CoDAS
ISSN 2317-1782 (Online version)

Original Article
Artigo Original

Acoustic characteristics of healthy voices of adults: from young to middle age

Características acústicas de vozes saudáveis de adultos: da idade jovem à meia-idade

Evelyn Alves Spazzapan[1]
Vanessa Moraes Cardoso[1]
Eliana Maria Gradim Fabron[1]
Larissa Cristina Berti[1]
Alcione Ghedini Brasolotto[2]
Viviane Cristina de Castro Marino[1]

Keywords

Voice
Acoustics
Evaluation
Adult
Middle Aged

ABSTRACT

Purpose: Characterize voices of adult individuals without vocal complaints and verify the effect of gender and age with the use of acoustic measures. **Methods:** One-hundred and seventy-six voice recordings belonging to adults between 19 and 59 years old, divided into four age groups, for decade, recorded in a database were analyzed. All voices analyzed were classified with no deviation in vocal quality. Acoustic analysis of the parameters was performed: Fundamental Frequency (sustained vowel and connected speech), Jitter, Shimmer and Noise-to-Harmonic Ratio through Multi Dimension Voice Program (KayPentax) software. The effect of gender, age and possible interactions were verified through the Factorial Anova test. When necessary, post hoc was performed with the Least Significant Difference test. **Results:** There were changes in the voice as a function of age, with a decrease in the Fundamental Frequency in the vowel and connected speech modalities in women and in the Fundamental Frequency of the speech in men. In men, an increase in shimmer measure was observed with the advancing age. Differences between genders were found in the measures of Fundamental Frequency, Jitter and Noise to Harmonic Ratio. **Conclusion:** Vocal changes due to advancing age can be identified acoustically at the end of adulthood, and in women, these changes can be marked previously to the menopausal period.

Descritores

Voz
Acústica
Avaliação
Adulto
Meia-idade

RESUMO

Objetivo: Caracterizar as vozes de indivíduos adultos sem queixas vocais e verificar o efeito de gênero e idade a partir de um conjunto de medidas acústicas. **Método:** Foram analisadas 176 gravações de vozes pertencentes a adultos com idades entre 19 e 59 anos, divididas em quatro grupos etários, por década, armazenadas em uma base de dados. Todas as vozes analisadas foram classificadas com ausência de desvio na qualidade vocal. Realizou-se análise acústica dos parâmetros: Frequência Fundamental (vogal sustentada e fala encadeada), *Jitter*, *Shimmer* e *Noise-to-Harmonic Ratio* por meio *software Multi Dimension Voice Program (KayPentax)*. O efeito de gênero, idade e possíveis interações foram verificados por meio do teste Anova Fatorial. Quando necessário, realizou-se *post hoc* com o teste *Least Significant Difference*. **Resultados:** Houve mudanças na voz em função da idade, com diminuição da Frequência Fundamental nas modalidades vogal e fala encadeada em mulheres e na Frequência Fundamental da fala em homens. Em homens, foi observado aumento da medida de *shimmer* com o avanço da idade. Foram verificadas diferenças entre os gêneros nas medidas de Frequência Fundamental, *Jitter* e *Noise to Harmonic Ratio*. **Conclusão:** Mudanças vocais decorrentes do avanço da idade podem ser identificadas acusticamente, no final da fase adulta e, em mulheres, essas mudanças podem ser marcadas previamente ao período da menopausa.

Correspondence address:
Evelyn Alves Spazzapan
Universidade Estadual Paulista "Júlio de Mesquita Filho" – UNESP
Av. Hygino Muzzi Filho, 737, Mirante, Marília (SP), Brasil, CEP: 17525-900.
E-mail: evelyn_spazzapan@yahoo.com

Received: October 26, 2017

Accepted: April 17, 2018

Study conducted at Departamento de Fonoaudiologia, Faculdade de Filosofia e Ciências, Universidade Estadual Paulista "Júlio de Mesquita Filho" – UNESP - Marília (SP), Brasil.

[1] Universidade Estadual Paulista "Júlio de Mesquita Filho" – UNESP - Marília (SP), Brasil.

[2] Faculdade de Odontologia de Bauru – FOB, Universidade de São Paulo – USP - Bauru (SP), Brasil.

Financial support: CAPES, nº 1615527.

Conflict of interests: nothing to declare.

INTRODUCTION

Voice differs between the genders and undergoes changes throughout the lifetime, with greater vocal stability observed in the adulthood[1-3]. Significant structural and functional modifications occur in the larynx[4-6] with the aging, causing prominent vocal changes from the 60 years of age[7]. Specifically in women, the vocal modifications were justified by the combination of the onset of aging and the transition from menopause[8] and pre-menopause[9]. This fact evidences the need to increase knowledge of how the gradual process of vocal changes occurs from younger adults to middle-aged adults.

