  | 63.32 10.61 | N.S. |
| mi     | 77.73 11.24  | 76.78 10.31 | N.S. |
| ni     | 78.87 12.03  | 77.10  9.40 | N.S. |
| a      | 10.27  5.04  | 9.42  7.47  | N.S. |
| i      | 11.17  5.31  | 9.75  3.03  | N.S. |
| s      | 1.18  2.34  | 0.75  2.10  | N.S. |
| m      | 91.75 4.01  | 91.18 5.53  | N.S. |
| oral sentence | 47.76 3.91  | 47.15 4.64  | N.S. |
| nasal sentence | 47.76 3.91  | 47.15 4.64  | N.S. |
| oro-nasal sentence | 47.76 3.91  | 47.15 4.64  | N.S. |

N.S. = not significant; SD = standard deviation.

Table III. Comparison of the normative nasalance scores between Group III and Group IV.

|        | Group III (n = 34) |        | Group IV (n = 41) |        |
|--------|------------------|--------|------------------|--------|
|        | Mean  SD |        | Mean  SD |        | P   |
| pa     | 5.29  0.76  | 6.10  1.00  | < 0.001 |
| ta     | 5.44  0.70  | 6.61  1.87  | < 0.001 |
| ka     | 7.24  2.31  | 6.83  0.95  | N.S. |
| sa     | 6.24  1.76  | 6.27  1.48  | N.S. |
| ja     | 5.65  1.30  | 5.76  2.00  | N.S. |
| pi     | 8.44  2.09  | 11.83 1.87  | < 0.001 |
| ti     | 15.21 3.78  | 13.85 3.12  | N.S. |
| ki     | 18.50 3.78  | 18.98 4.02  | N.S. |
| si     | 14.47 5.41  | 13.32 3.02  | N.S. |
| jí     | 16.09 4.32  | 14.20 5.02  | N.S. |
| ma     | 55.35 4.04  | 53.61 4.80  | N.S. |
| na     | 56.82 5.33  | 54.63 4.77  | N.S. |
| mi     | 62.97 4.85  | 60.93 5.32  | N.S. |
| ni     | 65.24 4.36  | 62.73 5.85  | < 0.05 |
| a      | 7.24  3.02  | 10.32 3.03  | < 0.001 |
| i      | 21.26 3.48  | 17.37 3.89  | < 0.001 |
| s      | 0.88  2.16  | 0.44  0.90  | N.S. |
| m      | 87.21 3.13  | 85.46 3.62  | < 0.05 |
| oral sentence | 8.79 3.11  | 6.88 1.29  | < 0.001 |
| nasal sentence | 47.76 3.91  | 47.15 4.64  | N.S. |
| oro-nasal sentence | 16.88 2.03  | 17.98 1.17  | < 0.05 |

N.S. = not significant; SD = standard deviation.

ANOVA revealed significant age-related differences in almost all tasks (apart from the prolonged /s/ and the nasal sentences) with overall decreased nasalance scores in children compared to adults (Table IV). Variables of significant differences between study groups were further analyzed using Scheffé test as post hoc test (Table V).

To evaluate the effect of Saudi Arabic dialect, nasalance scores of Saudi adult groups were compared to those in the Egyptian study (12). Syllable repetition tasks as well as sustained sound tasks, which are in common in both studies, were compared using unpaired t test. Also, the comparison was performed between the similar groups in both studies (Saudi adult males with Egyptian adult males and Saudi adult females with Egyptian adult females). The comparison regarding other groups was not applicable due to different study design regarding groups of patients. There were significant differences in almost all subtests of speech tasks apart from a few as shown in Table VI.

Discussion

The nasometer is a valuable instrumental method for assessment of nasality in speech, and it reaches its optimal clinical utility when used in conjunction with clinical judgments and other instrumental procedures (18,19). Nasalance measurements provide quantitative estimates of nasal resonance in speech and, thus, form an objective way for assessing resonance disorders (3,20). Nasalance data have been obtained for speakers with various resonance problems (12,21,22). However, a major prerequisite for assessing nasal resonance based on nasometric measures in a population is to compare the patient’s scores with normative data of the same language. Hence, several studies have been conducted to obtain normative values for various languages.

