# Vocal Dose in Older Adults with Presbyphonia: An Analytic, Cross-Sectional Study

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**Abstract: Purpose.** Older patients with age-related voice changes (presbyphonia) are considered vocal underdoers due to a reportedly low a amount and intensity of voice use (ie, low vocal dose). This low voice use may be consequential to negative effects of presbyphonia like throat discomfort, as well as anxiety and frustration from difficulty communicating. Causally speaking, vocal fold atrophy (presbylaryngis) may indicate inadequate intrinsic laryngeal muscle loading with low voice use, though research is lacking. As a first step, this study examined voice use objectively using vocal dosimetry in older adults with presbyphonia. We hypothesized participants, especially if retired, would exhibit low vocal doses, and lower than reported for other populations.

**Method.** This research used an analytic, cross-sectional design with subgroup analyses to determine feasibility of vocal dosimetry in older adults with presbyphonia. Thirteen older adults with presbyphonia (7 males) completed vocal dose monitoring using an ambulatory phonation monitor (APM). The APM measured vocal parameters over a day of monitoring, from which time, cycle, and distance doses were calculated. Data also were gathered on demographics, vocal handicap, and vocal effort.

**Results.** Descriptively, the group showed a low mean time dose as compared to published vocal dose data from other populations. Females exhibited significantly higher mean values of time dose, cycle dose, and fundamental frequency than males. Time dose for males was negatively correlated with vocal effort. Subgroup analyses failed to detect an effect of age group, but found significantly a higher mean value for time dose in employed, compared to retired, participants.

**Conclusions.** Consistent with self-report, we found older adults with presbyphonia exhibit low time doses, which were in contrast to high vocal doses published on teachers, patients with dysphonia, and even office workers. We found differences in vocal dose as a function of sex and employment status. Though a limited sample, findings suggest patients with presbyphonia may demonstrate low vocal dose, which may be a useful target in treatment.

**Key Words:** Vocal dose−Presbyphonia−Vocal fold atrophy−Vocal handicap−Vocal effort.

## INTRODUCTION

### Background

Treatment-seeking older patients with age-related voice changes (presbyphonia)[1] report a reduced amount and intensity of voice use, resulting in their classification as vocal under-doers.[3] The amount and intensity of voice use, otherwise known as vocal dose,[4-6] has been explored primarily as a risk factor for voice problems in vocally demanding occupations and patients considered vocal over-doers.[3,7,8] Contrary to conventional wisdom, a study of vocal dose data by Titze (2016) found daily speech in six male teachers, an occupation of high vocal demands, did not encompass much of the full human fundamental frequency and vocal intensity ranges.[9] He hypothesized their daily speech kept vocal folds in a shortened state, placed less stress on vocal fold muscle, and maintained muscle activation over a limited frequency range that did not favor optimal position of the vocal fold's thyroarytenoid muscle. This laryngeal contracture, he postulated, could negatively impact vocal longevity.

Research scarcely addresses the relationship between low vocal dose and the pathophysiologic process of vocal fold atrophy in older adults, a process that affects 25% of treatment-seeking voice patients greater than 64 years.[10] A "use it or lose it" hypothesis of presbyphonia is observed in a case study of monozygotic twins.[11] Twin 1, with more severe vocal fold atrophy than twin 2, lived alone, was quiet, and interacted little as a widower; whereas twin 2, with milder vocal fold atrophy than twin 1, lived with his spouse and was talkative. As far as microscopic vocal fold changes, a larynx not phonated for 10 years due to a stroke exhibited, histologically, muscle atrophy and a monolayer lamina propria expected of newborns. This larynx was lacking a vocal ligament, and did not evidence the typical trilayer structure of the lamina propria observed after puberty.[12] Evidence from studies involving aged animals indicates a relationship between aging, vocal activity, and deterioration in laryngeal structure and function, and a positive impact of increased laryngeal muscle use and electrical stimulation on older rats' vocal folds.[13-15]

A corollary to this vocal dose-presbyphonia association is the relationship between older adults' dose of physical

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Data for this study were obtained from participants at the Emory Voice Center between 2009 and 2010, where both Dr. Ziegler and Dr. Hapner were employed at the time of data collection. These data were presented as an oral presentation at the Fall Voice Conference, San Francisco, CA, 2-5 November 2011.