Studies by means of the acoustic analysis may increase the knowledge of these modifications[2,3,10], since it is an objective, non-invasive, easy-to-use assessment method that offers indirect data of the vocal function through specific measures[11], in normal and pathological conditions, assisting in the diagnostic process and in the monitoring of the treatment of vocal alterations[10]. The acoustic analysis also contributes to the voice evaluation, allowing comparing results to determine gender and age, and also allows confronting information obtained in clinical evaluations with normative data[3].

Previous studies have determined one or several vocal acoustic normality parameters for voices of adults[1,10-16] and elderly[10,12,14,16-19], allowing to infer the physiological mechanisms of the production of these populations[2,3]. However, few studies have analyzed acoustic parameters specifically for the middle-aged population or included middle-aged adults in their investigations for comparison with younger populations[2,3,9,12,14].

In relation to the fundamental frequency (F_0), higher values of F_0 are reported for women than for men[2,3,11,15], with variations according to age for both genders. With advancing age, a decrease in F_0 of the vowel /a/[3,10,16,18] and speech[10] is expected in women. Some studies have reported changes in F_0 in the pre-menopause phase (around 30 years of age)[12] or even around 48 years of age[9], suggesting that the vocal changes in the women would begin in the pre- menopause.

In women, vocal changes through the lifetime have been reported as a significant reduction of F_0 around 50 years of age[3] or a gradual decrease of this acoustic parameter up to 60 years for the sustained vowel /a/[2]. This fact can be attributed to the hormonal changes that markedly happen during the menopause that would result in edema and thickening of the vocal folds[3]. In a contradictory way, some researchers did not find changes in F_0 (vowel /a/) in women in different age groups, including middle age[1,14]. In most studies, the results were presented considering mean values (and standard deviation) of F_0[1,3,14] or, with the verification of vocal changes in different ages by the interpretation of F_0 variability measure, besides of its mean value[2]. Therefore, it is noticed that there is a need for additional information about the F_0 behavior of the women from young adulthood to middle age for a better understanding of when vocal changes begin in this population.

In relation to men, adults and middle-aged, there are no reports of changes in F_0 in both modalities, sustained vowel /a/[1,3,14,15] and F_0 speech[12], when mean values (standard deviation) were analyzed.

Studies about the disturbance indexes of frequency and amplitude, cycle-to-cycle, of the acoustic signal produced by vocal fold vibration, Jitter and Shimmer, are restricted to the middle-aged population.

In adults, higher values of Jitter were reported for women than for men[11,19] or, in a contradictory way, Jitter did not vary between genders[1,14,20]. Increased Shimmer values were reported for men when compared to women[11,14]; however, the difference between genders in adult voices was not always noticed[1,19,20].

In relation to the age, higher values of Jitter and Shimmer were observed for men and women[16] with increase in age, although the moment at which such increase occurs is not indicated. Jitter and Shimmer did not vary for middle-aged adult women when compared to younger populations[9] and also did not vary in studies with age groups that included middle age[1,14].

Noise measures were little explored in the literature for voices without alterations, although they may offer important information, particularly about vocal deterioration due to the aging[21].

In general, these measures present worse values of the acoustic signals in adult male voices when compared to the female voices[1,14,20]. In addition, the amount of noise in the vocal signal tends to increase with the advancing age[2,16-18,21].

The information presented in the literature indicates that noise measures may reflect processes involved in glottal closure[2], reflecting vocal deterioration due to the aging[16,21], such as oscillation in vocal fold vibration[21], vocal fold atrophy and presence of fusiform slits[4,5] that alter the glottal closure.

In some studies, however, acoustic measures pointed to a higher amount of noise in the vocal signal in women than in men, from the 50 years of age, suggesting that hormonal changes occurred during menopause would lead to such increase[2]. In other studies, the noise measure did not differ among age groups that included the middle age[1,9,14].

In general, it is noticed few descriptions of changes that occur from adult to middle age phase, identified, in particular, by a set of acoustic measures.

Acoustic information of F_0 measures, as well as disturbance and noise measures obtained for young adults up to middle age with normal voices, may contribute to a better understanding of vocal changes in these populations, allowing later clinical comparisons with pathological voices of corresponding age groups. Acoustic measures may be sensitive to point out subtle differences in adult vocal function by considering lower age ranges.

The present study aimed to characterize the normal voices of adult individuals, for decade, and to verify the effect of gender and age from a set of acoustic measures.

METHODS

Observational, cross-sectional study, approved by the Research Ethics Committee on Human Beings of the home institution (n. 0657/2013 and n. 1.054.283/2015), performed after all the participants signed the Informed Consent Form.

