The Influence of Gender and Age on the Acoustic Voice Quality Index and Dysphonia Severity Index: A Normative Study

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Summary: Objectives. The Acoustic Voice Quality Index (AVQI) and the Dysphonia Severity Index (DSI) are commonly used in research and clinical practice to quantify voice quality. The aim of this study was to investigate the influence of gender and age on AVQI and again on DSI.

Methods. In total, 123 vocally healthy adults (68 females, 55 males, and age ranging between 20 and 79 years) were evaluated.

Results. Gender had no effects on AVQI and DSI (both P values > 0.05). Additionally, AVQI showed no significant correlation with age ($P > 0.05$, $r^2 = 0.008$). However, DSI had a statistically significant correlation with age ($P < 0.05$), with 5% of the variance in DSI explained by the variance in age.

Conclusions. AVQI values do not depend on gender and age. DSI values do not depend on gender but correlated slightly with age. This finding confirms earlier research.

Key Words: Aging voice–Gender–Acoustic measurement–Acoustic Voice Quality Index–Dysphonia Severity Index.

INTRODUCTION

An objective measurement of voice quality, for example, with acoustics or aerodynamic methods, is useful in the evaluation of dysphonia and its severity. Combining various voice markers has shown to be more reliable and valid (for instance, in terms of correlation with auditory-perceptual judgment) than working with single measures.[1] Two examples of multiparametric models that quantified overall voice quality with acceptable correlation in both research and clinical practice are Acoustic Voice Quality Index (AVQI), which was developed by Maryn et al,[2] and Dysphonia Severity Index (DSI), which was proposed by Wuyts et al.[3]

AVQI is a multivariate construct based on linear regression analysis that combines six acoustic markers: smoothed cepstral peak prominence, harmonics-to-noise ratio, shimmer percentage, shimmer dB, general slope of the spectrum, and tilt of the regression line through the spectrum. A characteristic of this method is the concatenation of the voiced parts of a segment of continuous speech with the recording of a sustained vowel [a:]. This was chosen to improve ecological validity (ie, the representativeness for daily voice use patterns) of this measurement.[2,4] The AVQI finally yields a single score for this whole concatenation of voice samples. It runs completely in the freeware program Praat,[5] and because Praat implies a single-button method, it improves time- and labor-efficiency in everyday clinical practice.[6] In its initial studies, this acoustic index correlated reasonably well with the auditory-perceptual judgment of overall voice quality.[2,7] Later investigations consistently revealed acceptable diagnostic precision,[2,7–15] consistent and high concurrent validity,[2,7–16] robust interlanguage validity,[8–13,16] test-retest variability,[17] and high sensitivity to voice quality changes through voice therapy.[7,12]

DSI is based on a weighed combination of four vocal parameters to provide an objective and quantitative measure of voice quality, including jitter percentage, the highest frequency and the lowest intensity of a voice range profile, and maximum phonation time. This index was found to be a useful and feasible measurement[3,18–20] and is independent of the examiners.[21] Furthermore, it is a clinically applicable tool commonly used to evaluate effects after voice therapy, vocal training, and phonosurgery.[22–28] Further investigations of DSI showed geographical and ethnic variations,[29] interdevice differences,[30] reasonable test-retest variability,[20,31] and the impact of psychological state of subjects during a measurement.[3,24]

Gender and age have an effect on voice through changes of physical, psychological, and social factors.[32] Relating to voice quality, significant differences in gender and age have been exhaustively documented.[33–37] Considering their influence on voice quality, gender, and advancing age can be hypothesized to significantly affect AVQI and DSI. To differentiate the status of voice disorder from the status of anticipated vocal aging, it is pivotal to have norm-referencing values for these multivariate voice quality indices across representative age and gender groups. The influence of gender and age on DSI has been investigated before.[20,29,38–40] However, replication is valuable to strengthen the outcomes of these studies or to provide additional context for all studies' results. In case of AVQI, the present study is the first to evaluate the influence of gender and age.

The aim of the present study was to document the influence, if any, of gender and age on AVQI and again on DSI to obtain age- and gender-related normative data.