A major factor in language-based differences on nasalance is the frequency of nasal consonants in speech, that is, the ratio of nasal to oral consonants, contained in the speech of a particular language or language variety. However, other phonological/phonetic characteristics of a particular language may come also into play. These include syllable structure (15) and vowel nasalization (23).

Despite developing normative nasalance data for Egyptian Arabic speakers, comparison between our results and those of the Egyptian study (12) concerning the syllable repetition and sustained sound subtests (which are the only common subtests) has revealed significant differences in many subtests, which in turn points to the importance of developing normative data for various dialects in the Arabic region. This proves the results concluded by other...
Nasalance scores in Saudi speakers

Nasalance scores in Saudi speakers were studied (4,12,13), which showed that the quality of resonance is affected by minimal and subtle differences in posturing of the articulators or even articulatory timing of the velopharyngeal port opening during speech.

The Egyptian study was based on the MacKay–Kummer SNAP test (23), which was modified to be applicable to the Egyptian Arabic language. The Egyptian study was different also in the study design, where the patients groups were classified into three groups according to their ages: group I (n = 92) comprised children aged 3 years 3 months to 9 years (mean 6 years 10 months ± 2 years 2 months), group II (n = 73) comprised teenagers aged 9–18 years (mean 12 years ± 4 years 2 months), and group III (n = 132) comprised adults aged 18–54 years (mean 34 years 10 months ± 9 years).

In our study patients were classified into four groups from the start according to sex and age.

In this Saudi study, the lowest mean nasalance values were reported in the oral speech samples whether syllables, prolonged vowels, or sentences. The highest mean nasalance values were reported in the nasal speech samples whether syllable repetition, prolonged nasal sound, or sentences. This was in agreement with other studies (3–6,10,12). Moreover, the mean nasalance value for the three oro-nasal sentences was higher than the oral speech samples and lower than the nasal speech samples. These aforementioned findings provide evidence for the internal validity of nasalance measurements in this study.

There was a significant difference in nasalance scores demonstrated between children and adult groups. Nasalance scores in children were lower than in adults, which was in agreement with other studies (4,12). The difference between nasalance scores of adults and children can be attributed to change in the size of the vocal tract related to age (4).

The difference between nasalance scores of males and females in the children groups was noticed in many speech samples, while it was obvious in only very few speech samples in the two adult groups. These subtle differences between adult males and adult females were in common with other studies (5,12,24–26) and could be explained by the reported physiological and anatomical differences between males and females as shown in some studies (27–30). With respect to the velopharyngeal area, anatomical differences were represented in velum size, contact point, and nasal cross-sectional area (29). These anatomical differences have been found along with physiological differences in velar movement and height to influence the resonance in both males and females (29). Moreover, higher nasal airflow rates have been reported in females than males. Females can produce syllabic sequences with greater anticipatory