Samples of selected voices

A total of 176 recordings of audio voices (88 males and 88 females) belonging to 176 participants aged between 19 and 59 years, Brazilian Portuguese speakers, from the central-western region of the State of São Paulo were included. These voices were distributed in four age groups (G1-G4), for decade, containing 44 voices for group.

In this study, young adult participants were those aged between 19 and 29 years (G1); adult participants, those aged between 30 and 39 years (G2) and 40 and 49 years (G3); and middle-aged adults, those aged between 50 and 59 years. The division of the age grouping was based on previous studies[2,3,9]. The age group and the exact number of recordings included in each group and the mean age (standard deviation) of the participants who had their voices recorded for each age group, by gender, are presented in Table 1.

The study participants were interviewed at the time of the voice recordings by a speech-language therapist and answered a questionnaire, containing questions related to the general health conditions, menopause (in the case of women), vocal habits, as well as complaints related to speech, voice and hearing disorders.

Inclusion criteria were: participants of both genders, within the established age range, with no history of head and neck surgeries, neurological, pulmonary or respiratory diseases, speech therapy for voice and no voice, speech or hearing complaints, according to the questionnaire. In addition, all the participants presented absence of vocal alterations as determined by three speech-language therapists with experience in the evaluation of speech and voice alterations, based on an auditory-perceptual evaluation.

The speech-language therapists performed, simultaneously, and by consensus, judgments of the recordings containing the sustained vowel/a/ emitted by the participants, through the GRBAS scale. Such scale, elaborated by the Committee for Phonatory Function Tests of the Japan Society of Logopedics and Phoniatrics and published by Hirano[22], allows analyzing several aspects of vocal quality, including: voice roughness (R), breathiness (B), asthenia (A), strain (S) that together determine the general degree of dysphonia (G). Consensus perceptual judgments of the three speech-language therapists indicative of the general degree of vocal quality equal to zero were considered in the present study, for inclusion effect. Laryngeal visual evaluation was not performed in the participants of this study.

Exclusion criteria consisted of: smoker at the time of data collection or smoker history in the last five years, professional vocal training, history of head and neck surgeries, history of neurological, pulmonary or respiratory diseases, speech therapy for voice, as well as vocal complaints in the week of the recording. Participants who reported cold or allergic respiratory conditions on the day of collection or who were unable to perform the emission required to the recording of their voices were also excluded from the study.

Procedures

The 176 recordings of the selected voices for the study belonged to the database of the Laboratório de Análise Acústica da Unesp/Marília. All recordings were performed in a treated acoustically room. A single speech-language therapist captured the voices of 118 individuals in the period from 2013 to 2015 and trained other who captured the voices of 58 individuals in the period from 2016 to 2017.

At the time of the recordings, each participant was requested to produce the vowel /a/ in a prolonged way, three times, in the longest possible time, using pitch and loudness in a habitual way, and prior to the recording, the task was explained by the evaluator. It was also requested the reading of an oronasal text ("O cãozinho Totó") prepared for a previous study[23]. The sustained emission of the vowel is often used in studies involving the acoustic analysis of F_0 due to its stability[24]. The F_0 measure of speech is used to reflect the oral communication of an individual in a natural way, which brings relevant information to the real judgment of his/her everyday speech[24]. For this reason, both modalities were included in this study.

The voice and speech samples were obtained with the participant sitting on a chair, using Sennheiser microphone (model E855) and a digital recorder of the MARANTZ brand (model PMD660, configured for single-channel recording with sampling rate of 44 kHz and 16 bits of resolution). The microphone was positioned at 45 degrees and 20 cm in front of the participant's mouth. This distance from the microphone to the participant's mouth was established, since the voice recording of this study was performed simultaneously to the nasometric evaluation, for future analysis purposes. The combined use of audio recording and nasometric evaluation was described in a previous study[25], and there was no interference between the microphones of the equipment in the measures performed.

For the present study, only the acoustic signal captured by the microphone (audio recording) was of interest. The recording audio of the sustained emission of the /a/ were imported and edited in the PRAAT software[26], discarding the beginning and

Table 1. Groups of participants (G1-G4), age group and corresponding age for each gender

Groups	Age group (years)	Female			Male		
		N	Mean	SD	N	Mean	SD
G1	19-29	22	22.9	2.85	22	23.0	2.15
G2	30-39	22	32.8	2.29	22	32.7	2.09
G3	40-49	22	44.2	3.30	22	44.1	3.19
G4	50-59	22	53.6	2.38	22	53.5	2.69
Total	19-59	88	38.4	12.0	88	38.3	11.9

Caption: N = number of individuals; SD = standard deviation

end of the recording, selecting the most stable portion of the emission with mean duration of 3 seconds. All editions of the study were performed by the same speech-language therapist (first author of the study).