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activity and changes in muscle bulk and tone, and strength or function (sarcopenia), which is fairly well established. Research in that area shows inadequate dosing of muscular strength and muscular endurance training (ie, physical activity), in addition to aging as a contributing factor, results in sarcopenia and difficulty executing activities of daily living.[16,17] Changes in voice with advancing age appear similar to structural and functional changes observed in limb skeletal muscle. Analogously, decreased vocal dose may inadequately load the laryngeal system to maintain its structure and function, which ultimately may result in a loss of vocal independence.[18]

To date, no studies have assessed voice use patterns of patients with presbyphonia within their natural environment using vocal dosimetry. Vocal dose is a more objective method for estimating voice use than self-report, which is often over-estimated.[19] A vocal dosimeter is a non-invasive device that tracks vocal fold vibrations via a sensor placed on the neck to derive time, cycle, and distance doses. Although no research exists that examines vocal dose in the development of hypofunctional voice disorders, a dose–response relationship has been investigated using vocal dosimetry for voice problems that arise from hyperfunctional vocal behaviors in vocally demanding occupations.[8]

Patients with phonotraumatic lesions report substantial voice use, resulting in their classification as "vocal over-doers."[3] A recently published narrative review found mixed evidence on vocal dose and phonotrauma.[20] Two cross-sectional studies did not find differences in estimates of vocal dose measured between patients with dysphonia and those without voice complaints. On the other hand, a well-designed, prospective cohort study did report significant differences in estimates of vocal dose. Those with dysphonia demonstrated higher vocal doses than vocally healthy adults. In contrast to vocal over-doers, older adults in general indicate less time spent in activities involving communication and socializing and more time in sedentary and solitary activities than younger, sex-matched cohorts when questioned about daily activities.[21] It stands to reason that with reportedly low voice use, older adults would be more susceptible to a sarcopenic process of the vocal mechanism due to inadequate loading of phonatory musculature.

Older adults with presbyphonia report anxiety, frustration, and social isolation, so decreased voice use may be consequential to negative effects of presbyphonia.[2,22,23] Given in the elderly the strongest predictor of one's lifespan is the quality of social integration,[24,25] vocal dose is a potentially important factor in considering the negative impact of presbyphonia on quality of life. Or, as Roy and colleagues (2007) proposed, older adults may be at greater risk for voice problems with decreases in voice use.[2] Though the evidence is thin, research hints at a relationship between reduced voice use and the health and function of the vocal mechanism. The problem with current estimates of voice use is that they are likely overestimated, suggesting possibly even lower levels of voice use would be expected if measured objectively.

### *Objectives and hypotheses*

This study examined the voice use profiles of older adults diagnosed with presbyphonia. We hypothesized that older adults with presbyphonia would demonstrate lower vocal doses than reported in published studies on younger adults with and without voice complaints, and a negative relationship would exist between voice-related quality of life and vocal dose. Specific research questions addressed in this study were:

1. Is phonation ambulatory monitoring feasible in older patients with presbyphonia?
2. Do older patients with presbyphonia exhibit reduced voice use relative to published research as measured by vocal dosimetry (ie, time dose, cycle dose, and distance dose)?
3. Do demographic or voice factors demonstrate relationships with observed vocal doses?

## METHODS

### Study design

This study used a prospective, analytic cross-sectional design with blinding of participants to hypotheses and de-identification of participant data during analyses. This study did not involve a comparison group; subgroup analyses were performed. This study followed recommendations for reporting observational research described in the STROBE statement.[26]

### Setting

All procedures were approved by the Institutional Review Board at Emory University (IRB #00037045). The study took place in a quiet room at the voice center, and ambulatory phonation monitoring was accomplished within the patient's unique environment during the course of a self-selected typical weekday.

### Participants

Thirteen community-dwelling, ambulatory, and overall generally healthy older adults newly diagnosed with presbylaryngis and presbyphonia participated in the study. Given that presbylaryngis is a diagnosis of exclusion, participants showed no other laryngeal pathology that explained their dysphonia other than age-related changes of the larynx. They reported to be nonsmokers for 5 years, were taking current medications for at least 1 month, and did not report progressive neuromuscular diseases or other health problems known to affect voice. They denied a history of prior voice therapy or vocal fold surgery. They all had perceptually normal speech and language as assessed informally in conversation by a certified speech-language pathologist (SLP).

Only 12 participants had signals that were analyzable for all variables; one female participant's signal was corrupt and was excluded from analyses. The remaining participants with analyzable signals ranged in age from 66 to 91 years, and seven (54%) were male. Ten participants were Caucasian,

one was African-American, and one was Asian-American. Participants passed screenings for hearing using pure tone audiometry provided in field,[27] cognition (Mini-mental state exam, cutoff score $\geq$ 20),[28] and mood (Geriatric Depression Scale-Short Form, cutoff score $\leq$ 5).[29] These participants were involved in a larger study published on Phonation Resistance Training Exercises (PhoRTE) where further participant characteristics are provided.[30]

## Procedures

### *Recruitment and screening*

Recruitment was performed by a voice-specialized SLP who was part of a multidisciplinary voice care team. Participants were seen for evaluation by a fellowship-trained laryngologist and SLP to obtain diagnoses of vocal fold atrophy (presbylaryngis) and age-related voice changes (presbyphonia), respectively. They were approached about participation in vocal dose monitoring using a consecutive sampling procedure. Once a participant was identified, the SLP obtained written informed consent.

