Frailty Syndrome, Cognition, and Dysphonia in the Elderly

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Abstract

Purpose: The purpose of the current study is to determine the relation of frailty syndrome to acoustic measures of voice quality and voice-related handicap.

Methods: Seventy-three adults (52 community-dwelling participants and 21 assisted living residents) ages 60 and older completed frailty screening, acoustic assessment, cognitive screening, and the Voice-Handicap Index-10 (VHI-10). Factor analysis was used to consolidate acoustic measures. Statistical analysis included multiple regression, Analysis of variance, and Tukey post-hoc tests with alpha of 0.05.

Results: MoCA® and exhaustion explained 28% of the variance in VHI-10. MoCA® and sex explained 27% of the variance in Factor 1 (spectral ratio), age and MoCA® explained 13% of the variance in Factor 2 (CPP for speech), and slowness explained 10% of the variance in Factor 3 (CPP for sustained /a/). There were statistically significant differences in two measures across frailty groups: VHI-10 and MoCA®. Acoustic factor scores did not differ significantly among frailty groups ($p > .05$).

Conclusions: Voice-related handicap and cognitive status differed among robust and frail older adults, yet vocal function measures did not. The components of frailty most related to VHI-10 were exhaustion and weight loss rather than slowness, weakness, or inactivity. Based on these findings, routine screening of physical frailty and cognition are recommended as part of a complete voice evaluation for older adults.

Key words: Presbyphonia; Aging voice; Acoustic; Patient-reported outcome; Frailty; Cognition

1. Introduction

Presbyphonia, or age-related dysphonia (ARD), is characterized by breathiness, roughness, pitch instability or tremor, decreased loudness, phonation breaks, or pitch change [1-3]. Chronological age alone does not predict whether or when an adult will begin to experience ARD and several research groups have focused on co-morbidity analysis to identify factors that predispose older adults to develop these voice changes. Hearing loss was found to increase the likelihood of poor voice-related quality of life [4], and thyroid disease, low or normal weight, chronic obstructive pulmonary disease, asthma, and self-reported intermediate or low health status increases the likelihood of having age-related dysphonia [5]. Roy et al. [6], however, found that the diagnosis of non-specific hoarseness was independent from diagnosis of age related co-morbidities. Co-morbidities, then, might precipitate or underlie ARD for some older adults, but not all. The focus of the current study is to examine evidence for an alternative hypothesis: that the presence of frailty syndrome increases the likelihood of developing ARD. Recognizing the association between ARD and frailty, if one exists, would alter our understanding the nature of ARD and have implications for assessment and treatment of voice disorders in the elderly.

Frailty syndrome, as described by Fried et al. [7], is a geriatric syndrome characterized by a lack of resiliency across multiple physiological systems, distinct from normal aging, co-morbidity, and disability. Frail older adults experience significant changes in health and independence following relatively minor stressors, with difficulty returning to baseline [7-9]. Frailty is one of the strongest predictors of poor health outcomes for older adults [7, 10, 11]. In line with the Fried phenotype, frail elders present with compromise in at least three of the following five areas: weakness, weight loss, exhaustion, slowness, and inactivity [7]. Though the physical characteristics defined by Fried and colleagues are core features of frailty, cognitive, social, and psychological function are sometimes evaluated as well (e.g., the frailty index of Rockwood and Mitnitski [12].

Consistent with our hypothesis that the presence of frailty syndrome increases the likelihood of developing ARD, several features of physical frailty are consistent with descriptions of ARD. *Weakness* (i.e., sarcopenia) of the respiratory and laryngeal muscles is often described as the primary underlying deficit in ARD [13], *weight loss* occurs in almost 20% of people with age-related atrophy, though does not significantly increase the odds of developing atrophy [14], and *inactive* older adults complain of dysphonia twice as often as active older adults [15]. *Exhaustion* and *slowness* do not directly relate to descriptions of ARD, though exhaustion might be consistent with patient reports of having to use a lot of effort to talk [13].

