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Biobehavioral Measures of Presbylaryngeus

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Abstract

OBJECTIVE: The objective of this observational study was to assess the relationship between established aging biobehavioral measures and voice decline in normally aging adults.

STUDY DESIGN: Cross-sectional study

LEVEL OF EVIDENCE: 4

METHODS: Participants 60–85 years of age were divided into two age and sex matched groups, based on the presence or absence of presbylaryngeus. Both groups underwent a battery of tests measuring anthropometric variables, inflammatory markers, general health measures and vocal function parameters. Differences from the norm were calculated for all variables. Parametric and non-parametric tests were performed to assess group differences. In addition, variable selection

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analysis was performed to determine variables that were most influential in predicting the occurrence of presbylaryngeus in our current sample.

RESULTS: Fifty-three participants were divided into age and sex matched groups of ‘presbylaryngeus’ (n=26) and ‘non-presbylaryngeus’ (n=27). The two groups were statistically different in select measures of inflammatory markers, general health measures and vocal function parameters. Anthropometric measures were not statistically different. Based on variable selection, the variables most predictive of the presence of presbylaryngeus were measures of the Physical Activity Scale of the Elderly, C-reactive protein, laryngeal airway resistance and vocal roughness.

CONCLUSIONS: In addition to group differences in vocal function measures, results for the presbylaryngeus group consistently trended sub-optimally on anthropometric measures, two inflammatory markers, and general health measures. These results suggest that this sample of individuals with presbylaryngeus demonstrated greater biobehavioral deficits associated with aging as compared to age and sex-matched non-presbylaryngeus individuals.

Keywords

biobehavioral measures; presbylaryngeus; aging; voice

INTRODUCTION

It is estimated that 29% of independent living individuals over the age of 65 years suffer with occupationally and socially limiting vocal dysfunction.[1] We define vocal dysfunction as the inability to produce and project voice, so that it can be effectively heard and understood. Considering that 20% of the US population will be over the age of 65 by the year 2030, factors that limit occupational and social interactions will increasingly and negatively impact older individuals.[2] Given the significance of effective communication for maintaining independence and psychological well-being, it is important to understand whether typical biobehavioral measures of aging can distinguish individuals with and without presbylaryngeus. Understanding these distinguishing factors could lead to early identification of individuals who are at risk for age-related vocal dysfunction and may permit the development of interventions and treatments that delay or reverse voice decline.

Biomarkers of aging reflect a person’s rate of aging and thus functional age as opposed to chronological age.[3] Functional biomarkers help to determine functional ability or functional declinein terms of physiological, cognitive, and physical function with relevance for morbidity and mortality.[4] The biobehavioral measures chosen for the study included select measures that were widely reported as established biomarkers for aging. Our focus was to parallel previously reported measures in the aging voice population, with already established biobehavioral measures of aging. Additionally, there was a logistic component to choosing select measures since these were feasible to be obtained at the University of Kentucky. A variety of biobehavioral measures of normal aging have consistently been reported in the aging literature including anthropometric measures (e.g. waist to hip ratio, body mass index (BMI),[5,6] inflammatory markers (e.g. C-reactive protein (CRP), interleukin 6(IL6),[7] and general health measures (e.g. activity level, perceived stress, balance).[8–10] For example, interleukin-6 (IL6) is a robust non-specific marker of adverse health outcomes such as disease, disability, and mortality in older adults along with the other two common biomarkers C-reactive protein (CRP) and tumor necrosing factor-alpha (TNFA).[11] In short, as an individual ages, the percentage of fat increases in relation to lean body mass,[5,6,12] inflammatory markers, as measured through blood chemistries, increase;[7] balance decreases while activity level decreases and perceived stress is increased.[8,9] Increased levels of the inflammatory markers have been associated with loss of muscle strength,[13] sarcopenia,[14–16] decreased grip strength,[17,18] and lower pulmonary function.[19] Age-related increases in BMI and waist-hip ratio and decreases in physical activity level have been associated with inflammation.[20,21] Increased levels of perceived psychological stress have been associated with elevated markers of biological aging.[22] Consequently, age-related muscular decline and heightened inflammation may also be linked to changes in vocal folds that precipitate presbylaryngeus.