The analysis of the acoustic parameters was performed automatically by means of the Multi Dimension Voice Program (MDVP) from the Voice Lab *Computerized Speech Lab*, Model 4400, Kay-Pentax. The following parameters were extracted: Fundamental Frequency (F_0); Jitter% (Jitt); Shimmer% (Shim) and Noise-to-harmonic-ratio (NHR). The extraction of the mean value of F_0 speech was performed by the PRAAT software from the recording of the reading text. The choice of the PRAAT software was due to the ease of extraction of this measure by this program and the fact that the MDVP is specific for the analysis of sustained vowel.

Data analysis

The acoustic parameters investigated (F_0 of the vowel /a/ and F_0 speech and Jitter, Shimmer and NHR of vowel /a/) were presented descriptively for each age group and corresponding gender. The Factorial Anova test was used to verify the effect of gender and age and respective interactions. When necessary, post-hoc analysis was performed with the Least Significant Difference (LSD) test. The value of $\alpha < 0.05$ was established.

RESULTS

The descriptive results of the acoustic parameters analyzed are shown in Table 2.

F_0 measure of the sustained vowel and speech

The F_0 measure of the sustained vowel /a/ showed a significant effect for gender ($F(1.17) = 570.28$, $p < 0.00$) and for interaction between gender and age ($F(3.17) = 3.71$, $p = 0.01$). When considering all age groups, F_0 values for women ($\bar{X} = 202.656$, SD = 21.62) were significantly higher than those obtained for men ($\bar{X} = 125.46$, SD = 21.09). The post-hoc analysis showed effect of age for the female gender.

The F_0 values of the vowel /a/ from G1 ($\bar{X} = 210.58$, SD = 21.03) were higher than G3 ($\bar{X} = 197.04$ SD = 22.8) ($p = 0.03$) and G4 ($\bar{X} = 194.09$, SD = 20.98) ($p = 0.01$), and G2 ($\bar{X} = 208.84$ SD = 21.65) was higher than G4 ($p = 0.02$), indicating that younger women present F_0 values higher than those with higher age.

The F_0 analysis of the speech showed significant effect for gender ($F(1,168) = 700,84$, $p < 0.00$). The values of the women ($\bar{X} = 198.44$, SD=16.23) were higher than those of the men ($\bar{X} = 126.03$, SD = 19.78). There was an effect for age ($F(3.17) = 5.69$, $p = 0,00$). Groups with lower age (G1 = 167.68, SD = 19.84; G2 = 168.21, SD = 18.63) had higher values than those of older age (G3 = 158.04, SD = 18.20 and G4 = 155.01, SD = 15.34), for both genders. There was no significance between gender and age for F_0 speech.

Disturbance measures of the acoustic signal of the vowel /a/

In relation to the Jitter measure, there was a significant difference for gender ($F(1,168) = 6.23$, $p < 0.01$), indicating that women aged from 19 to 59 years presented higher Jitter values ($\bar{X} = 0.95$, SD = 0.75) than men ($\bar{X} = 0.73$, SD = 0.41)

Table 2. Mean values (standard deviation) of the acoustic measures in the different age groups (G1 = 20-30, G2 = 30-40, G3 = 40-50 and G4 = 50-60), by gender

		G1		G2		G3		G4		Fatorial ANOVA (LSD)
		F	M	F	M	F	M	F	M	
F_0 /a/	Mean (SD)	210.58 (21.03)	121.50 (19.09)	208.915 (21.65)	122.84 (17.97)	197.04 (22.80)	129.43 (24.21)	194.09 (20.98)	128.09 (23.09)	Gen**p<0.00** Age p>0.7 Gen*age**p<0.01** F>M
F_0speech	Mean (SD)	206.84 (19.24)	128.52 (20.44)	207.90 (15.08)	128.52 (22.18)	191.34 (17.77)	124.74 (18.62)	187.67 (12.82)	122.36 (17.86)	Gen**p<0.00** Age**p<0.00** Gen*age p>0.1 F>M G3/G4 < G1/G2
Jitt	Mean (SD)	1.05 (0.62)	0.75 (0.40)	1.05 (0.77)	0.54 (0.30)	0.91 (0.98)	0.69 (0.41)	0.79 (0.61)	0.92 (0.54)	Gen**p<0.01** Age p>0.9 Gen*age p<0.1 F>M
Shim	Mean (SD)	4.41 (1.11)	3.71 (0.81)	4.39 (1.30)	3.49 (1.13)	3.68 (1.47)	4.49 (1.30)	4.04 (1.64)	5.29 (2.40)	Gen p>0.6 Age p>0.8 Gen*age**p<0.00** --
NHR	Mean (SD)	0.14 (0.02)	0.14 (0.02)	0.14 (0.03)	0.14 (0.02)	0.14 (0.01)	0.15 (0.01)	0.14 (0.02)	0.16 (0.06)	Gen**p<0.01** Age p>0.1 Gen*age p>0.2 M>F

Caption: F = female; M = male; F_0 /a/ = Fundamental Frequency in the context of the vowel /a/; F_0speech = Fundamental Frequency in the context of reading text; Jitt= *Jitter*; Shim = *Shimmer*; NHR = *Noise to Harmonic Ratio*; LSD = *Least Significant Difference*

with corresponding ages. There was no significance for age or interaction between age and gender for this measure.