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METHODS

Subjects

A group of 123 vocally healthy individuals (68 females and 55 males) were examined at the Department of Otolaryngology of the Lithuanian University of Health Sciences, Kaunas, Lithuania. The median age of the total group was 30 years, with a range between 20 and 79 years. The median age of the female group was 29 years (range 20–73 years) and 32.5 years in the male group (range 22–79 years). Table 1 provides the number of subjects per gender and per age decade. To avoid the effects of vocal mutation and maturation, the minimum age was 20 years. The subjects had no complaints concerning their voice, no history of chronic laryngeal diseases or other long-lasting voice disorders, no hearing problems, and they were free from common cold or upper respiratory infections at the time of voice recording. There were no pathologic alterations in the larynx during videolaryngostroboscopy (VLS) utilizing a XION EndoSTROB DX device (XION GmbH, Berlin, Germany) and a 70° rigid endoscope. The following four standard VLS parameters were evaluated based on the protocol elaborated on the Committee on Phoniatrics of the European Laryngological Society[41]: (1) glottal closure, (2) regularity of vibrations, (3) mucosal wave, and (4) symmetry of vibrations. All parameters had to be judged as normal to exclude pathologic alterations of the vocal folds. Three experienced clinical voice specialists served as raters for the VLS judgment. They were blinded regarding the subject's identity, age, gender, diagnosis, and disposition. Detailed rating procedure was described in Uloza et al.[42]

Furthermore, all these voice samples were evaluated as healthy by clinical voice specialists. Blinded for all relevant information regarding the subject (ie, identity, age, gender, diagnosis, and disposition of the voice samples), the clinical voice specialists performed auditory-perceptual evaluations of the voice samples. Both the GRBAS scale[43] and the Consensus Auditory-Perceptual Evaluation of Voice[44] were used for the evaluation.

This study was approved both by Kaunas Regional Ethics Committee for Biomedical Research (No. P2-24/2013) and by Lithuanian State Data Protection Inspectorate for Working with Personal Patient Data (No. 2R-648 (2.6-1)).

Voice recordings

All voice recordings took place in a T-series silent room (T-room, CA Tegner AB, Bromma, Sweden). *Post hoc* signal-to-noise ratio was used to verify that environmental noise was not affecting acoustic voice quality measurements. In concordance with Deliyski et al,[45,46] all voice samples were accompanied with acceptable signal-to-noise ratio levels above 30 dB, indicating sufficient sound recording circumstance for clinical purposes.

For AVQI analysis, voice recordings were performed in seated position with a cardioid AKG Perception 220 microphone (AKG Acoustics GmbH, Vienna, Austria) placed 10 cm from the mouth and with a circa 90° microphone-to-mouth angle. The voice recordings were captured at a sampling frequency of 44.1 kHz and exported in 16-bit wav-file format. The external audio interface M-Audio (Cumberland, RI) was used for recording digitization.

For DSI analysis, the four required voice parameters were obtained from the sustained phonation of the vowel [a:], which was captured using the lingWAVES (WEVOSYS, Forchheim, Germany) sound pressure level meter placed at a 30.0-cm distance from the mouth and at about 90° microphone-to-mouth angle.

TABLE 1.
Numbers of Subjects per Age Group

Age (y)	Subjects: Female	Male	Total
20–30	38	26	64
31–40	4	9	13
41–50	10	3	13
51–60	7	7	14
61–70	5	6	11
71–80	4	4	8
Total	68	55	123

Acoustic Voice Quality Index

The AVQI analysis was applied on (a) a chain of the voiced segments from the Lithuanian sentence "Turėjo senelė žilą oželį" [The grandmother had a little gray goat] and (b) a 3-second midvowel segment of [a:]. The subjects were asked to phonate on comfortable pitch and loudness for both speech tasks. Extraction of the voiced segments from the continuous speech recordings, as well as the determination of the six acoustic markers and the successive AVQI values, was accomplished with the AVQI script version 02.02 developed for the program Praat.[5] Although AVQI was originally developed for and validated in Dutch, the AVQI has also been validated for Lithuanian speakers.[13]

Dysphonia Severity Index

To calculate the DSI, segments of the sustained vowel [a:] were analyzed using the Voice Diagnostic Center (lingWAVES software, Version 2.5, WEVOSYS). First, jitter percentage was determined in acoustic voice signals containing at least 2 seconds of sustained [a:] at comfortable pitch and loudness. Second, maximum phonation time was determined in [a:] vowels phonated as long as possible at habitual pitch and loudness after maximal inspiration. Third, the vocal range of the subjects was profiled through instructing the subjects to phonate the vowel [a:] for at least 2 seconds at their lowest and highest pitch, as well as their lowest and highest loudness. From this vocal range profile, the highest fundamental frequency and the lowest intensity level were selected to complete the DSI formula.