Normal aging-related changes also occur in all subsystems of the voice producing mechanisms of respiration, phonation and resonance.[23–40] Although age-related voice changes do not necessarily produce a voice disorder, such changes do lead to vocal dysfunctions that are sufficient to significantly alter communication and negatively affect the ability to function in occupational and social settings.[1] Established risk factors for voice disorders in the general population include a variety of medical conditions and/or voice use patterns related to occupational needs (e.g. teaching, sales, service industries).[41–52] Additional risk factors specific to normal aging-related vocal decline are absent.

It was the purpose of this preliminary observational study was to investigate the extent to which established biobehavioral measures of aging could distinguish individuals with and without presbylaryngeus. We hypothesized that individuals with presbylaryngeus would present with different patterns of biobehavioral measures as compared to an age-matched cohort not judged to be presbylaryngeus.

MATERIALS AND METHODS

Following approval by the University of Kentucky Institutional Review Board, 53 participants, 23 male and 30 female, between the ages of 60 – 85 years volunteered for this study. Participants were recruited via flyer and word of mouth. Data collection was completed between the periods of January, 2014 to June, 2016. Exclusions to the study included those who were current smokers or had a history of smoking in the past five years; history of blunt trauma to the head, neck, or chest; presence of vocal fold lesions; evidence of neurological speech or voice disorder; professionally trained singers; hearing problems that would preclude completion of the study tasks; and presence of cognitive deficits. Subjects who met inclusion and exclusion criteria as determined through an initial phone screen were invited to participate in a one-time onsite visit, at which time the subject was consented and further screened for inclusion with a medical health questionnaire, administration of the Mini-Cog,[53] and a laryngeal videostroboscopic examination to rule out the presence of laryngeal pathology. Video of the stroboscopic examination was later used to determine group assignment. Subjects who passed the second level of screening were included in the experimental protocol. All research procedures took place in the University of Kentucky Laryngeal and Speech Dynamics Laboratory and the outpatient unit of the

Center for Clinical and Translational Science (CCTS) in the University of Kentucky Medical Center.

Experimental Protocol

Appendix A lists detailed methods of data collection for all anthropometric measures, inflammatory markers, general measures of health, and vocal function measurements used in this study. Except for the total body dual-energy x-ray absorptiometry (DXA) scan, phlebotomy and biomarker/cytokine assay, all data collection was completed by the authors. Laryngeal videostroboscopy, perceptual voice assessment, acoustic, and aerodynamic analyses were completed by two certified speech-language pathologists (authors 1 & 6), each with more than 10 years experience working with voice disordered individuals. Assessors were blinded to condition.

Group Assignment

Two licensed and certified speech-language pathologists, with extensive experience in rating laryngeal stroboscopic parameters, reviewed and rated the laryngeal videostroboscopic examinations made during the initial screening. Raters did not participate in the initial screening procedures and were blinded to the study objectives. Stroboscopic ratings included the following:

- glottal gap – present/absent
- vocal fold atrophy – present/absent
- mucosal wave – normal/increased/decreased
- amplitude – normal/increased/decreased
- symmetry – symmetrical/asymmetrical

Individuals identified by the raters with the characteristics of presbylaryngeus, glottal gap and vocal fold atrophy, were assigned to the presbylaryngeus group with the remaining participants assigned to the non-presbylaryngeus group. Table 1 presents the group distribution by age and sex.

Statistical Analysis

Statistical analyses were performed using SPSS ver. 22. Frequencies and descriptive statistics for the sample are available in Appendix B. On obtaining frequency results, the presbylaryngeus and non-presbylaryngeus groups showed a high degree of variance across all dependent variables under study as a result of the sex differences within each sample. To account for variances in sex differences, difference from the mean of the normative range or difference from normative threshold values were calculated for each variable under study (See Appendix B). In our results and discussion, we refer to these values as ‘difference from the mean.’ After calculating the difference from the mean for each variable, we were successful in further normalizing data for statistical analysis. Normality for each variable was determined using the Shapiro-Wilk test. For the final comparison and regression analyses, means and standard deviations of the differences between the presbylaryngeus and non-presbylaryngeus groups for all variables were calculated.

Though we were successful in reducing the amount of variance after calculating difference from the mean, select variables did not pass our test for normality. For variables that showed normal distribution based on the Shapiro-Wilk test, an independent sample t-test (parametric test) was applied to compare differences. A Mann-Whitney u test (non-parametric) was applied for variables that were not normally distributed. Finally, to determine variables that were most influential in predicting the occurrence of presbylaryngeus in our current sample, a backward stepwise regression was performed.