In the Shimmer measure, there was a significant effect for interaction between gender and age ($F(3.17) = 6.08$, $p = 0.00$). The post-hoc analysis showed effect of age for males. G1 ($\bar{X} = 3.71$, $SD = 0.81$) differentiated from G4 ($\bar{X} = 5.28$, $SD = 2.40$) ($p = 0.00$), and G2 ($\bar{X} = 3.49$, $SD = 1.13$) differentiated from G3 ($\bar{X} = 3.68$, $SD = 1.47$) ($p = 0.01$) and G4 ($p = 0.00$), indicating that younger age groups presented lower amount of amplitude disturbance than older age groups.

Acoustic signal measure of the vowel /a/

In relation to the NHR measurement, there was a significant effect for gender ($F(1.17) = 5.96$, $p < 0.02$), suggesting a greater amount of noise in the vocal signal in men ($\bar{X} = 0.15$, $SD = 0.03$) than in women ($\bar{X} = 0.14$, $SD = 0.02$). There was no significance for age or interaction between gender and age.

DISCUSSION

This study aimed to characterize normal voices of adult individuals, for decades, as well as verify the effect of gender and age from the acoustic measures of F_0 (vowel and speech); Jitter; Shimmer and NHR.

Considering that the acoustic analysis allows inferring about the physiological mechanisms of the vocal production[2,3], it was sought to verify if the acoustic parameters investigated could reflect possible changes, even subtle, in anatomical and physiological components involved in the voice production of adult from the young age to middle age, of both genders.

The F_0 in adults was widely reported in the literature[1,10,11,13-15]. However, this acoustic parameter was included in the investigation because of the need to provide information for an age group few explored, ranging from young adults to middle age.

The F_0 measures of sustained vowel and speech were presented for both genders and distinct age groups (19-29 years, 30-39 years, 40-49 and 50-59 years). When considering all the age groups, it was verified that the F_0 measures of the vowel /a/ and speech of the women were higher than the men, confirming previous findings[2,3,11,14,15], which justify them because of the anatomical and physiological differences between the gender. The F_0 is largely affected by the gender of the individual, as well as the age, as it reflects the characteristics of the vocal folds, such as length, mass, vibration, stretching, strain and its relationship with subglottal pressure[7].

The F_0 of both, vowel /a/ and speech, varied according to age. In women, the F_0 (of the vowel /a/ and speech) of younger age groups (20s and 30s) was higher than of the participants in the 50s. Such effect was verified even among participants in this study from the 20s and 40s, since that all women between the ages of 40-49 years had not been through the menopause period at the time of data collection, according to their reports. The results of this study agree with previous findings involving F_0 of the vowel[9].

The decrease in F0 of the vowel /a/ and speech noticed in this study in the 50s, on the other hand, could be explained by the influence of the hormonal alterations associated with menopause (reduction of progesterone and estrogen)[27] as well as the physiological changes of the aging[9].

The decrease in F_0 due to hormonal changes that occur during menopause has been reported by several researchers[2,3,8]. As summarized by D'haeseleer et al.[8], the menopause period may affect the laryngeal tissue, which in turn, it causes muscle atrophy and edema in the vocal folds. Changes in the vocal quality due to menopause are also reported by the author and include hoarseness, changes in vocal timbre with difficulty in reaching high frequency and instability.

Consistently with reports of previous investigations which compared adult voices of adult men for decades[1,14], the F_0 of the vowel /a/ for the male gender did not vary according to the age. Soltani et al.[3] reported reduction in F_0 of the vowel /a/ for the age group of 50-52 years, when compared to younger age groups (20-22, 30-32, 40-42 years), however, such reduction was not significant. The fact that F_0 of the vowel /a/ does not vary according to the age suggests that this parameter remains stable in adult men until middle-age.

In relation to the F_0 speech, in this study, there was a decrease in the values found in middle-aged men. The F_0 speech is related to the physiological characteristics of the vocal folds and to the control of the larynx musculature[28]. Nishio and Niimi[12] did no found decrease F_0 speech when comparing voices of young adults and elderly men for decades. A study involving 63 men from 48 to 78 years found higher F_0 for men who presented hormonal changes (reduction of estradiol), but for only a third of this population[29]. The F_0 findings of the present study can be attributed to the possible hormonal changes in male participants.