Statistical analysis

Statistical analyses were completed using SPSS for Windows version 23.0 (IBM Corp., Armonk, NY). First, a one-way analysis of variance was used to determine significant differences in gender of AVQI and DSI. Second, the proportional relationship between age, and AVQI and DSI was assessed with the partial

TABLE 2.
Descriptive Outcome of Gender Differences of AVQI and DSI

	AVQI		DSI	
Gender	Mean	SD	Mean	SD
Female	2.30	0.70	6.04	2.18
Male	2.35	0.89	5.41	1.78
Total	2.32	0.79	5.76	2.03

Abbreviation: SD, standard deviation.

correlation coefficient (r) by controlling gender. Furthermore, the degree with which the variance in one variable is accounted for by the variance in another variable was examined with the coefficient of determination (r^2). Interpretation guidelines for r were provided by Frey et al[47]: r < 0.20 slight correlation (almost negligible relationship), r = 0.20–0.40 low correlation (small relationship), r = 0.41–0.70 moderate correlation (substantial relationship), r = 0.71–0.90 high correlation (marked relationship), r > 0.90 very high correlation (very dependable relationship).

Finally, backward linear multiple regression analysis was used to determine any interaction effects between the two variables of age and gender on AVQI and DSI.

All results were considered statistically significant at $P \leq 0.05$.

RESULTS

Table 2 shows the descriptive outcomes of AVQI and DSI between men and women. The results of the one-way analysis of variance revealed no significant differences between genders for both multiparametric indices (AVQI: $F = 0.146$, $P = 0.703$; DSI: $F = 2.969$, $P = 0.087$).

The data showed, according to Frey et al,[47] a slight nonsignificant correlation between AVQI and age (r = 0.089, $P = 0.329$) (Figure 1). With $r^2 = 0.008$, no reasonable portion (0.8%) of the variance in AVQI is explained by the variance in age. However, the correlation between DSI and age revealed slightly higher and statistically significant correlation (r = –0.218, $P = 0.015$). As illustrated in Figure 2, this correlation was negative for both genders, indicating that with increasing age, the DSI decreases. With $r^2 = 0.05$, no meaningful portion (ie, only 5%) of the variance in DSI is explained by the variance in age.

The results of linear multiple backward regression revealed that gender and age had no significant relationship to AVQI (t = –0.382, $P = 0.703$, and t = 1.023, $P = 0.308$, respectively), and gender had no significant relationship to DSI (t = 1.458, $P = 0.148$). These variables were therefore removed because of the criteria probability of $F \geq 0.100$. Only age showed a signif-