RESULTS

Group raw data including means and standard deviations for all the dependent variables are presented in Appendix B. As previously stated, difference from a predetermined mean was calculated for each variable under study as reported below. For the purpose of this paper, we will be presenting results as compared to optimal measures.

Anthropometric measures (BMI, waist-to-hip ratio, hand-grip strength, mean expiratory pressure (MEP), total fat percentage on DXA) (Table 2):

Based on scores obtained on differences from the mean for variables of BMI, MEP and fat percentage, the presbylaryngeus group presented with sub-optimal measures as compared to their counterparts. For measures of hand grip strength, the non-presbylaryngeus group performed sub-optimally as compared to their counterparts. There were no statistically significant differences for anthropometric measure between the two groups.

Inflammatory markers (TNFA, IL6, CRP) (Table 3):

Differences from the means for inflammatory markers demonstrated that the presbylaryngeus group performed suboptimally as compared to their counterparts for measures of CRP and IL6. For measures of tumor necrosis factor, alpha (TNFA), the non-presbylaryngeus group demonstrated suboptimal results as compared to the presbylaryngeus group. On comparing the two groups, statistically significant differences were observed for measures of TNFA ($p=0.001$).

General health measures (Tinetti test total scores for Gait and Balance, Physical Activity Scale for the Elderly (PASE), Perceived Stress Scale (PSS-10) (Table 4):

The presbylaryngeus group performed sub-optimally as compared to their counterparts for all general health measures. On comparing the two groups, statistically significant differences were observed for the PASE ($p=0.02$).

Vocal function assessment (Maximum Phonation Time (MPT), Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V), Reflux Symptom Index (RSI), Voice Handicap Index (VHI), Subglottic Pressure (Psub), airway resistance (LAR), airflow rate, Cepstral Spectral Index of Dysphonia (CSID), jitter, shimmer, and noise-to-harmonic-ratio (NHR)) (Table 5):

For ease of explanation, this section is divided into five different categories of voice parameters which include aerodynamic parameters, acoustic parameters, VHI scores, RSI scores and auditory perceptual measures.

Aerodynamic measures:

The presbylaryngeus group performed sub-optimally as compared to their counterparts for measures of subglottic pressure and airflow rate. The non-presbylaryngeus group demonstrated sub-optimal differences from the mean scores for laryngeal airway resistance, as compared to the presbylaryngeus group. No statistically significant differences were observed for aerodynamic measures between the two groups.

Acoustic measures:

Based on scores obtained on differences from the means, the presbylaryngeus group demonstrated sub-optimal scores for all measures except CSID measures for voiceless plosives. The non-presbylaryngeus group demonstrated sub-optimal measures for CSID-voiceless plosives, as compared to the presbylaryngeus group. Statistically significant differences were observed for measures of shimmer, CSID values of sustained vowel ($p=0.004$) and all-voiced sentence ($p=0.05$), and noise-to-harmonic-ratio ($p=0.042$).

Patient self-report (VHI):

The presbylaryngeus group demonstrated sub-optimal scores for total VHI scores, as compared to the non-presbylaryngeus group. No statistically significant differences were observed between the two groups.

Auditory-perceptual measures (CAPE-V scores):

The presbylaryngeus group demonstrated sub-optimal scores for all measures on the CAPE-V as compared to the nonpresbylaryngeus group. Statistically significant differences were observed for measures of overall severity ($p=0.001$), roughness ($p=0.003$), breathiness ($p<0.001$) and strain ($p=0.00$).

Reflux Symptom Index:

Based on scores obtained on differences from the means, the presbylaryngeus group demonstrated sub-optimal scores for RSI, as compared to their counterparts. Statistically significant differences were observed for the two groups for RSI scores ($p=0.017$).

Backward Stepwise Regression

To determine the factors that were most predictive of prebylaryngeus in the present study sample, a logistic regression model was run using a backward stepwise regression for variable selection. Variables for the regression model were selected based on correlation analysis for all the variables ($p \leq 0.05$). The initial model included differences from the means for BMI, waist to hip ratio, hand grip strength, maximum expiratory pressure, CRP, IL6, PASE scores, RSI scores, VHI scores, Tinetti scores, laryngeal airway resistance measures, CSID measures for sustained vowel, auditory-perceptual measures for roughness and noise-to-harmonic-ratio measures.

After running the backward stepwise regression, variables left in the model were differences from mean scores of C-reactive protein, Physical Activity Scale Elderly, laryngeal airway resistance and auditory perceptual roughness. The point estimates for variable selection are included in Table 6.