There is little discussion of Frailty syndrome in the aging voice literature. Johns, Arviso, and Ramadan [1] described the importance of considering frailty status when planning treatment for older adults with dysphonia, since the presence of frailty increases the likelihood of poor surgical outcomes. Nichols, Varadarajan, Bock, and Blumin [16] examined the relation of patient-reported frailty to voice handicap in nursing home and assisted living residents. They found a low, yet significant, correlation ($r = 0.20$) between the Voice Handicap Index-10 (VHI-10) [17] score and a questionnaire for frailty, the Vulnerable Elders Survey (VES-13) [18]. Though the correlation was low, this study provides early evidence that frailty might be important in the development of age-related dysphonia. A large percent (76%) of participants were identified as frail, and that might lead to underestimating the relation of frailty to voice-related handicap.

The aims of the current study are to determine the relation of frailty to acoustic measures of voice quality and voice-related handicap. It is hypothesized that 1) the components of weakness, weight loss, and inactivity will explain significant variability in VHI-10 scores and acoustic measures of voice quality, and that 2) VHI-10 score and acoustic measures will differ among robust, pre-frail, and frail older adults.

2. Materials and Methods

All study procedures were approved by an Institutional Review Board at the University of Arizona. Participants were recruited through their participation of one of two separate studies conducted by the first author (RS). One of the studies involved community-dwelling older adults and the other involved residents in an assisted living facility.

2.1 Inclusion and exclusion criteria: Community-dwelling adults ages 70 and older were included if they contacted the first author's laboratory to participate and consented to study procedures. Adults in assisted living were included if they were 60 years of age or older and consented to participate in the study. Potential participants were accepted into the study based on interest in participating, without consideration of their current or previous voice, speech, or hearing symptoms. Participants were excluded from analysis if the patient-reported outcomes or acoustic data were missing.

2.2 Data collection: All participants completed frailty testing with the Fried Frailty Phenotype criteria [7], voice recording of a sustained "ah" and the sentences from the CAPE-V [19], the Montreal Cognitive Assessment (MoCA® or MoCA-Basic®; mocatest.org), and a patient-reported outcomes tool in a single visit. The community-dwelling participants completed the full Voice Handicap Index (VHI) [20] and assisted living residents completed the VHI-10. Voice recordings for the community-dwelling participants were made in a single-walled sound booth with either a C1000S (AKG, Vienna, Austria) or C520 (AKG) microphone at a constant mouth-to-microphone distance and digitized directly to the hard drive of a computer through Computerized Speech Lab (Model 4500, Pentax Medical, Montvale, NJ). Assisted living residents were recorded in a quiet room at their facility using the C520 microphone coupled to a

Zoom H5 Handy Recorder (Zoom, San Jose, CA) and digital recordings were later transferred to the computer. A sampling rate of 44,100 Hz was used for both recording methods.

2.3 Data analysis: Frailty data were entered into a Microsoft Access Database for scoring robust or frail for each component. Consistent with Fried et al. [7], participants were placed in the overall "frail" category if they were frail in three or more components, in the "pre-frail" category if they were frail in one or two components, and "robust" if they were not frail in any components. The 10 items of the VHI-10 were extracted from the full 30-item VHI for the community-dwelling group and totaled. Recordings of the "ah" vowel and the sentences "The blue spot was on the key again," "We were away a year ago," and "Peter will keep at the peak" were imported into Analysis of Dysphonia in Speech and Voice (ADSV; Pentax Medical) and segmented for individual analysis. The mean cepstral peak prominence (CPP) and spectral ratio (L/H ratio) were computed within the program using default settings and exported to an excel spreadsheet.

2.4 Statistical analysis: Factor analysis was completed to determine whether the CPP and L/H measures for the various speech samples provided unique information. Factor scores were then used as dependent variables for further analyses rather than the individual CPP and L/H values. Regression analysis was used to identify the age, sex, cognitive, and frailty factors that explain significant variance in VHI-10 score and the acoustic factors. Analysis of variance (ANOVA) was used to determine whether the acoustic factors, voice handicap, and cognitive status differed across frailty syndrome groups. Tukey post-hoc tests were used to identify the particular group differences that were present for each significant main effect. Because is not certain that participants with low MoCA® scores are adequate reporters of voice-related handicap, factor analysis, regressions, and ANOVA were repeated for all participants with MoCA® scores greater than or equal to 19, a cut-off score for dementia [21]. All analyses were completed using SPSS version 24 (IBM Corp) with alpha of 0.05.