| Table IV. Analysis of variance of normative scores among the study groups. |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Group I: Adult females (n = 71)                  | Group II: Adult males (n = 73) | Group III: Female children (n = 34) | Group IV: Male children (n = 41) |
| Mean    | SD    | Mean    | SD    | Mean    | SD    | Mean    | SD    |
| pa      | 6.93  | 1.32  | 7.29  | 2.29  | 5.29  | 0.76  | 6.10  | 1.00  | < 0.001 |
| ta      | 8.15  | 3.03  | 8.32  | 3.05  | 5.44  | 0.70  | 6.61  | 1.87  | < 0.001 |
| ka      | 9.86  | 3.35  | 9.99  | 3.70  | 7.24  | 2.31  | 6.83  | 0.95  | < 0.001 |
| sa      | 8.15  | 2.86  | 8.70  | 3.47  | 6.24  | 1.76  | 6.27  | 1.48  | < 0.001 |
| ja      | 8.20  | 2.94  | 8.86  | 3.70  | 5.65  | 1.30  | 5.76  | 2.00  | < 0.001 |
| pi      | 14.77 | 6.15  | 13.52 | 5.24  | 8.44  | 2.09  | 11.83 | 1.87  | < 0.001 |
| ti      | 21.20 | 8.46  | 17.77 | 8.19  | 15.21 | 3.78  | 13.85 | 3.12  | < 0.001 |
| ki      | 23.86 | 6.97  | 19.85 | 7.47  | 18.50 | 3.78  | 18.98 | 4.02  | < 0.001 |
| si      | 19.63 | 8.16  | 17.12 | 7.74  | 14.47 | 5.41  | 13.32 | 3.02  | < 0.001 |
| ji      | 21.45 | 7.97  | 18.52 | 7.34  | 16.09 | 4.32  | 14.20 | 5.02  | < 0.001 |
| ma      | 58.77 | 9.57  | 58.90 | 7.72  | 55.35 | 4.04  | 53.61 | 4.80  | < 0.001 |
| na      | 65.79 | 14.49 | 63.32 | 10.61 | 56.82 | 5.33  | 54.63 | 4.77  | < 0.001 |
| mi      | 77.73 | 11.24 | 76.78 | 10.31 | 62.97 | 4.85  | 60.93 | 5.32  | < 0.001 |
| ni      | 78.87 | 12.03 | 77.10 | 9.40  | 65.24 | 4.36  | 62.73 | 5.85  | < 0.001 |
| a       | 10.27 | 5.04  | 11.84 | 6.31  | 7.24  | 3.02  | 10.32 | 3.03  | < 0.001 |
| i       | 23.55 | 10.40 | 23.88 | 12.79 | 21.26 | 3.48  | 17.37 | 3.89  | < 0.001 |
| s       | 1.18  | 2.34  | 0.75  | 2.10  | 0.88  | 2.16  | 0.44  | 0.90  | N.S.   |
| m       | 91.75 | 4.01  | 91.18 | 5.53  | 87.21 | 3.13  | 85.46 | 3.62  | < 0.001 |
| oral sentence | 11.17 | 5.31  | 9.75  | 3.03  | 8.79  | 3.11  | 6.88  | 1.29  | < 0.001 |
| nasal sentence | 49.70 | 8.95  | 47.97 | 7.38  | 47.76 | 3.91  | 47.15 | 4.64  | N.S.   |
| oro-nasal sentence | 22.06 | 6.93  | 20.92 | 5.87  | 16.88 | 2.03  | 17.98 | 1.17  | < 0.001 |

N.S. = not significant; SD = standard deviation.
Table V. Post hoc test of the significant variables in ANOVA.