DISCUSSION

Participants between the ages of 60–85 years were recruited to determine if typical biobehavioral measures of aging would distinguish individuals with and without presbylaryngeus. Upon meeting the inclusion/exclusion criteria, 53 volunteer participants were divided by voice experts blinded to the study into presbylaryngeus and nonpresbylaryngeus groups based on the presence/absence of vocal fold atrophy. All participants were subjected to extensive testing yielding a variety of biobehavioral measures typically reported in the aging literature. These measures included anthropometric measures, inflammatory markers, and general health measures. All participants also underwent extensive vocal function evaluation including selected measures from auditory perceptual, self-assessment, acoustic, and aerodynamic measures, as well as the Reflux Symptom Index. (Appendix A) Several levels of analysis were conducted including descriptive statistics and parametric and non-parametric tests. In addition, a variable selection analysis using a backward stepwise regression demonstrated the variables that were most influential in predicting the occurrence of presbylaryngeus in this sample population.

Because of the large number of variables studied, the current sample size limits the generalizability of these data, but does present interesting preliminary results as we seek to better understand individuals who develop presbylaryngeus. A distinct pattern emerged through the study. When comparing age and sex-matched groups, the presbylaryngeus group scored sub-optimally on 26 of the 30 total measures with 12 comparisons demonstrating statistical significance at $p \leq 0.05$.

Though not statistically significant, the anthropometric profile of the groups indicated that individuals with presbylaryngeus trended to a higher body mass index, higher waist to hip ratio, and a higher fat percentage. These results are consistent with the literature that demonstrates that frailty is more prevalent in individuals with a higher BMI with waist circumference serving as a surrogate for increased body fat.[54] Similarly, lower maximum expiratory pressure measures in the presbylaryngeus group are consistent with findings by Enright and colleagues who found that negative predictors for MEP were age and waist size.[55] The presbylaryngeus group also demonstrated increased levels of two of the three inflammatory markers, IL6 and CRP. These results were consistent with the findings of Wassel et. al (2010) who found that increased IL6 and CRP in normally aging men was associated with 15% and 12% decrease in survival time respectively.[56]

In terms of a general health profile, the presbylaryngeus group had significantly lower levels of physical activity, higher levels of perceived stress, and impaired balance scores. The voice profile of the presbylaryngeus group was characterized by increased vocal hyperfunction, decreased glottic valving, increased vocal perturbation, decreased voice related quality of life, and increased roughness, breathiness, strain and pitch, and reduced loudness. These results are consistent with those reported in the literature for aging voice.[29,37,57]

Overall, these preliminary results suggest that individuals with presbylaryngeus may demonstrate greater age-related biobehavioral deficits as compared to non-presbylaryngeus individuals. Using variable selection by backward stepwise regression, the combination of variables most predictive of the presence of presbylaryngeus were an increase in the inflammatory marker CRP, a decreased level of physical activity, decreased laryngeal airway resistance, and increased voice roughness. This study was successful in filtering out select biobehavioral measures to be further studied to inform our understanding of presbylaryngeus. Clinical implications will require further investigation of these interactions.

Limitations

Considering the number of variables under study, the major limitation of the present study was the sample size. In addition, the present study did not lend itself to the study of differences between the sexes. The data trends lead us to conclude that larger samples would permit both problems to be resolved. Based on the trends observed in the present study, future studies may also be able to limit the number of necessary dependent variables.

Conclusions

These preliminary results suggest that distinct biobehavioral characteristics, beyond laryngeal and vocal characteristics, may distinguish individuals with and without presbylaryngeus. These results suggest that individuals with presbylaryngeus demonstrate greater age-related biobehavioral deficits associated with aging as compared to nonpresbylaryngeus individuals. Future longitudinal research is needed to demonstrate/confirm whether these or other age-related biobehavioral measures are predictive of the development of presbylaryngeus. Early identification of individuals who are at risk for age-related vocal dysfunction may permit the development of interventions and treatments that delay or reverse voice decline.