3. Results

3.1 Participants: Seventy-three adults met inclusion criteria: 52 community-dwelling participants and 21 assisted living residents. Participant characteristics can be found in Table 1. Higher VHI-10 scores reflect higher voice-related handicap and a score greater than 11 is considered outside the normal range for adults without voice disorders [22]. Eighteen participants (24.7%) had VHI-10 scores above 11. Higher MoCA® scores reflect stronger cognitive function. Three groups of participants were established based on MoCA® scores: normal cognition (>24), mild cognitive impairment (19 to 24) and dementia (<19) (21]. MoCA® results were not available for four participants.

3.2 Acoustic measures: Factor analysis was completed using Principal Component Analysis and Varimax rotation with Kaiser Normalization. Three factors emerged from the factor analysis and the loadings are shown in Table 2. Factor 1 represents spectral ratio for all four speech samples, Factor 2 represents CPP for the three sentences, and Factor 3 represents CPP for sustained /a/. Note that CPP for the all-voiced sentence "We were away a year ago" loaded onto both Factors 2 and 3, though was more closely related to Factor 2. As described in section 2.4, data from participants with MoCA® scores less than 19 (i.e., in the range of dementia) were excluded and factor analysis repeated. Two factors emerged and the loadings are shown in Table 3. The factors are similar to factors 1 and 2 for all subjects. The measure CPP for sustained /a/ did not load highly onto either factor.

3.3 Regression analyses: Stepwise linear regressions were used to identify the extent to which age, sex, MoCA® score, the five individual components of frailty, and overall frailty explained variance in VHI-10 score and the acoustic factors. Together, MoCA® and the exhaustion scale of the Fried frailty criteria explained 28% of the variability in VHI-10 score (adjusted $R^2 = 0.284$, $F(2, 65) = 14.3$, $p < .001$). MoCA® and sex explained 27% of the variance in Factor 1 (spectral ratio) score (adjusted $R^2 = 0.266$, $F(2,63) = 12.8$, $p < .001$), age and

MoCA® score explained 13% of the variance in Factor 2 (CPP for speech) score (adjusted R^2 = .132, $F(2,63) = 6.0$, $p = 0.004$), and the slowness scale of the Fried frailty criteria explained 10% of the variance in Factor 3 (CPP for sustained /a/) score (adjusted $R^2 = 0.10$, $F(1, 64) = 8.2$, $p = .006$).

Regressions were repeated for participants with MoCA® scores 19 and above. For these participants, the weight scale of the Fried frailty criteria and overall Frailty score together explained 22% of the variability in VHI-10 score (adjusted $R^2 = 0.223$, $F(2, 55) = 9.2$, $p < .001$). Similar to findings when all participants were included, MoCA® and sex explained 33% of the variance in Factor 1 (spectral ratio) score (adjusted $R^2 = 0.332$, $F(2, 53) = 14.7$, $p < .001$). Age explained 6% of the variance in Factor 2 (CPP for speech) score (adjusted $R^2 = 0.059$, $F(1,54) = 4.5$, $p = 0.039$).

3.4 Differences among frailty groups: One-way ANOVA showed statistically significant differences in two measures across frailty groups: (1) VHI-10 ($F(2,70) = 5.621$, $p = .005$) and (2) MoCA® ($F(2,66) = 9.913$, $p < .001$). Acoustic factor scores did not differ significantly among frailty groups ($p > .05$). Tukey HSD post-hoc tests demonstrated significant ($p < 0.05$) differences between mean VHI-10 scores in robust (5.30 ± 6.087) and frail (15.43 ± 8.979) participants and mean MoCA® scores between robust (26.05 ± 3.559) and pre-frail (20.63 ± 6.547) participants. No other comparisons were statistically significant. VHI-10 and MoCA® scores for each frailty group are shown in Figure 1.