In the present study, variations in the modalities of speech tasks (sustained vowel or connected speech) could justify the distinct findings found in the F_0 of men, since the connected speech associated with the greatest variations and broadest range of frequencies and amplitude[16], when compared to the vowel /a/. Information about the effect of age on F_0 in young adult populations at middle age is still limited, complicating comparisons between the findings.

In general, the literature shows information about male voices, comparing adults and elderly people. Some studies have found an increase in F_0 of the vowel /a/ in the elderly[2,3], pointing to such increase as product of hormonal changes that would lead to a reduction in muscular tissue in men in the aging process[3]. Others, however, did not observe differences in F_0 of the vowel /a/ between voices of young and elderly people[10,15] or, they also determined a decrease in F_0 of the vowel /a/ for the elderly people, when compared with the young people[17]. Although divergences between the results for elderly populations have been observed, the tendency to increase F_0 seems to occur for men with more advanced ages and they are not reflected in younger age groups.

The disturbance measures of frequency (Jitter) and amplitude (Shimmer) provide short-term information about irregularities in the acoustic wave generated by the larynx, which, when subtle, refer to the normal variations associated with vocal production[19], and can be influenced as by gender and by the speaker's age[7].

In the present study, the Jitter measure varied according to gender, that is, women from 19 to 59 years presented greater values of this measure than men with corresponding ages, going along with previous reports of studies which investigated Jitter in adults[11,19]. Greater Jitter values (greater irregularity in the voice signals) for women than men could be justified by factors such as F_0 and vocal intensity[19]. However, significant differences in Jitter between men and women were not found in other adult populations (20-40 years[20], 20-50 years[1], 30-80 years[14].

It is worth mentioning that, in general, the Jitter values obtained in the present study for participants of both genders are found within the normal range of the MDVP (women = 0.633, with a maximum threshold of 1.040, men 0.59, with maximum threshold of 1.04), according to reported in the literature[13,30]. The study data provide additional information on how Jitter behaves when normal voices of adults of both genders are analyzed. Such findings should be considered for clinical purposes, particularly when women and men's voices are compared.

In relation to age, there was no change in the Jitter measure when comparing groups of young adults to middle-age, which corroborates previous reports[1,9,14], suggesting that the frequency disturbance measure is stable in adults, including in the middle age.

In relation to the Shimmer measure, there were no differences between the genders, going along with previous studies involving the adult population[1,19,20]. There was interaction between gender and age for Shimmer, indicating that, in men, the values of this acoustic parameter change with the increase in age.

More specifically, higher Shimmer values were observed for adults in the 50s than younger adults (20s and 30s). Although previous studies have identified increased disturbance values of amplitude in older men[10,17,18], the data from the present study suggest that the Shimmer measure begins to rise in the adulthood, particularly in the 50s, a suggestive fact of the beginning of possible anatomical and physiological modifications of the larynx that can reflect in the greater disturbance of the acoustic signal, which would accentuate with the increase of the age.

In the present study, mean values of Shimmer obtained for men from G1 (19-29 years) and G2 (30-39 years) were found within the normal measure proposed by the MDVP (2.52, with a maximum threshold of 3.810) while for G3 (40-49 years) and G4 (50-59 years) these were higher. Mean value of Shimmer higher than the MDVP normality measure was also found for adult men in previous studies for the 30s[14] and the 20s, 30s, 40s, and 50s[30]. In women, mean values of Shimmer were also found higher than the normality measure proposed by the MDVP (1.997, with a maximum threshold of 3.810) for the age groups G1 (19-29 years), G2 (30-39 years) and G4 (50-59 years), going along with findings previously reported[30].

The noise measure quantifies the additional noise in the vocal signal and may reflect processes involved in glottal closure[2], being relevant for clinical purposes. In this study, there was an effect of gender in the NHR measure in which men presented higher amount of noise in the vocal signal than women, going along with previous findings[1,14,16,20], but disagreed with a study that found high values of this measure for women[2].

For the better understanding of this finding, it would be important the development of research that related this measure with others about glottal closure from laryngeal exams. In relation to the age, the findings of this study did not point differences in the NHR measure among the studied groups, suggesting that this measure is more stable during the adult phase, including middle age, with expected changes only in the third age[21].

The mean NHR values of this study presented within the normality values of the MDVP, being 0.120 (with a maximum threshold of 0.190) for men and 0.112 (with a maximum threshold of 0.190) for women[30].

The present study characterized the normal voices of adults from young age to middle age from a set of acoustic measures. By providing acoustic data for adult voices, recorded for decades, this study allows the identification of subtle changes that occur at the end of adulthood and that should be considered in clinical practice in order to assist in the diagnosis of diseases that may affect laryngeal function of this population.