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APPENDIX A

Anthropometric Measures

- **Body mass index (BMI):** BMI was determined using height and weight measurements taken the day of the study. Subjects were assessed for waist circumference at their natural waist. Hip circumference was measured at its widest point. Both measures were taken using a flexible, flat tape over lightweight clothing while the subject was standing with muscles relaxed. Both measures were repeated twice to ensure accuracy.[58–60]

- **Total Body Dual-Energy X-ray Absorptiometry (DXA) Scan**:[61] (Lunar Prodigy, GE Lunar Inc., Madison, WI) Each participant received a DXA scan performed at the CR-DOC in the University of Kentucky Medical Center by study personnel trained in this procedure. The scan was performed using a bone densitometer prior to any physical activity. The subjects were instructed to remove all objects such as jewelry or eyeglasses and wear a hospital gown, or a light weight shirt and shorts (containing no metal) during the scanning procedure. All scans were analyzed by trained and certified personnel using the GE Lunar software version 10.0. DXA bone mineral content (BMC; kg), DXA bone mineral density (BMD; g/cm2), DXA fat-free mass (FFM; kg), DXA mineral-free lean mass (MFL; kg), DXA fat mass (Fat; kg), and DXA percent fat (% Fat) were assessed.

Inflammatory Markers

- **Non-Fasting Blood Draw**: Approximately 10–20 ml of blood was taken to perform blood chemistries, which include the inflammatory markers IL6,[62] TNFA,[62] and CRP.[63] Subjects were advised not to exercise or complete any strenuous activity before coming to the study so that inflammatory marker levels were not increased due to activity. Blood was drawn and analyzed at the outpatient unit of the CCTS in the University of Kentucky Medical Center.

General Health Measures

- **Handgrip Strength:** (Jamar Hydraulic Hand Dynamometer) A handgrip dynamometer was used for the assessment of handgrip strength in the dominant hand. The subject stood, arms at their side, not touching their body, and elbow flexed to 90 degrees. The subject squeezed the dynamometer with as much force as possible, being careful to squeeze only once for each measurement. Three trials were made with a pause of 1-minute between each trial to avoid the effects of muscle fatigue. Each trial was recorded to the nearest pound. If the difference in scores was within 6.6 lbs., the test was complete. If the difference between any two measures was more than 6.6, then the test was repeated once more after a rest period.[64,65]

- **Respiratory Expiratory Pressure:** (Dwyer Magnehelic Differential Pressure Gauge, 2000) Maximum expiratory pressure (MEP) measured at the mouth is an indirect measure of expiratory muscle strength. The measurement tool consists of a mouthpiece connected to a differential pressure gage by tubing. MEP was measured with the subject standing, and their nose occluded with a nose clip. After inhaling to total lung capacity, the subjects placed their lips around the mouthpiece and blew out as forcefully as possible. Repeated measures were taken with a 1- to 2-minute rest between each trial, until three values within 5% of each other were obtained. The average of the three values was recorded.[66]

- **Gait and Stability:** The Tinetti Balance Assessment Tool consists of balance and gait sections. In the balance section, the study participant's balance is evaluated in while sitting, standing and then turning. The gait section assesses gait initiation, stepping, trunk sway, stance, walking path and time.[10]

- **Physical Activity Level:** The Physical Activity Scale for the Elderly (PASE) is a 24-item self-report physical activity questionnaire designed to assess current level of activity (occupational, household, and leisure) of community-dwelling older persons through self-report of a one week period. The PASE was found to be both valid and reliable.[8]
- **Perceived Stress:** The 10-item Perceived Stress Scale (PSS-10) assesses the degree to which subjects perceive their daily life during the previous month as either unpredictable, uncontrollable, or overloaded. The PSS-10 is a valid and reliable measure of perceived stress.[9]

Vocal Function Assessment

- **Visual-perceptual:** (Kay PENTAX Rhino-Laryngeal Stroboscope – Model RLS 9100B coupled to a 70-degree Kay PENTAX rigid scope - Model SN 1541) To observe vocal fold appearance and gross movement, a small rigid scope attached to a digital video recorder was placed in the mouth and a video recording made as the subject produced the sound "ee".[67]
- **Audio-perceptual:** (KayPENTAX CSL, Model 4500, Shure SM-48 [mouth-to-microphone distance = 3 inches]) A digital audio recorder was used to obtain a recording of the voice. To complete the audio recording, subjects were asked to produce some common sounds, read, and speak a standard reading passage into a standard microphone. Apart from acoustic analyses, these recordings were used for auditory-perceptual evaluations of voice (Consensus Auditory-Perceptual Evaluation of Voice [CAPE-V]).[68,69]
- **Aerodynamic assessment:** (KayPENTAX Phonatory Aerodynamic System, Model 6000) Measurements of airflow rate, air pressure, and laryngeal airway resistance were taken. Airflow measures were taken through a mask placed over the nose and mouth while the subject produced voice and speech. For Psub and LAR, a small tube inserted through the mask was placed just inside the mouth behind the front teeth, resting on the tongue. Subjects were instructed to hold the facemask in place and say "pa" five to seven times at a comfortable loudness and at a rate of approximately 1.5 seconds per syllable. Three trials of each task were collected and averaged. Prior to data collection, the subjects practiced the accurate performance of the tasks.[70]
- **Acoustic analysis:** (KayPentax CSL, Model 4500) Participants were asked to produce pre-determined standardized voice samples, which included vowels and sentences. The Kay Pentax Multi-Dimensional Voice Profile (MDVP) and Analysis of Dysphonia for Speech and Voice (ADSV)[71] were utilized for analysis of acoustic stimuli.
- **Voice Quality of Life:** Subjects completed the Voice Handicap Index (VHI), a 30-item self-report questionnaire that assesses the perceived impact of vocal