### *Vocal dosimetry*

Participants underwent placement of the KayPENTAX Ambulatory Phonation Monitor (APM) Model 3200, which is no longer manufactured due to lack of market demand. Newer vocal dosimeters are smaller than the APM and make use of mobile phone technology. The APM is a portable device that measured the duration of time the participant was monitored, tracked phonation during that time, and estimated the average sound pressure level (SPL) and fundamental frequency ($f_0$) for all phonation. From those parameters, time, cycle, and distance doses were calculated to provide estimates of vocal dose.[5,37] The manufacturer sets the APM to extract data for all parameters at a sampling rate of 20 times per second during the monitoring period, and 5 minutes was the time interval over which data were averaged for visual presentation.

The SLP placed a throat sensor consisting of an accelerometer (Model BU-27135, Knowles Electronics, Inc., Itasca, IL) just above the participant's sternal notch by using a medical adhesive of non-irritating silicone. The accelerometer detects the vibration of the skin in response to phonation, which are used to estimate vocal parameters and vocal dose estimates. The influence of ambient noise on measurements is minimal. The SLP carried out calibration procedures as recommended by the manufacturer using the APM software. In brief, calibration required participants to vocalize into a calibrated microphone on /a/ across total $f_0$ and SPL ranges. The microphone contained a spacer bar of 15 cm to standardize the distance of the microphone from the mouth. Starting softly and low in pitch, participants produced /a/ on one breath for a period of approximately 8-10 seconds, during which time they increased their loudness and pitch until they achieved their loudest voice and highest pitch. These calibration procedures were carried out until the software and SLP approved the production as valid.

Participants wore the APM on a self-selected weekday that they determined was a typical day. They were told to select a day that was neither overly isolated nor unusually busy. Monitoring occurred before treatment-naïve participants engaged in voice therapy as part of their involvement in a clinical trial.[30] They were told to carry out their day using a typical voice without adjusting speaking pitch and loudness, altering speaking time, or changing their daily routine. Participants started monitoring in the morning (typically between 9 and 11 am), and were encouraged to stay connected to the APM for as long as possible, for a minimum of 8 hours. Participants were advised to carry on with their normal routine over the course of monitoring; they were told to avoid water while wearing the APM. Participants were advised to stop monitoring before they showered, or before sleeping, at the end of the day. To end monitoring, they detached the sensor cable from the APM unit and peeled the sensor from the throat. They returned the APM after monitoring for dose processing and data analysis.

## Variables, data sources, and measurements

Participant characteristics were collected using a medical health questionnaire (ie, sex, age, employment status, marital status, smoking history, etc). Participants kept a written log to track the activities that occurred over the monitoring period. Duration of monitoring time was the amount of time participants wore the vocal dosimeter (hh:mm:ss). Duration of phonation time during the monitoring time was the amount of time that the vocal folds were vibrating (hh:mm:ss). Percentage of phonation time (%) was derived by dividing phonation time by the monitoring time and computing a percent of time the vocal folds vibrated. Average SPL and $f_0$ were calculated for the full sample of vocal fold vibrations. Cycle dose (total cycles) and distance dose (meters) were derived from vocal parameters of phonation time, SPL, and $f_0$. Vocal handicap was assessed using the *Voice-Related Quality of Life* (V-RQOL), a self-administered, patient-reported measure.[31] Vocal effort (VE) was assessed using direct magnitude estimation.[32-34] Participants rated their VE on a scale in which 100 is comfortable effort. On this scale, 200 would indicate twice as much effort as comfortable, 50 would indicate half as much effort as comfortable, and no floor or ceiling limitations were placed on VE ratings.

## Statistical analyses

Summary values were generated for SPL, $f_0$, monitoring time, phonation time, percent phonation, cycle dose, intensity dose, V-RQOL, and VE. Descriptive statistics (mean, SD, min, max, range, and frequencies) were calculated depending on variable type. Welch's independent-sample *t* tests, which do not assume equal population variances, were performed to explore factors that might account for differences in vocal dose (ie, age, sex, and employment status). In addition, Pearson's correlation was performed to

examine associations among vocal dose measures, V-RQOL, and VE. All tests were conducted two-tailed because of the hypothesis-generating focus of this study. An alpha level of 0.10 was used to minimize the type II error rate in analyzing effects. A more liberal significance level was used with the small number of participants to avoid failing to reject a false null hypothesis and falsely inferring the absence of an effect that in fact exists. Findings were interpreted with caution.

## RESULTS

### Analysis of participant characteristics

Thirteen older adults diagnosed with presbylaryngis and presbyphonia agreed to complete vocal dose monitoring for about 8 hours over the course of a typical weekday. One female participant had equipment issues and data were not fully retrievable. Thus, a total of 12 participants contributed data to analyses. Participants included 7 males (58.3%), and the average age of the overall group was 76.2 ±6.1 years. One participant experienced a cardiac event several weeks after monitoring, which likely did not impact his vocal dose estimates. Five reported a prior smoking history, although all participants were nonsmokers for at least 5 years. On average, participants consumed 25.0 ±17.3 ounces of non-caffeinated fluids per day, 1.7 ±1.5 caffeinated beverages per day, and 2.6 ±3.7 alcoholic drinks per week. Six participants were currently employed at least part-time (nature of employment and occupational history unknown); the other six were retired (time since retiring unknown). Participants reported an average of 125 ±228 minutes of mobile phone use per week. Mean overall V-RQOL score was 85.8 ±10.7 and mean VE was 131.2 ±44.9. Selected participant characteristics are displayed in Table 1.