| Dependent variable | (I) Group       | (J) Group       | Mean difference (I–J) | Significance |
|--------------------|-----------------|-----------------|-----------------------|--------------|
| Pa                 | Adult females   | Female children | 1.64                  | < 0.001      |
|                    | Adult males     | Female children | 1.99                  | < 0.001      |
|                    |                 | Male children   | 1.19                  | < 0.05       |
| Tą                 | Adult females   | Female children | 2.62                  | < 0.05       |
|                    | Adult males     | Female children | 2.87                  | < 0.001      |
|                    |                 | Male children   | 1.71                  | < 0.05       |
| Ka                 | Adult females   | Female children | 2.62                  | < 0.05       |
|                    | Adult males     | Female children | 2.75                  | < 0.001      |
|                    |                 | Male children   | 3.16                  | < 0.001      |
| Sa                 | Adult females   | Female children | 1.92                  | < 0.05       |
|                    | Adult males     | Female children | 2.46                  | < 0.001      |
|                    |                 | Male children   | 2.43                  | < 0.001      |
| Já                 | Adult females   | Female children | 2.55                  | < 0.05       |
|                    | Adult males     | Female children | 3.22                  | < 0.001      |
|                    |                 | Male children   | 3.11                  | < 0.001      |
| Pi                 | Adult females   | Female children | 6.33                  | < 0.001      |
|                    | Adult males     | Female children | 5.08                  | < 0.001      |
|                    | Female children | Male children   | 1.11                  | < 0.05       |
| Tį                 | Adult females   | Adult males     | 3.43                  | < 0.05       |
|                    |                 | Female children | 5.99                  | < 0.05       |
|                    | Adult males     | Male children   | 7.34                  | < 0.001      |
| Ki                 | Adult females   | Adult males     | 4.01                  | < 0.05       |
|                    |                 | Female children | 5.36                  | < 0.05       |
|                    |                 | Male children   | 4.88                  | < 0.05       |
| Si                 | Adult females   | Female children | 5.16                  | < 0.05       |
|                    |                 | Male children   | 6.32                  | < 0.001      |
| Jį                 | Adult females   | Female children | 5.36                  | < 0.05       |
|                    |                 | Male children   | 7.26                  | < 0.001      |
| Ma                 | Adult females   | Male children   | 4.33                  | < 0.05       |
| Na                 | Adult females   | Female children | 8.97                  | < 0.05       |
|                    |                 | Male children   | 11.15                 | < 0.001      |
| Mi                 | Adult females   | Female children | 14.76                 | < 0.001      |
|                    |                 | Male children   | 16.81                 | < 0.001      |
| Nį                 | Adult females   | Female children | 13.04                 | < 0.001      |
|                    |                 | Male children   | 16.14                 | < 0.001      |
| A                  | Adult females   | Female children | 3.03                  | < 0.001      |
|                    | Adult males     | Female children | 4.60                  | < 0.001      |
| I                  | Adult females   | Male children   | 1.91                  | < 0.05       |
|                    | Adult males     | Male children   | 6.51                  | < 0.05       |
| M                  | Adult females   | Female children | 4.54                  | < 0.001      |
|                    | Adult males     | Female children | 6.28                  | < 0.001      |

(Continued)
Nasalance scores in Saudi speakers

Despite the aforementioned differences in some studies, the majority of studies have failed to find any gender-related differences among mean nasalance scores both in adults and in children (15,31,32). Few studies have indicated that females had higher nasalance scores than males, mainly in reading material containing nasals (2,8); yet, a contradicting finding was obtained by Fletcher (33). Generally, the reported gender differences on mean nasalance, wherever obtained, were small.

On comparing nasalance scores between groups regarding age, there was a consistent increase in nasalance scores in adults compared to children. This was in common with Hirschberg et al. (9), who reported that resonance grows with aging.

Cross-linguistic comparison of adults’ normal nasalance scores revealed that nasalance scores for the Saudi Arabic oral sentences were lower than those for Greek (n = 80), North American (n = 148), and French Canadian (n = 56), while they were higher than those for Flemish (n = 56) (see Supplementary Appendix B available online at http://informahealthcare.com/doi/abs/10.3109/14015439.2014.907339 for mean nasalance scores across different languages).

This can be explained by vowel nasalization that has been documented in oral and nasal contexts in some languages (34). Regarding nasal sentences, Saudi Arabic showed higher nasalance than Greek and French Canadian while showing less nasalance than Flemish and North American. Also, there was a common tendency in oro-nasal sentences to show significantly lower nasalance scores in Saudi Arabic speech compared to Greek, Flemish, Northern American, and Canadian French languages. This can be attributed mainly to context-related differences. As the ratio of oral to nasal sounds in balanced oro-nasal materials reflects the phonemic composition of lexical items for a particular

Table V. Comparing adults’ nasalance values in Saudi and Egyptian studies.

| Dependent variable | (I) Group | (J) Group | Mean difference (I–J) | Significance |
|--------------------|-----------|-----------|----------------------|--------------|
| oral sentence      | Adult females | Female children | 2.37 | <0.05 |
|                    | Adult males | Male children | 4.21 | <0.001 |
| oro-nasal sentence | Adult females | Female children | 5.17 | <0.001 |
|                    | Adult males | Male children | 4.08 | <0.05 |

Table VI. Comparing adults’ nasalance values in Saudi and Egyptian studies.