functioning on quality of life. The VHI also assesses functional, physical, and emotional domains of voice quality of life. This instrument has been found to be both reliable and valid.[72]

- **Reflux Symptoms:** The Reflux Symptom Index (RSI) is a 9-item self-report questionnaire to document symptom severity in laryngopharyngeal reflux.[73] The RSI is a valid and reliable outcomes instrument.

APPENDIX B

Table 1:

Raw scores and means and SDs for anthropometric measures

(Calculated mean indicates optimal values based on clinical threshold or clinical range)

Measures	Parameters	Calculated mean	Mean and SD for non-presbylaryngeus group		Mean and SD for presbylaryngeus	
Anthropometric measures	Body mass index (BMI)	25	Males (n=11)	Females (n=16)	Males (n=12)	Females(n=14)
			26.99 (3.64)	25.33 (3.66)	26.81 (3.5)	27.82 (4.15)
	Waist- hip ratio	Males: 0.9 Females: 0.85	0.92 (0.034)	0.84 (0.057)	0.92 (0.044)	0.85 (0.11)
	Hand-grip strength	Males: 74 Females: 46	52.9 (23.6)	45.3 (10.25)	76.1 (24.7)	42.9 (9.85)
	Mean expiratory pressure	Males: 105 Females: 70	74.8 (74.7)	79.47 (34.23)	76.1 (24.7)	74.6 (25.4)
	Total fat percentage	Males: 25.9 Females: 41.2	31.21 (3.55)	37.6 (6.35)	30.7 (8.08)	42.9 (5.8)

Table 2:

Raw scores and means and SDs for inflammatory markers

Measures	Parameters	Calculate d mean	Mean and SD for non-presbylaryngeus group		Mean and SD for presbylaryngeus	
Inflammatory markers			Males (n=11)	Females (n=16)	Males (n=12)	Females(n=14)
	CRP	1	1.84 (3.32)	1.73 (1.26)	4.52 (3.64)	1.55 (1.55)
	Tnf-alpha	9.97	4.07 (1.48)	3.65 (1.09)	4.5 (3.2)	4.6 (4.3)
	iL6	15.67	4.5 (5.72)	3.64 (2.8)	2.15 (0.91)	1.81 (0.64)

(Calculated mean indicates optimal values based on clinical threshold or clinical range)

Table 3:

Raw scores and means and SDs for general health measures

Measures	Parameters	Calculated mean	Mean and SD for non-presbylaryngeus group		Mean and SD for presbylaryngeus	
General measures	Tinetti total score for gait and balance	24	Males (n=11)	Females (n=16)	Males (n=12)	Female s(n=14)
			26.29 (3.06)	27.06 (2.17)	25.5 (3.09)	26.31 (3.06)
	PASE	Males: 125 Females:92	240.77 (82.8)	232.73 (119.8)	166.97 (72.1)	148.47 (68.16)

Measures	Parameters	Calculated mean	Mean and SD for non-presbylaryngeus group		Mean and SD for presbylaryngeus	
	PSS	20	11.36 (5.76)	10.69 (7.32)	13.08 (7.5)	13.43 (6.65)

(Calculated mean indicates optimal values based on clinical threshold or clinical range)

Table 4:

Raw scores, and means and SDs for vocal function measures

Measures	Domain	Parameters	Calculated mean	Mean and SD for non-presbylaryngeus group		Mean and SD for presbylaryngeus	
				Males (n=11)	Females (n=16)	Males (n=12)	Females(n=14)
Voice measures	Acoustic analysis	Jitter	1	0.66 (0.25)	0.83 (0.47)	0.91 (0.66)	0.99 (0.6)
		Shimmer	0.35	1.36 (1.55)	3.08(1.53)	4.09 (142)	3.44 (1.98)
		Noise to harmonics ratio	0.194	0.135 (0.018)	0.12 (0.015)	0.15 (0.024)	0.13 (0.027)
		CSID /a/	14	8.75 (11.75)	6.61 (13.5)	24.7 (21.03)	16.7 (14.48)
		CSID- Easy Onset	21.08	1.16(13.06)	4.1 (9.76)	3.76(11.02)	9.43 (12.86)
		CSID- All Voiced	14.4	−12.02 (16.9)	0.797 (10.35)	2.57 (6.73)	2.11 (10.69)
		CSID- Hard Glottal Attack	19.6	1.59 (13.9)	8.65 (7.56)	8.16 (5.39)	6.14 (11.9)
		CSID – Voiceless Plosive	29.2	12.1 (14.8)	15.4 (7.97)	11.98 (8.9)	16.24 (8.95)
	Patient selfassessment	Voice Handicap Index- Total	30	6.27 (6.27)	10.94 (13)	18.25 (22.1)	13.2 (12.45)
		Reflux Symptom Index	13	4.45 (5.33)	6.31 (6.49)	8.42 (7.1)	10.5 (8.68)
	Aerodynamic analysis	Subglottic pressure	6	9.65 (3.04)	6.92 (2.06)	8.29 (2.7)	7.6 (3.59)
		Laryngeal Airway Resistance	45	54.36 (28.27)	101.4 (64.59)	57.06 (42.4)	77.5 (36.8)
		Mean airflow rate	140	0.2 (0.086)	0.093 (0.049)	0.18 (0.1)	0.12 (0.063)
	CAPE-V measures	Overall severity	10	2.45 (3.8)	13.4 (14.5)	24(20.3)	24.7(16.2)
		Roughness	10	3.82 (4.5)	13.2 (15.2)	20.8 (6.02)	14.5(3.8)
		Breathiness	10	1.64 (2.9)	9.5 (10.75)	26.6(18)	22.7(10.5)
		Strain	10	3.73 (5.3)	16.06 (18.2)	28.8 (20.6)	28.2 (14.3)
		Pitch	10	2.9 (8.9)	3.2 (5.04)	3.55 (1.02)	17.72(4.73)
		Loudness	10	0.45 (0.68)	7.69 (11.08)	13.28 (3.83)	13 (3.47)

(Calculated mean indicated optimal value based on clinical threshold or clinical range)

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Table 1:

Group distributions by age and sex

Group	n	Males	Females	Mean age (years)	p-value
Non-Presbylaryngeus	27	11	16	71.76	0.14
Presbylaryngeus	26	12	14	69.33	
Total	53	23	30		

Table 2:

Means, Standard deviation and comparisons for anthropometric measures

Difference from the mean Measure	Group	n	Mean	Std. Deviation	p-value
Body Mass Index	Non-Presbylaryngeus	27	1.02	3.71	0.199
	Presbylaryngeus	26	2.38^{+}	3.83	
Waist to Hip Ratio	Non-Presbylaryngeus	27	0.003	0.05	0.815
	Presbylaryngeus	26	0.007^{+}	0.07	
Hand grip strength	Non-Presbylaryngeus	27	-8.98^{+}	19.51	0.172
	Presbylaryngeus	26	−1.61	19.21	
Maximum Expiratory Pressure	Non-Presbylaryngeus	27	−6.71	36.62	0.846
	Presbylaryngeus	26	-8.53^{+}	30.72	
Fat percentage	Non-Presbylaryngeus	27	−0.3	6.73	0.075
	Presbylaryngeus	26	3.13^{+}	7.02	

('+' indicates sub-optimal score on difference from the means, significance level set at $p \leq 0.05$)

Table 3:

Means, Standard deviation and comparisons for inflammatory markers

Difference from the mean measure	Group	n	Mean	Std. Deviation	p-value
CRP	Non-Presbylaryngeus	27	0.77	1.73	0.188
	Presbylaryngeus	26	2.15+	3.21	
IL6	Non-Presbylaryngeus	25	−11.73	4.01	0.402
	Presbylaryngeus	26	−11.11+	3.75	
TNFA	Non-Presbylaryngeus	27	−6.14+	1.26	<0.001*
	Presbylaryngeus	26	−7.99	0.79	

('+' indicates sub-optimal score on difference from the means, significance level set at $p \leq 0.05$)