ANOVAs were repeated after eliminating data from the 10 participants whose MoCA® scores were < 19 and the four participants without MoCA® results. Significant differences among frailty groups were present for the same two measures: VHI-10 ($F(2,56) = 7.966$, $p < .001$) and MoCA® ($F(2,56) = 11.346$, $p = .001$. Once again, acoustic factor scores did differ significantly among frailty groups ($p > .05$). Tukey HSD post-hoc tests demonstrated significant ($p < 0.05$) differences between mean VHI-10 scores in robust (4.68 ± 4.125) and frail (15.00 ± 10.488)

participants and pre-frail (6.15 ± 5.770) and frail (15.00 ± 10.488) participants. Significant differences in mean MoCA® scores occurred between robust (26.82 ± 2.504) and pre-frail (23.60 ± 3.789) and robust (26.82 ± 2.504) and frail (21.40 ± 3.362) participants. No other comparisons were statistically significant. VHI-10 and MoCA® scores for each frailty group are shown in Figure 2.

4. Discussion

The findings from this study provide evidence of a significant relationship among frailty, cognition, voice-related handicap, and acoustic measures of voice quality (section 4.1). Results indicate that the interaction of physical frailty and cognitive impairment might be more important to voice production than physical frailty alone (section 4.2).

4.1 Acoustic measures, voice handicap, and frailty. Three concepts emerge from the data: 1) frailty might be more strongly related to voice handicap than acoustic measures of quality, 2) participant age and sex influences acoustic measures, and 3) age-related voice changes have a multi-factorial etiology.

Self-reported voice-related handicap differed by frailty status, yet acoustic measures of voice quality generally did not. This is notable given that the previous study of age-related voice change and frailty used VHI-10 scores as the sole measure of voice disorder [16]. Acoustic measures and VHI-10 are known to provide unique information, since patient handicap results from many factors in addition to the severity of dysphonia [23-25]. Aspects of an individual's personality, experiences, expectations, and environment all contribute to the effects that dysphonia will have on their daily life. Frailty, particularly the exhaustion scale, can reasonably impact VHI-10 scores, contributing to difficulty projecting the voice, increased effort, restricted activities, and feeling handicapped. In future studies, the examining clinicians should review the VHI-10 with participants to be certain they are rating the effects of voice changes rather than general health.

Age was a significant predictor variable for Factor 2 (CPP for connected speech). Cepstral peak prominence reflects the regularity of harmonic content. It decreases with poor glottal closure[26] and with severity of dysphonia in aging voice[27], so this measure is likely to respond to the changes that occur with both typical aging and age-related dysphonia. The development of normative database for several age groups of older adults is indicated, given that all participants in this study were 60 years or older. Participant sex explained significant variance in Factor 1 score (spectral ratio). The measure of spectral ratio used in this study is a ratio of the spectral energy below 4 KHz to the spectral energy above 4 KHz. Lower values reflect increased energy in higher harmonics, a feature associated with breathiness. Women presented with slightly lower values than men in this study, a finding consistent with normative expectations[25].

It is common to associate aging voice and age-related dysphonia with sarcopenia or weakness of the laryngeal and respiratory muscles. Strengthening these muscles is often a goal of voice therapy programs [13, 28, 29]. Neither the weakness nor activity subtest scores in the current study significantly explained variance in VHI-10 or an acoustic factor. This might be because the strength measure for the frailty testing consisted of grip strength, and grip strength might not correspond to laryngeal or respiratory muscle strength. Even if this is true, a broader view of age-related dysphonia is indicated, with strong consideration of factors in addition to sarcopenia that contribute to dysphonia and voice-related handicap. In the current study, scores for weight loss and exhaustion significantly explained variance in VHI-10, and the slowness score explained significant variance in Factor 3 (CPP for sustained /a/). This broader view is consistent with descriptions in reviews of aging voice that changes to cartilage, mucosal viscoelasticity, joint mobility, and overall motor control are as important as atrophy in age-related voice changes [1, 3, 30].

4.2 Physical frailty and cognitive impairment: Cognitive impairment (i.e., MoCA® score) differed amongst frailty groups. Cognitive status is not considered in the Fried Frailty Phenotype [7], but frailty score is known to predict cognitive impairment, with lower cognitive scores for frail elderly adults than their non-frail peers [31]. Recent interest in the relation of cognitive impairment to physical frailty led an international consensus group to propose a condition called "cognitive frailty," which is characterized by physical frailty and cognitive impairment not explained by Alzheimer's disease or other diagnosed dementia [32]. The causal nature is not well understood; there are data showing that physical frailty predicts future cognitive impairment and that cognitive impairment predicts future physical frailty [33, 34].