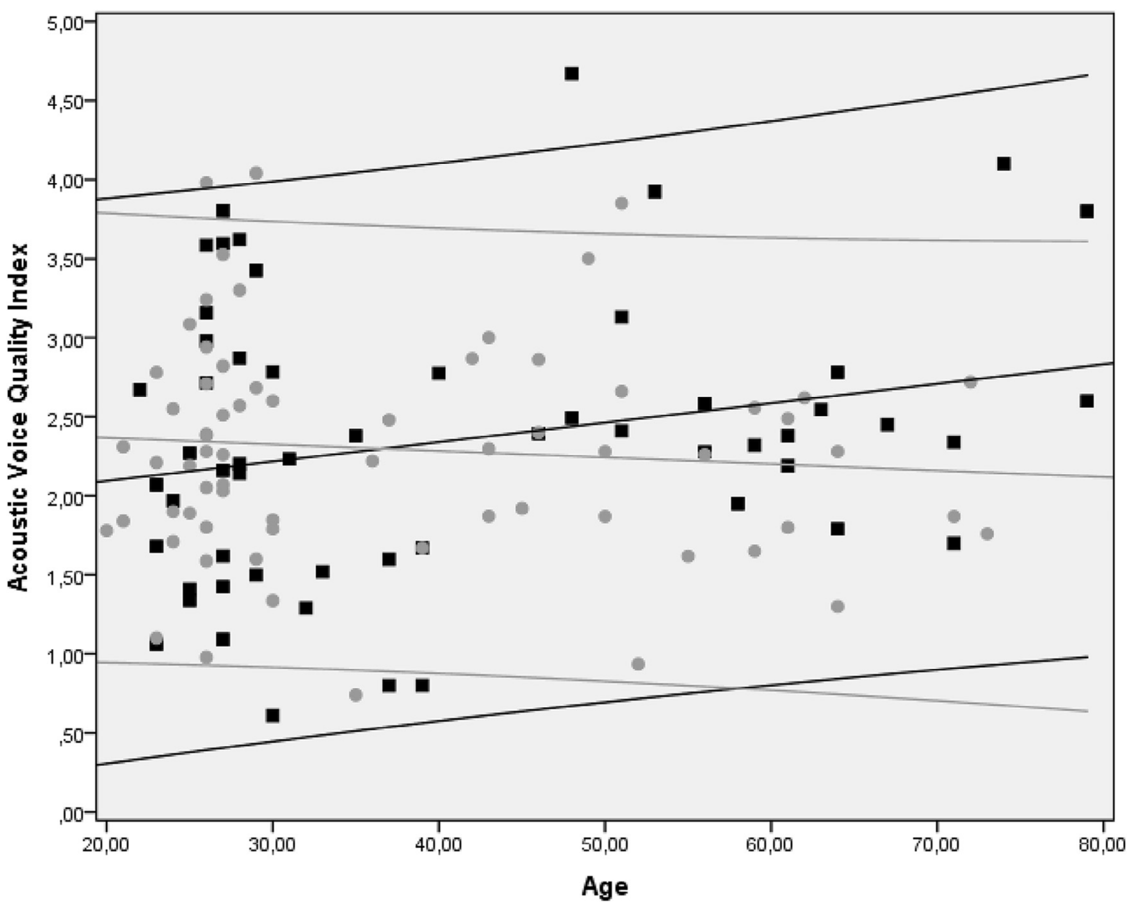

FIGURE 1. Scatterplots of the Acoustic Voice Quality Index and age for women (ie, gray circles) and men (ie, black rectangles) with regression lines and 95% confidence intervals divided into the same color as the gender.

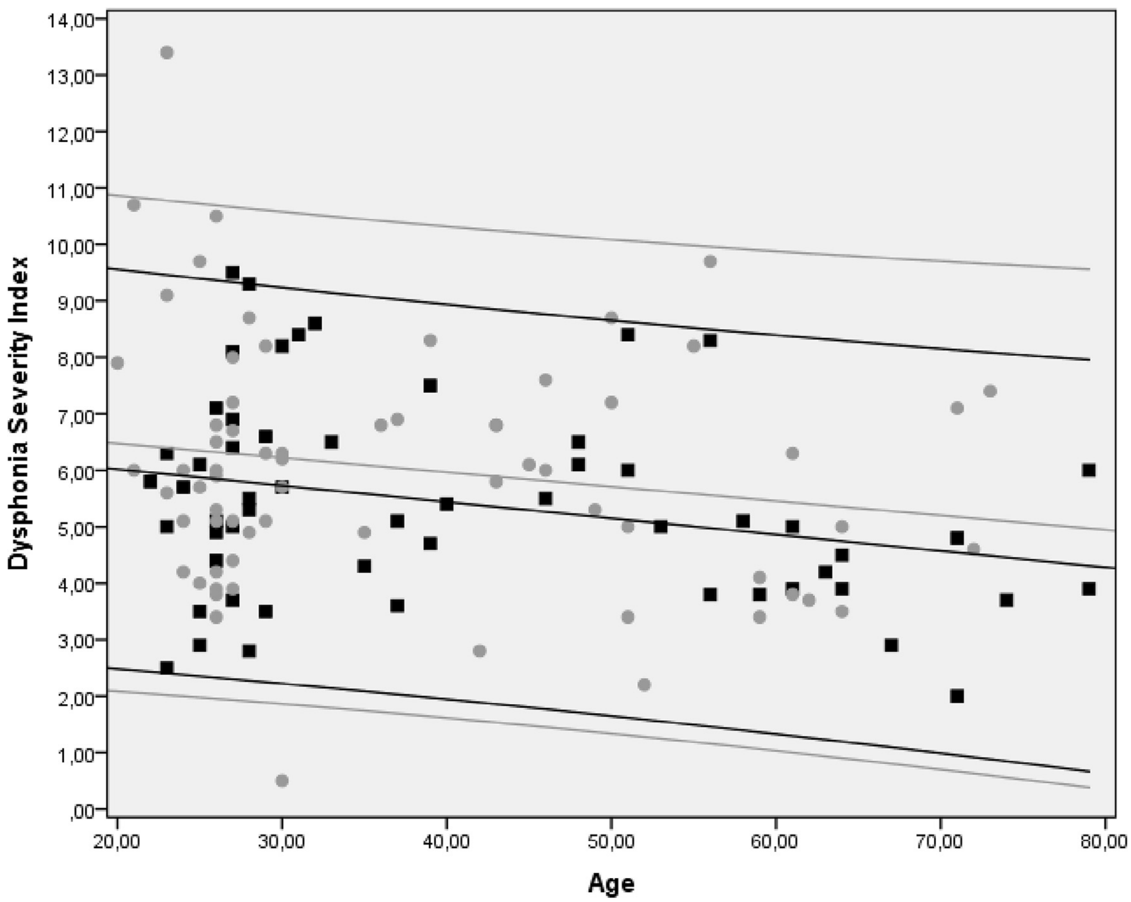

FIGURE 2. Scatterplots of the Dysphonia Severity Index and age for women (ie, gray circles) and men (ie, black rectangles) with regression lines and 95% confidence intervals divided into the same color as the gender.

icant relationship to DSI (t = –2.634, $P = 0.010$). The formula of a prediction model for age on DSI was as follows: DSI = 6.889 – 0.029 * age (in years).