Table 4:

Means, Standard deviation and comparisons for general health measures

Difference from the mean measure	Group	n	Mean	Std. Deviation	p-value
PASE	Non-Presbylaryngeus	27	130.17	105.09	
	Presbylaryngeus	26	49.78+	68.98	0.002*
PSS-10	Non-Presbylaryngeus	27	−9.04	6.62	
	Presbylaryngeus	26	−6.58+	7.09	0.198
Tinetti total score	Non-Presbylaryngeus	27	2.74	2.55	
	Presbylaryngeus	25	1.92+	3.04	0.251

('+' indicates sub-optimal score on difference from the means, *significance level set at $p \leq 0.05$)

Table 5:

Means, Standard deviation and comparisons for vocal function measures

Difference from the mean Measure	Group	n	Mean	Std. Deviation	p-value
Subglottic pressure (Psub)	Non-Presbylaryngeus	27	1.44	3.35	0.516
	Presbylaryngeus	26	1.95+	3.13	
Airflow rate	Non-Presbylaryngeus	27	−0.008	0.08	0.431
	Presbylaryngeus	25	0.01+	0.08	
Laryngeal airway resistance	Non-Presbylaryngeus	27	37.2+	57.22	0.423
	Presbylaryngeus	26	23.07	40.08	
Jitter	Non-Presbylaryngeus	27	−0.23	0.4	0.274
	Presbylaryngeus	26	−0.042+	0.62	
Shimmer	Non-Presbylaryngeus	27	0.074	1.21	0.029*
	Presbylaryngeus	26	0.84+	1.69	
Noise to Harmonic Ratio	Non-Presbylaryngeus	27	−0.067	0.02	0.042*
	Presbylaryngeus	26	−0.05+	0.028	
CSID /a/	Non-Presbylaryngeus	27	−6.55	12.71	0.004*
	Presbylaryngeus	26	6.44+	17.98	
CSID (Easy onset)	Non-Presbylaryngeus	27	−18.21	11.03	0.22
	Presbylaryngeus	26	−14.26+	12.16	
CSID (All Voiced)	Non-Presbylaryngeus	27	−18.6	14.29	0.05*
	Presbylaryngeus	26	−12.07+	8.91	
CSID (Hard glottal attacks)	Non-Presbylaryngeus	27	−13.82	10.98	0.473
	Presbylaryngeus	26	−11.77+	9.58	
CSID Voiceless plosives	Non-Presbylaryngeus	26	−14.99+	10.96	0.979
	Presbylaryngeus	26	−14.92	9.01	
Voice Handicap Index total score	Non-Presbylaryngeus	27	−20.96+	10.88	0.139
	Presbylaryngeus	26	6.44	17.98	
Reflux Symptom Index	Non-Presbylaryngeus	27	−7.44	11.02	0.017*
	Presbylaryngeus	26	−2.96+	13.5	
CAPE-V Overall score	Non-Presbylaryngeus	27	−21.04	12.57	0.001*
	Presbylaryngeus	26	−5.62+	17.86	
CAPE-V Roughness	Non-Presbylaryngeus	27	−20.59	12.83	0.003*
	Presbylaryngeus	26	−7.96+	17.36	
CAPE-V Breathiness	Non-Presbylaryngeus	27	−23.70	9.24	<0.001*
	Presbylaryngeus	26	−5.42+	14.27	
CAPE-V Strain	Non-Presbylaryngeus	27	−18.96	15.51	<0.001*
	Presbylaryngeus	26	−1.46+	17.16	
CAPE-V Pitch	Non-Presbylaryngeus	27	−26.89	6.76	0.686
	Presbylaryngeus	26	−14.46+	17.39	

Difference from the mean Measure	Group	n	Mean	Std. Deviation	p-value
CAPE-V Loudness	Non-Presbylaryngeus	27	−25.26	9.176	0.007*
	Presbylaryngeus	26	−16.23+	13.018	

(‘+’ indicates sub-optimal score on difference from the means, *significance level set at $p \leq 0.05$)

Table 6:

Results from variable selection using a backwards elimination method

Difference from the mean variables	Point Estimate	95% Wald Confidence Limits	
CRP	0.578	0.339	0.986
PASE	1.016	1.005	1.027
Laryngeal Airway resistance	1.021	1.000	1.041
CAPE-V Roughness	0.924	0.869	0.983

(CRP: C-Reactive Protein, PASE: Physical Activity Scale for the Elderly)