Notably, MoCA® explained variance in VHI-10 for the full sample in the current study, but not when only participants with MoCA® greater than or equal to 19 were included in the analysis. This finding leads to the question of whether a combination of physical and cognitive frailty influences self-perception of voice handicap more than physical frailty alone. The percent of robust (Figure 3A) and pre-frail/frail (Figure 3B) participants reporting elevated voice handicap were plotted for each cognitive group. It appears that a higher percent of participants with physical frailty and cognitive impairment (middle and right columns in Figure 3B) reported elevated voice handicap than those with typical cognition who were robust (left column in Figure 3A) or pre-frail/frail (left column in Figure 3B). The small and unequal number of participants per group preclude statistical analysis, yet the findings warrant further investigation in a larger study.

4.3 Clinical implications: Frailty and cognitive impairment occur frequently enough in older adults with dysphonia that routine frailty and cognitive screenings are indicated during voice evaluation. Knowledge of pre-frail or frail status might be important to surgical planning [1] and will likely influence voice therapy.

As reviewed by Joseph et al. [35], patients with frailty syndrome generally have more surgical complications, longer hospital stays, and less independence at discharge than their robust peers undergoing similar procedures. The American College of Surgeons National Surgery Quality Improvement Program (ACS/NSQIP)/American Geriatrics Society Best Practices Guidelines for the Optimal Preoperative Assessment of the Geriatric Surgical Patient recommends determining a patient's frailty score prior to surgery [36] . Therefore, it is critical to identify those frail and pre-frail patients and counsel them accordingly as to their treatment options. As a result, nonsurgical treatment may be more strongly considered in this population. If surgery is the chosen course of treatment, the otolaryngologist might counsel the patient about their frailty status and its association with potential negative postoperative sequelae.

Although it is not possible to completely reverse frailty once diagnosed, treatment should be considered. This can include structured exercise training [37, 38] , and sometimes nutritional recommendations such as following a Mediterranean Diet [39] or Vitamin D supplements [40].

In line with these recommendations, patients with physical frailty and dysphonia should be strongly encouraged to complete exercise or physical fitness regimens alongside voice therapy. Further investigation is necessary to determine whether the combination of treatments will improve voice quality more than either treatment alone.

It is reasonable to speculate that older adults with cognitive impairment will have more difficulty generalizing voice therapy strategies and adhering to recommendations. Knowledge of mild or more significant cognitive impairment will lead speech-language pathologists to embed memory strategies into therapy to improve adherence and carry-over.

Beyond these specific examples, recognition of the interaction of physical frailty, cognitive impairment, and voice disorders opens the door to studies with more power to describe subgroups of older adults likely to develop voice disorders and subsequent preventative community-based vocal health programs.

4.4 Limitations and future directions: A larger sample is needed to better represent the range of disordered voice and frailty, and to determine whether physical or cognitive frailty moderate treatment response in older adults with voice disorders. Medical history regarding previous or current laryngeal or neurological disorders affecting communication was not available for the 21 participants residing in the assisted living community. Because the frequency and nature of laryngeal and neurological disorders in the sample is not fully known, it is not possible to determine whether frailty syndrome and cognitive impairment were more common in older adults with particular diagnoses (e.g., age-related dysphonia, vocal fold paralysis, etc.). This limitation makes it difficult to generalize the results to specific older adults. Videostroboscopic evaluation and medical history should be included for all participants to better define the study sample and determine the specific laryngeal and neurological disorders where frailty syndrome is likely to occur. More information about vocal fold vibration and a larger sample size will allow separate assessment of men and women as well as subgroup analysis to identify whether physical or cognitive frailty are important aspects of dysphonia for specific groups of patients.

6. Conclusions

Several key findings emerged from this study. 1) Voice-related handicap and cognitive status differed among robust and frail older adults, yet vocal function measures did not. 2) The components of frailty most related to VHI-10 were exhaustion and weight loss rather than slowness, weakness, or inactivity. 3) It is possible the combination of physical frailty and cognitive impairment was more related to voice handicap than either alone. Based on these findings, routine screening of physical frailty and cognition are recommended as part of a complete voice evaluation for older adults.