### Voice use profile (APM) data

Means (M) and standard deviations (SD) for the APM vocal dose measures of time dose, cycle dose, and distance dose as well as estimated SPL and $f_0$ are presented in Table 2. Welch's independent samples $t$ tests were conducted on vocal dose measures as well as SPL and $f_0$ between males and females. Significant sex differences were found for time dose ($t[5.341] = 2.487$, $P = .052$), cycle dose ($t[4.719] = 3.154$, $P = .027$) and $f_0$ ($t[5.657] = 9.675$, $P < .001$). Females, as compared to males, demonstrated higher mean time dose, cycle dose, and $f_0$. No sex differences were found for distance dose or SPL.

### Analyses of voice use profiles by age group as well as employment status

Analyses were completed of subgroups based on age grouping (young old versus old−old and oldest−old) and employment status, with M and SD provided in Table 3. Individual time dose estimates by participant, coded for sex and employment, are displayed in Figure 1. Welch's independent samples $t$ tests failed to detect age group differences between those 65-74 years (young old [n = 5]) and those 75+ years (old−old [n = 6] and oldest−old [n = 1, 91 years]) on vocal dose measures, SPL, and $f_0$. Welch's independent samples $t$ tests were conducted as a function of employment, which revealed significant differences between employed and retired participants for time dose ($t[8.257] = 1.846$, $P = .101$). Employed participants exhibited a higher mean time dose than retired participants. No other differences between employed and retired participants were found.

### Correlations between vocal dose measures and patient reported outcome measures

Neither V-RQOL nor VE were significantly correlated with any of the vocal dose measures (ie, time, cycle, and distance doses; $ps > 0.10$) when considering overall group data. When considering data from males only, time dose and cycle dose were significantly negatively correlated with VE, $r(7) = -0.78$, $P = .038$ and $r(7) = -0.75$, $P = .054$, respectively. As VE increased, both time dose and cycle dose decreased. These correlations were not present when considering data from only females ($ps > 0.10$). Scatterplots of time dose and cycle dose estimates as a function of VE for male participants are displayed in Figure 2.

## DISCUSSION

This study examined vocal dose in community-dwelling older adults diagnosed with presbyphonia over a typical day. Participants consisted of seven males and six females over the age of 65 who evidenced vocal fold atrophy, with six participants (3 males) employed at least part time. All the participants completed vocal dose monitoring for a roughly 8-hours period selected by the participant without any reported problems. One female participant's signal demonstrated a technical issue that excluded her data from analyses. Participants' comments about undergoing vocal dosimetry indicated two concerns: the APM device was cumbersome to wear, though newer vocal dosimeters take advantage of smaller, more portable mobile phone technology, and some participants reported mild skin irritation from the silicone adhesive. Thus, we have established the feasibility of vocal dosimetry over an 8-hour period in a group of community-dwelling, ambulatory, and generally healthy older adults with presbyphonia to estimate vocal dose.

Though a small sample size and limited monitoring duration, both crucial to consider in interpreting results, our vocal dose data presented here are the first to demonstrate low time dose in older adults with presbyphonia. Self-selection of monitoring day may have impacted results even though participants were blinded to the study hypothesis. Though encouraged to pick a typical day with a normal amount of vocal activity, participants may have selected a day that was convenient rather than representative, which could skew data toward lower vocal dose estimates. Other participants may increase their vocal activity to provide the researcher with more data in an effort to satisfy their conviction about the purpose of the study, which could skew data

**TABLE 1.**
**Selected Participant Characteristics for Overall Group by Sex**

| | Overall, N = 12 | Males, n = 7 (58.3%) | | Females, n = 5 (41.7%) | |
|---|---|---|---|---|---|
| **Age (y)** | 76.2 ± 6.1 | 74.3 | 4.6 | 79.0 | 7.4 |
| **Currently employed (yes)** | 6, 50% | 3 | 42.9% | 3 | 60% |
| **Former smoker (yes)** | 5, 41.7% | 3 | 42.9% | 2 | 40% |
| **Chemical/dust exposure (yes)** | 1, 8.3% | 0 | 0% | 1 | 20% |
| **Water (ounces)** | 25.0 ± 17.3 | 23.4 | 13.7 | 27.2 | 23.0 |
| **Caffeine (drinks/d)** | 1.7 ± 1.5 | 2.0 | 1.8 | 1.2 | 1.1 |
| **Alcohol (drinks/wk)** | 2.6 ± 3.7 | 3.5 | 4.4 | 1.3 | 2.1 |
| **Cellular phone use (min)** | 125 ± 228 | 99 | 180 | 162 | 301 |
| **V-RQOL-Total (unitless)** | 85.8 ± 10.7 | 91.1 | 8.0 | 78.5 | 10.1 |
| **V-RQOL-Physical Subscale (unitless)** | 82.3 ± 11.1 | 87.5 | 10.2 | 75.0 | 8.3 |
| **V-RQOL-Social-emotional Subscale (unitless)** | 91.1 ± 11.8 | 96.4 | 7.1 | 83.7 | 13.7 |
| **VE (DME, 100 = comfortable)** | 131.2 ± 44.9 | 117.9 | 39.1 | 150.0 | 50.0 |