DISCUSSION

In the present study, the influence of gender and age on AVQI and DSI was investigated. The batch of subjects upon which this study's results regarding DSI was based on and comparable with Hakkesteegt et al,[38] Jayakumar and Savithri,[29] and Goy et al.[39] However, the criteria for considering a subject to be vocally healthy were stricter than in all other studies. Next to self-reporting (ie, free of voice complaints, no history of chronic laryngeal diseases or other long-lasting voice disorders, and no hearing problems), a VLS examination and an extra clinical judgment of clinical voice specialists took place for each subject, which revealed stricter criteria for the selection of a vocally healthy voice. Notwithstanding the stricter criteria selection of vocally healthy subjects, some abnormal AVQI (ie, threshold above 2.97)[13] and DSI values (ie, threshold under 3.0)[18] were found. This effect shows that there is a small variance in perceptual judgment, which could not be accounted for by AVQI and DSI. Further studies might be useful to improve the validity of these objective measurements attaining a higher consensus in the judgment of voice quality.

Although interdevice differences of the DSI calculation were ascertained,[30] which might have an impact on the research question, the following discussion about the DSI attempted to compare the present results with the previous studies. The present study used the lingWAVES instrument for the calculation of the DSI, also by Maruthy et al.[40] Other studies used Kay Pentax instruments,[29,38] and other software and hardware instruments.[20,39]

The present results showed that gender had no significant influence on AVQI and DSI ($P = 0.703$, and $P = 0.087$, respectively), whereas the influence of age revealed differences between both multiparametric indices. Although age did not correlate with AVQI ($r = 0.089$, $P = 0.329$), it correlated significantly low with DSI ($r = –0.218$, $P = 0.015$).

The backward linear regression analyses confirmed these previously mentioned statistics. A predictive model could only be created for age and DSI to demonstrate to what extent age affects DSI (ie, DSI = = 6.889 – 0.029 * age [in years]).

Although voice quality changes have been documented across age decades,[34–36] AVQI remained invariant with age and gender. This implies that the AVQI is more isolated from age-related anatomy or physiology changes in the vocal folds, in comparison with the DSI.

DSI was also hypothesized to be similar between gender groups, because the differences in Fhigh (ie, higher in females) and maximum phonation time (MPT) (ie, longer in males) are opposite and compensating.[3] The most recent studies[20,38] that investigated this effect, as well the present study, confirmed this hypothesis. Only one study showed a gender-based difference in DSI values of individuals with no voice disorders (ie, the mean DSI values were higher in women), which was explained by the smaller difference in MPT between men and women.[29] Although some single parameters of the DSI differed between genders (ie, MPT,[20,29,38] Jitter%,[3] and Fhigh[3,20,29,38]), gender had no meaningful influence on DSI values resulting from the present findings and some previous studies.

It is generally accepted that age has a significant effect on DSI, for example, the DSI decreases significantly with advancing age in women[38,40] and men.[38,39] Age-related differences in DSI were also present in both female singers and nonsingers.[40] In both these groups, the younger subjects demonstrated significantly higher average DSI values than the older subjects. The decrease in DSI with advancing age can be explained by lowering of Fhigh,[38,40] reduction in MPT,[40] and increase of Jitter.[35–37,39] However, the present findings confirmed a statistically significant correlation between age and DSI, but the proportion between these two factors showed only a small relationship. There is a recommendation for daily clinical practice to consider age for the prediction of DSI.[38] This prediction model by Hakkesteegt et al[38] is nearly comparable with the present regression analysis.[38] However, the present findings revealed a more conservative position for this proposal because the meaningfulness of the relationship between DSI and age is poor ($r^2 = 0.05$).

CONCLUSIONS

The present study investigated the influence of gender and age of two multiparametric indices to more objectively quantify voice quality. The results showed no impact of gender and age for AVQI values. It can thus be concluded that AVQI appears independent of age- and gender-related vocal physiology and anatomy. The DSI values revealed no impact of gender. Age, however, correlated significantly low with DSI. Previous studies confirmed this finding. It can therefore be concluded that DSI is also independent of gender, yet slightly dependent on age.

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