|                  | Saudi females (n = 71) | Egyptian females (n = 70) | P value | Saudi males (n = 73) | Egyptian males (n = 62) | P value |
|------------------|------------------------|---------------------------|---------|----------------------|-------------------------|---------|
| pa                | 6.93 1.32              | 22.0 16.0                 | <0.001  | 7.29 2.29            | 15.0 7.0                | <0.001  |
| ta                | 8.15 3.03              | 19.0 10.0                 | <0.001  | 8.32 3.05            | 14.0 7.0                | <0.001  |
| ka                | 9.86 3.35              | 26.0 17.0                 | <0.001  | 9.99 3.70            | 15.0 7.0                | <0.001  |
| sa                | 8.15 2.86              | 30.0 27.0                 | <0.001  | 8.70 3.47            | 19.0 10.0               | <0.001  |
| ja                | 8.20 2.94              | 31.0 27.0                 | <0.001  | 8.86 3.70            | 20.0 10.0               | <0.001  |
| pi                | 14.77 6.15             | 30.0 11.0                 | <0.001  | 13.52 5.24           | 29.0 19.0               | <0.001  |
| ti                | 21.20 8.46             | 42.0 20.0                 | <0.001  | 17.77 8.19           | 36.0 28.0               | <0.001  |
| ki                | 23.86 6.97             | 39.0 20.0                 | <0.001  | 19.85 7.47           | 38.0 27.0               | <0.001  |
| si                | 19.63 8.16             | 48.0 20.0                 | <0.001  | 17.12 7.74           | 43.0 32.0               | <0.001  |
| ji                | 21.45 7.97             | 47.0 25.0                 | <0.001  | 18.52 7.34           | 51.0 34.0               | <0.001  |
| ma                | 58.77 9.57             | 68.0 14.0                 | <0.001  | 58.90 7.72           | 70.0 18.0               | <0.001  |
| na                | 65.79 14.49            | 70.0 13.0                 | N.S.    | 63.32 10.61          | 68.0 19.0               | N.S.    |
| mi                | 77.73 11.24            | 81.0 17.0                 | N.S.    | 76.78 10.31          | 85.0 9.0                | <0.001  |
| ni                | 78.87 12.03            | 84.0 10.0                 | <0.01    | 77.10 9.40           | 85.0 10.0               | <0.001  |
| a                 | 10.27 5.04             | 22.0 15.0                 | <0.001  | 11.84 6.31           | 15.0 6.0                | <0.05   |
| i                 | 23.55 10.40            | 21.0 10.0                 | N.S.    | 23.88 12.79          | 33.0 30.0               | <0.05   |
| s                 | 1.18 2.34              | 0.0 0.0                   | <0.001  | 0.75 2.10            | 0.0 0.0                 | <0.05   |
| m                 | 91.75 4.01             | 95.0 4.0                  | <0.001  | 91.18 5.53           | 92.0 5.0                | N.S.    |

N.S. = not significant.
language, this may readily account for the nasalance differences observed between Arabic and other languages. The representative percentage of nasal consonants of the oro-nasal sentences in Saudi Arabic speech (11.45%) was lower than in Flemish (57%) (8), English (35%) (16), and Spanish (33.3%–60%) (35).

As many societies are becoming multicultural and multilingual, it is worth delineating the cross-linguistic differences in nasalance scores to be able to assist in the proper evaluation of velopharyngeal function in multilingual patients.

Conclusion
Cross-linguistic and cultural differences in nasalance scores do exist, not only among people who speak different languages but also among people speaking the same language with different dialects. Normative nasalance scores for Saudi Arabic speakers were obtained in this study. The authors developed an Arabic speech material that can be generalized in Arabian Gulf countries since the Saudi dialect has a lot in common with other dialects spoken by other Arabian Gulf countries. The data were generally comparable to the results obtained for other languages. The developed speech material in this study was easy to use and understandable by different ages. The use of this material will help in further research studying patients with velopharyngeal or resonance disorders including cleft palate, hearing impairment, cochlear implantation, and any other speech or neurological disorders that have any impact on speech resonance.

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Supplementary material available online

Supplementary Appendix A and B to be found online at http://informahealthcare.com/doi/abs/10.3109/14015439.2014.907339