*Notes.* V-RQOL, voice-related quality of life (lower values are worse); VE, vocal effort; DME, direct magnitude estimation.

toward higher vocal dose estimates. A longer duration of monitoring as well as random assignment of monitoring days would likely demonstrate a more representative sample of vocal behaviors. Still, this investigation yielded several findings that will be discussed in relation to three clinical questions: (1) could low vocal dose, in addition to aging, contribute to the development of presbyphonia, (2) does low vocal dose reflect the negative psychosocial consequences of presbyphonia, and (3) is vocal dose a potentially useful target in treatment?

## Key study results

**Vocal parameters of fundamental frequency and vocal intensity:** We found a significant difference in fundamental frequency ($f_0$) measured over the course of ambulatory phonation monitoring. As expected, females demonstrated a higher mean $f_0$ than males, and both were similar to previously published data on older adults' $f_0$ in speech.[42-44] We did not find a difference between sexes for vocal intensity (dB SPL). Both males and females exhibited typical vocal intensity levels as reported in other research on older adults, with females slightly higher numerically than males. Low vocal intensity indicates inefficiencies in converting aerodynamic energy into acoustic energy, in part, by the larynx,[45,46] as well as respiratory deficits that limit the generation of large expiratory forces.[47] Also, no differences in dB SPL were found between age groups (65-74 years vs. 75 + years) or between employed and retired participants.

**Estimates of vocal dose in older patients with presbyphonia:** As hypothesized, the group of participants examined in this study demonstrated substantially low vocal activity time numerically over the course of a self-selected typical weekday. Our group mean time dose estimate is considerably less than what has been reported for teachers,[6,8,35,36] singers,[38,39] patients with phonotraumatic lesions,[48] patients with muscle tension dysphonia,[49] and even compared to office workers, a group with low vocal demands.[7] Differences between the estimates found in this study and published data is likely due to a variety of factors including differences in participants' age, employment status, size of social circles, and other variables that would affect voice use and communication patterns.[21] In addition, study protocols differed, including the type of device used for ambulatory phonation monitoring that likely impacts vocal dose calculations and estimates.

**Relationships between vocal dose and demographic and voice factors**: When considering participant sex, older male

**TABLE 2.**
**APM Vocal Dose Data for Overall Group and by Sex**

| | Overall, N = 12<br>*M* ± *SD* | Male, *n* = 7<br>*M* ± *SD* | Female, *n* = 5<br>*M* ± *SD* | *P* Value |
|---|---|---|---|---|
| **Vocal intensity (dB SPL)** | 69.0 ± 8.2 | 68.8 ± 6.2 | 70.3 ± 11.6 | 0.796 |
| **Fundamental frequency (Hz)** | 176 ± 27 | **153.0 ± 5.4** | **201.0 ± 10.1** | **< 0.001*** |
| **Monitoring time (hh:mm:ss)** | 07:50:56 ±00:45:46 | 07:37:15 ±00:56:28 | 08:05:18 ±00:28:20 | - |
| **Phonation time (hh:mm:ss)** | 00:17:23 ±00:11:49 | 00:10:59 ±00:05:24 | 00:26:22 ±00:12:56 | - |
| **Time dose (%)** | 3.7 ± 2.2 | **2.4 ± 1.2** | **5.4 ± 2.5** | **0.052*** |
| **Cycle dose (# cycles)** | 193,304 ± 145,067 | **101,602 ± 51,055** | **314,485 ± 144,627** | **0.027*** |
| **Distance dose (m)** | 847 ± 669 | 547 ± 390 | 1,268 ± 789 | .114 |

*Notes.* dB SPL, sound pressure level in decibels; Hz, Hertz in cycles/s; m, meters; - , no analyses; M, sample mean; SD, sample standard deviation.
Significance at $P \leq .10$, two-tailed; * indicates statistically significant result.