For clinical purposes, the findings presented in this study show that the acoustic measures investigated presented mostly within the normal limits (including maximum threshold) of the MDVP program. The F_0 measures of sustained vowel and speech, as well as the disturbance measure of Shimmer, were the most sensitive to show the effect of age on the voice. However, the Shimmer values were higher in this study than the normal limits of the MDVP program.

The study also contributes to the description of the F_0 measure of the speech in adults, a measure that is not well explored in the studied age group and which can corroborate in the voice evaluation, since it offers relevant information to the actual judgment of speech in an individual. In addition, the information about the disturbance measures analyzed may contribute to a greater understanding of the effect of gender, since previous information presented is still contradictory.

Although the relevance of the acoustic findings of the present study, it is limited to a specific age group. Further studies are needed in order to characterize normal voices throughout life, with a wide age range, from a set of acoustic measures.

CONCLUSION

Vocal changes due to advancing age can be identified acoustically at the end of adulthood and, in women these changes can be marked particularly before the menopause period.

Through the studied measures, it was observed that, in relation to age, women present modifications in the F_0 measure of the vowel and speech, and in men, the beginning of the vocal modifications are indicated by the F_0 measure of speech and Shimmer. Men and women present gender differences in F_0measures, Jitter and NHR. Clinically, these acoustic findings should be considered for comparison effects with pathological populations.

REFERENCES

1. Dehqan A, Ansari H, Bakhtiar M. Objective voice analysis of Iranian speakers with normal voices. J Voice. 2010;24(2):161-7. http://dx.doi.org/10.1016/j.jvoice.2008.07.005. PMid:19230602.
2. Stathopoulos ET, Huber JE, Sussman JE. Changes in acoustic characteristics of the voice across the life Span: measures from individuals 4-93 years

of age. J Speech Lang Hear Res. 2011;54(4):1011-21. http://dx.doi.org/10.1044/1092-4388(2010/10-0036). PMid:21173391.