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Table 1: Participant information. VHI-10 = Score on the Voice Handicap Index-10. CPP = cepstral peak prominence, in dB. Note that some data points were missing for some participants. Percentages are based on the number of participants with valid responses for each item.

	Men	Women	All participants
Total # participants	28	45	73
Mean age (SD) in years	76.2 (6.5)	77.3 (8.6)	76.9 (7.8)
Age range, in years	66-89	62-93	62-93
Frail: Weight loss (#)	0% (0)	8.9% (4)	5.5% (4)
Frail: Weakness (#)	25% (7)	28.9% (13)	27.4% (20)
Frail: Slowness (#)	17.9% (5)	28.9% (13)	24.7% (18)
Frail: Exhaustion (#)	21.4% (6)	26.7 (12)	24.7% (18)
Frail: Activity (#)	0% (0)	11.1% (5)	6.8% (5)
Overall Robust (#)	60.7% (17)	46.7% (21)	52.1% (38)
Overall Pre-Frail (#)	35.7% (10)	40% (18)	38.4% (28)
Overall Frail (#)	3.6% (1)	13.3% (6)	8.6% (7)
VHI-10 >11 (#)	21.4% (6)	26.7% (12)	24.7% (18)
Mean VHI-10 score (SD)	7.2 (8.2)	8.6 (8.9)	8.1 (8.6)
Range VHI-10	0-36	0-32	0-36
Mean CPP from “We were away a year ago” (SD)	7.9 (1.7)	7.9 (1.5)	7.9 dB (1.6)
Range CPP from “We were away a year ago”	4.2-10.5	4.4-11	4.2-11
Mean MoCA® (SD)	23.9 (4.9)	23.4 (6.0)	23.6 (5.6)
Range MoCA®	12-30	3-30	3-30
18 < MoCA® < 25 (#)	33.3% (9)	26.2% (11)	29.0% (20)
MoCA® < 19 (#)	11.1% (3)	16.7% (7)	14.5% (10)

Table 2: Factor analysis results for all participants

Measure	Component		
	1	2	3
LH ratio for /a:/	**0.762**	-0.014	0.172
LH ratio for “The blue spot is on the key again”	**0.888**	0.047	-0.190
LH ratio for “We were away a year ago”	**0.898**	0.162	0.042
LH ratio for “Peter will keep at the peak”	**0.870**	-0.046	-0.059
CPP for “The blue spot is on the key again”	-0.006	**0.890**	0.016
CPP for “We were away a year ago”	0.104	**0.688**	0.463
CPP for “Peter will keep at the peak”	0.055	**0.870**	-0.014
CPP for /a:/	-0.038	0.054	**0.942**

Table 3: Factor analysis results: Participants with MoCA® ≥ 19

Measure	**Component**	
	1	**2**
LH ratio for /a:/	**0.725**	0.011
LH ratio for “The blue spot is on the key again”	**0.920**	-0.029
LH ratio for “We were away a year ago”	**0.889**	0.121
LH ratio for “Peter will keep at the peak”	**0.862**	-0.025
CPP for “The blue spot is on the key again”	0.045	**0.814**
CPP for “We were away a year ago”	0.033	**0.793**
CPP for “Peter will keep at the peak”	0.212	**0.779**
CPP for /a:/	-0.205	0.384

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Figure Legends

Figure 1: Two measures that differed across frailty group ($p \leq .05$) when all participants were included: a) Voice Handicap Index – 10 (VHI-10), b) Montreal Cognitive Assessment (MoCA®). * indicates difference between groups significant ($p \leq .01$).

Figure 2: Two measures that differed across frailty group ($p \leq .05$) when participants with MoCA® < 19 were excluded: a) Voice Handicap Index – 10 (VHI-10), b) Montreal Cognitive Assessment (MoCA®). * indicates difference between groups significant ($p \leq .01$).

Figure 3: The percent of participants that are robust (panel A) or pre-frail/frail (panel B) who report voice handicap, shown by cognitive group.

Vitae

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