**TABLE 3.**
**APM Vocal Dose Data by Age Group and Employment Status**

| | Age Group | | | Employment Status | | |
|---|---|---|---|---|---|---|
| | *65–74 Years Old, n = 5* 3M, 2F; *71.2 ±3.1 years* | *75+ Years Old, n = 7* 4M, 3F; *79.6 ±5.0 years* | *P* Value | *Employed, n = 6* 3M, 3F | *Not Employed, n = 6* 4M, 2F | *P* Value |
| **Vocal intensity (dB SPL)** | 66.8 ± 5.7 | 71.3 ± 9.9 | 0.345 | 65.8 ± 4.5 | 73.0 ± 10.2 | 0.161 |
| **Fundamental frequency (Hz)** | 174.7 ± 31.6 | 171.8 ± 23.3 | 0.867 | 175.7 ± 26.9 | 170.3 ± 26.8 | 0.736 |
| **Time dose (%)** | 3.1 ± 1.6 | 4.1 ± 2.8 | 0.460 | 4.7 ± 2.5 | 2.5 ± 1.5 | 0.101* |
| **Cycle dose (# cycles)** | 151,075 ± 106,823 | 218,324 ± 169,634 | 0.420 | 255,941 ± 167,848 | 124,666 ± 88,230 | 0.131 |
| **Distance dose (m)** | 648 ± 447 | 990 ± 794 | 0.367 | 905 ± 533 | 790 ± 832 | 0.783 |

*Notes.* dB SPL, sound pressure level in decibels; Hz, Hertz (cycles/s); m, meters; M, male; F, female.
?Significance at $P \leq .10$, two-tailed; * indicates statistically significant result.

participants demonstrated a mean time dose that was almost half of what was observed for older females, and this difference was significant. Male time dose data were strongly negatively correlated with vocal effort, indicating that males may be speaking less because of the vocal effort required to speak. A significant effect of employment status was found for time dose. As hypothesized, the group of participants in this study who were still working at least part time exhibited a significantly higher time dose than retired participants. Differences in time dose are observed in published literature for working vs nonworking monitoring periods[38-41], as well as among different professions.[20] Interestingly, when inspecting individual time dose estimates, the participants with the two lowest time dose estimates in this study were retired males while the participants with the two highest time dose estimates were employed females (Figure 1). We did not observe a difference in vocal dose measures between age groups. This finding was unexpected given that reported involvement in daily social activities changes with age, and has been reported to become more solitary.[21]

Though associations were not present among estimates of vocal dose and V-RQOL or vocal effort for the overall group, the data from males only demonstrated a negative relationship between time dose and vocal effort. Male participants with presbyphonia who felt more vocal effort in producing voice exhibited lower time dose values. This relationship is not surprising given complaints of strain and pain in patients with presbyphonia.[2,50] Strain and pain is likely due to compensatory muscle tension attempting to improve phonatory closure due to the presence of glottal insufficiency associated with vocal fold atrophy.[51] This squeezing pattern likely also serves to improve phonatory laryngeal resistance to increase subglottal pressure as compensation for inadequate expiratory force generation from the lungs. That this relationship was not observed in female patients with presbyphonia indicates presbyphonia may impact females and males differently. Males are reported to be disproportionately affected by the degree of vocal fold atrophy,[10] which would create a larger phonatory gap to overcome.

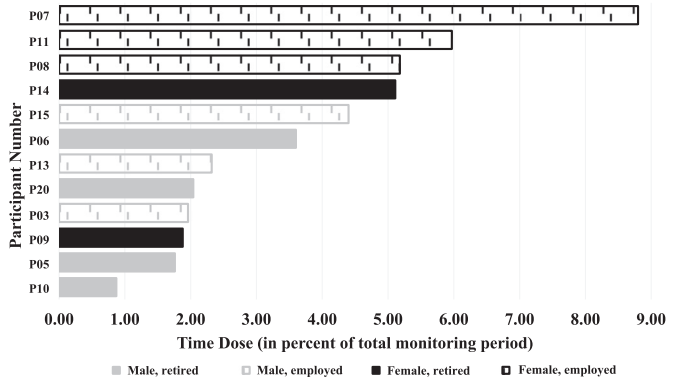


**FIGURE 1.** Individual participant data for time dose estimates by sex and employment status.

Unexpectedly, we did not observe any relationships between vocal dose estimates and V-RQOL scores for the overall group data. This finding indicates that at least for this sample vocal handicap does not strongly correlate with vocal activity as measured by vocal dose. Participants were drawn from a pool considered appropriate candidates for voice therapy, as opposed to patients with larger glottal gaps who were excluded from the larger voice therapy clinical trial.[30] Patients who are not responsive to voice therapy typically benefit more from surgical procedures to improve any glottal insufficiency resulting from vocal fold atrophy.[52] The severity of age-related voice changes in this sample of participants and its impact on their quality of life may have been less than for patients with worse presbyphonia, greater vocal fold atrophy, and a larger phonatory glottal gap.

Another possibility is that the V-RQOL did not adequately capture the negative impact of presbyphonia, and another measure might better reflect the handicapping nature of presbyphonia. If someone is unemployed or retired, then one of the V-RQOL items may likely not be relevant and thus a complete score is unachievable. The highest possible total V-RQOL score in that case would be 46, which represents an 8% reduction from the highest possible score when all items are included in the total score.