3. Soltani M, Ashayeri H, Modarresi Y, Salavati M, Ghomashchi H. Fundamental frequency changes of Persian Speakers across the life Span. J Voice. 2014;28(3):274-81. http://dx.doi.org/10.1016/j.jvoice.2013.10.012. PMid:24461477.
4. Pontes P, Brasolotto A, Behlau M. Glottic characteristics and voice complaint in the elderly. J Voice. 2005;19(1):84-94. http://dx.doi.org/10.1016/j.jvoice.2004.09.002. PMid:15766853.
5. Pessin ABB. A voz do idoso: características clínicas, endoscópicas, vocais e morfológicas [tese]. Botucatu: Universidade Estadual Paulista; 2015.
6. Machado FCM, Cielo CA, Lessa MM, Barbosa LHF. Vocal characteristics of elderly women engaged in aerobics in private institutions of Salvador, Bahia. J Voice. 2016;30(1):127-e9. PMid:25795360.
7. Behlau M, Madazio G, Feijó D, Pontes P. Avaliação de voz. In: Behlau M, editor. Voz: o livro do especialista. São Paulo: Revinter; 2001. p. 139-41.
8. D'haeseleer E, Depypere H, Claeys S, Van Borsel J, Van Lierde KM. The menopause and the female larynx, clinical aspects and therapeutic options: a literature review. Maturitas. 2009;64(1):27-32. http://dx.doi.org/10.1016/j.maturitas.2009.06.009. PMid:19632797.
9. D'haeseleer E, Depypere H, Claeys S, Wuyts FL, Baudonck N, Van Lierde KM. Vocal characteristics of middle-aged premenopausal women. J Voice. 2011;25(3):360-6. http://dx.doi.org/10.1016/j.jvoice.2009.10.016. PMid:20189350.
10. Goy H, Fernandes DN, Pichora-Fuller MK, van Lieshout P. Normative voice data for younger and older adults. J Voice. 2013;27(5):545-55. http://dx.doi.org/10.1016/j.jvoice.2013.03.002. PMid:23769007.
11. Demirhan E, Unsal EM, Yilmaz C, Ertan E. Acoustic voice analysis of young Turkish speakers. J Voice. 2016;30(3):378.e21-5. http://dx.doi.org/10.1016/j.jvoice.2015.04.018. PMid:26223964.
12. Nishio M, Niimi S. Changes in speaking fundamental frequency characteristics with aging. Folia Phoniatr Logop. 2008;60(3):120-7. http://dx.doi.org/10.1159/000118510. PMid:18305390.
13. Beber BC, Cielo CA. Medidas acústicas de fonte glótica de vozes masculinas normais. Pró-Fono R Atual Cient. 2010;22(3):299-304. http://dx.doi.org/10.1590/S0104-56872010000300024. PMid:21103722.
14. Santos AO. Parâmetros acústicos e perceptivo-auditivos da voz de adultos e idosos [dissertação]. Bauru: Universidade de São Paulo; 2012.
15. Zraick RI, Smith-Olinde L, Shotts LL. Adult normative data for the KayPENTAX phonatory aerodynamic system model 6600. J Voice. 2012;26(2):164-76. http://dx.doi.org/10.1016/j.jvoice.2011.01.006. PMid:21600731.
16. Lortie CL, Thibeault M, Guitton MJ, Tremblay P. Effects of age on the amplitude, frequency and perceived quality of voice. Age. 2015;37(6):117. http://dx.doi.org/10.1007/s11357-015-9854-1. PMid:26578457.
17. Xue S, Deliyski D. Effects of aging on selected acoustic voice parameters: preliminary normative data and educational implications. Educ Gerontol. 2011;27(2):159-68.
18. Dehqan A, Scherer RC, Dashti G, Ansari-Moghaddam A, Fanaie S. The effects of aging on acoustic parameters of voice. Folia Phoniatr Logop. 2012;64(6):265-70. http://dx.doi.org/10.1159/000343998. PMid:23328404.
19. Brockmann M, Drinnan MJ, Storck C, Carding PN. Reliable jitter and shimmer measurements in voice clinics: the relevance of vowel, gender, vocal intensity, and fundamental frequency effects in a typical clinical task. J Voice. 2011;25(1):44-53. http://dx.doi.org/10.1016/j.jvoice.2009.07.002. PMid:20381308.
20. Felippe ACN, Grillo MHMM, Grechi TH. Normatização de medidas acústicas para vozes normais. Rev Bras Otorrinolaringol. 2006;72(5):659-64. http://dx.doi.org/10.1590/S0034-72992006000500013.
21. Ferrand CT. Harmonics-to-noise ratio: an index of vocal aging. J Voice. 2002;16(4):480-7. http://dx.doi.org/10.1016/S0892-1997(02)00123-6. PMid:12512635.
22. Hirano M. Clinical examination of voice. New York: Springer-Verlag; 1981. 100 p.
23. Marino VC, Dutka JDCR, de Boer G, Cardoso VM, Ramos RG, Bressmann T. Normative nasalance scores for Brazilian Portuguese using new speech stimuli. Folia Phoniatr Logop. 2015;67(5):238-44. http://dx.doi.org/10.1159/000441976. PMid:26844554.
24. Parsa V, Jamieson DG. Acoustic discrimination of pathological voice: sustained vowels versus continuous speech. J Speech Lang Hear Res. 2001;44(2):327-39. http://dx.doi.org/10.1044/1092-4388(2001/027). PMid:11324655.
25. de Boer G, Bressmann T. Application of Linear Discriminant Analysis to the Long-term Averaged Spectra of Simulated Disorders of Oral-Nasal Balance. Cleft Palate Craniofac J. 2016;53(5):e163-71. http://dx.doi.org/10.1597/14-236. PMid:26068387.
26. Boersma P, Weenink D. Praat: doing phonetics by computer. Version 5.3.56 [Internet]. Amsterdam: University of Amsterdam; 2007 [citado em 2007 Maio 17]. Disponível em: http://www.praat.org
27. Abitbol J, Abitbol P, Abitbol B. Sex hormones and the female voice. J Voice. 1999;13(3):424-46. http://dx.doi.org/10.1016/S0892-1997(99)80048-4. PMid:10498059.
28. Baken RJ. The aged voice: a new hypothesis. J Voice. 2005;19(3):317-25. http://dx.doi.org/10.1016/j.jvoice.2004.07.005. PMid:16102660.
29. Gugatschka M, Kiesler K, Obermayer-Pietsch B, Schoekler B, Schmid C, Groselj-Strele A, et al. Sex Hormones and the Elderly Male Voice. J Voice. 2010;24(3):369-73. http://dx.doi.org/10.1016/j.jvoice.2008.07.004. PMid:19185460.
30. Smits I, Ceuppens P, De Bodt MS. A comparative study of acoustic voice measurements by means of Dr. Speech and Computerized Speech Lab. J Voice. 2005;19(2):187-96. http://dx.doi.org/10.1016/j.jvoice.2004.03.004. PMid:15907433.

Author contributions

EAS: principal researcher, elaboration of the research, elaboration of the schedule, literature review, collection and analysis of the data, manuscript writing, submission and paperwork of the article; VMC: collection and collaboration of the data analysis; EMGF: collaboration in data analysis, data interpretation and article writing; LCB: collaboration in data analysis, statistical analysis, interpretation of data and in the final writing of the article; AGB: collaboration in the interpretation of data and in the final writing of the article; VCCM: supervisor, coordination of the research, data analysis, correction of article writing, approval of the final version.