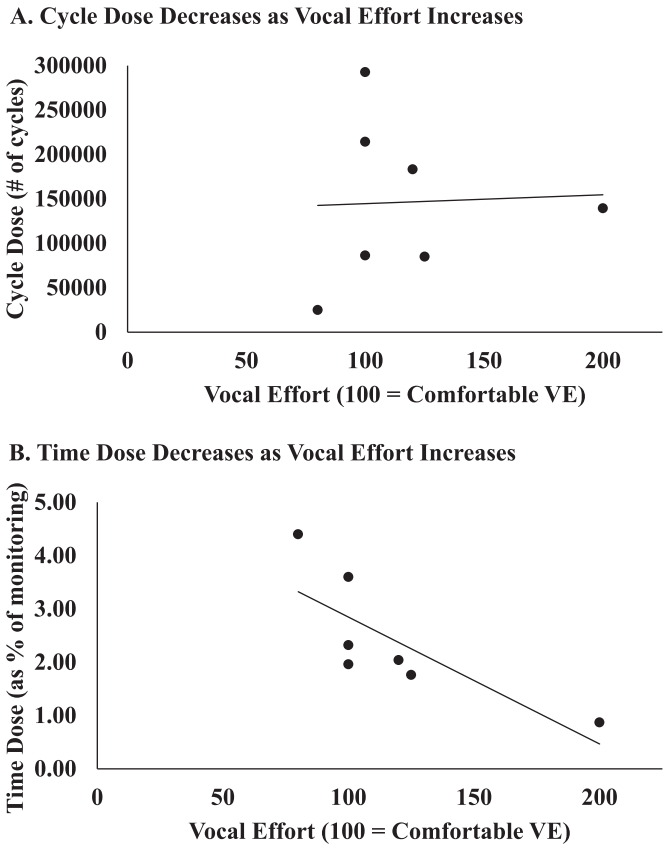


**FIGURE 2.** Scatterplots of correlations for male participants between (A) cycle dose and vocal effort and (B) time dose and vocal effort.

Inspection of the data revealed that some retired participants rated the item concerning the impact of their voice problem on professional activities greater than *never, not a problem* (ie, rating of 1). Thus, the V-RQOL may not demonstrate high precision in quantifying vocal handicap in the presbyphonia population.

## Could talking less cause presbyphonia?

Few human studies exist that have investigated the underlying causes of presbyphonia. These vocal dose estimates indicate patients with presbyphonia seldom vocalize as evidenced by low vocal doses over a roughly 8-hour monitoring period (Figure 1). These data are the first that hint at a possible dose–response relationship in which low vocal dose is a risk factor for vocal fold muscle atrophy. Suggestions of a negative vocal dose–vocal mechanism response relationship have been proposed in the literature by Sato (2011) and Titze (2016).[12,9] Furthermore, cadaver studies of older larynges indicate changes to the intrinsic laryngeal muscles and the nerves that innervate them.[53]

Though thin in quantity, the evidence is compelling for a use-it-or-lose-it mechanism of sarcopenic changes to the vocal mechanism. However, with the current study's design, support for this claim is only conjecture. This study did not include control participants such as those without vocal fold atrophy and without voice complaints, those without vocal fold atrophy and with voice complaints, and those with vocal fold atrophy but without voice complaints. In addition, participants were not followed longitudinally to establish a temporal relationship (ie, going from normal voice to presbyphonia), and thus causality cannot be claimed.

## Do age-related voice changes cause less talking?

The low time doses observed in the participants in this study may have resulted from altered voice use as a *consequence* of atrophy rather than the cause. Older males were found over a span of 5 years to have a poorer acoustic signal of the voice, and reportedly became less social as they aged.[23] Along such lines, observations of substantially reduced vocal dose in older adults with presbyphonia might reflect negative changes in social behavior and communication participation as a consequence of age-related voice changes. Anxiety, frustration, increased vocal effort, discomfort with voicing, and impaired voice-related quality of life are all associated with voice disorders in the elderly.[2] Patients with presbyphonia complain of decreased loudness that could negatively impact their ability to successfully interact with people with hearing impairments or in large, noisy environments such as nursing homes. The handicapping nature of presbyphonia may be particularly isolating for older adults because of these factors.

Contrary to expectations, we did not observe a relationship between V-RQOL scores and estimates of vocal dose for the overall group, or as a function of sex. This lack of association in this sample of participants with presbyphonia may be because the V-RQOL[31] does not adequately capture effects of voice changes on the quality of older adults' participation in life activities requiring communication. For example, one question in the V-RQOL addresses the impact of voice problems on working, which did not apply to half of our participants. If that question does not apply, participants who do not work can never achieve a full V-RQOL score. Recently published, the *Aging Voice Index* is a quality of life scale specific to age-related voice changes.[54] This scale may better reflect the negative impact of presbyphonia on older adults' vocal activity. Additionally, other social changes may be factors in low vocal dose, such as loss of a spouse, retirement, death of friends, or relocating to a different residence. Without a doubt, more research needs to crack the chicken-or-egg problem of reduced vocal dose in patients with presbyphonia.

## Is vocal dose a useful treatment target?

The strength of social integration to predict the lifespan of older adults suggests that measures capturing participation in communication and social activities are needed to determine effectiveness of treatments for presbyphonia. Irrespective of whether a low vocal dose is the cause or an effect of presbyphonia, vocal dose would provide

a functional estimate of voice use that ideally would increase after completion of voice therapy. Roy (2014) pointed out that little is known about dosing of voice therapy.[55] These vocal dose estimates provide early normative data on voice use in participants with presbyphonia before receiving voice therapy. Future studies on interventions for patients with presbyphonia, including clinical trials on voice therapy, should examine the impact of different voice therapy dosing to the structure and function of the vocal mechanism, and evaluate any pre−post changes in vocal dose that arise as a positive treatment response to voice therapy.

One potential treatment that may directly impact distance dose is PhoRTE, which targets vocal intensity as a workload to theoretically overload musculature of the vocal mechanism in patients with presbyphonia.[30] Because observed vocal intensity during monitoring was low for the overall group, and given vocal intensity contributes to the calculation of distance dose, PhoRTE may be a viable therapeutic option for increasing distance dose in older patients with presbyphonia (and time dose, with the addition of practice of PhoRTE voice exercises to a patient's daily routine). Other voice therapy programs that show promise in rehabilitating presbyphonia are Lee Silverman Voice Treatment[50,56] and vocal function exercises.[57,58] Their benefit may be due to an impact on vocal dose, though research is not available to support that claim.

In clinical practice, vocal dosimetry could be used to monitor the quantity and quality of home practice completed by patients. A vocal dosimeter could be used to observe carry-over of gains made by patients in the voice therapy session to their conversation. Generalization could be further assisted using the vocal dosimeter with biofeedback through vibration of the dosimeter unit. The vibratory biofeedback as the vocal intensity dips below a predetermined threshold alerts patients to vocalize with greater vocal power as they go about their daily routine.

### Limitations

Several limitations with this study warrant discussion. First, findings from this study should be interpreted with caution as the sample size was small and a liberal alpha level was assumed. That said, the median number of participants was 12 across the 15 studies included in a recent integrative narrative review on vocal dose, and the sample size ranged from two participants to 103.[20] Another limitation is that vocal dose data were obtained from only one day of monitoring, and a longer monitoring period to obtain a more representative sample of communication behaviors may have improved the accuracy of vocal dose estimates. Further, monitoring periods were not assigned at random. Despite advice to select a typical day and adhere to a normal routine, patients may have selected a less busy day so as to not be bothered with wearing the APM, introducing selection bias. Conversely, participants may have modified their communication by providing more data to analyze in response to their awareness of being observed, also known as observer effect.

Similarly, many participants were also patients, and treatment-seeking patients may have higher vocal demands—and a higher vocal dose—than older adults who have presbyphonia but elect not to seek treatment. Again, this selection bias may have affected the accuracy of vocal dose estimates in this study. Finally, a limitation for the published body of research using dosimetry to establish a causal relationship, including this study, is that the predominant experimental designs are cross-sectional and case series.[20] Those study designs are limited in establishing causality.

### Future directions

Studies of large samples are needed to capture the variety of factors that affect vocal patterns. Monitoring periods of future research should strive to include longer durations of monitoring and a greater number of monitoring days. Along that line, the days of monitoring should be randomly selected and assigned. Studies also should conduct test−retest reliability on vocal dose measures by monitoring some participants over two randomly selected time periods. More details should be collected about voice use history, current voice demands, and other variables likely to impact vocal dose (ie, personality). Future research should involve longitudinal study designs with comparison group to define the relative risk for developing presbyphonia from exposure to low levels of voice use. Finally, one other possible use of vocal dosimetry in research is to monitor adherence to home practice and changes in voice use with voice therapy in a randomized control trial.

### Generalizability

Vocal dose data were captured from a nearly equal mix of males and females, a variety of ages of older adults, and equal numbers of retired and employed individuals. Thus, vocal dose estimates are representative for community-dwelling, ambulatory, generally healthy older adults diagnosed with presbyphonia.

## CONCLUSION

This evidence is the first objective data to indicate that older adults diagnosed with presbyphonia exhibit less vocal activity than previously published vocal dose data in teachers, singers, patients with hyperfunctional voice disorders, and even office workers. Reduced time dose may have resulted from altered voice use as a *consequence* rather than as a *cause* of atrophy. Alternatively, vocal fold atrophy may have caused changes in the sound of the voice, or at least in men increased vocal effort, that resulted in withdrawal from vocal activities. Given limitations in study design, more research is needed to better understand the nature of voice use patterns in older adults and their relationship to presbyphonia.

## OTHER INFORMATION

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## AUTHOR CONTRIBUTIONS

Study concept and design: Ziegler, Hapner; Acquisition of data: Ziegler, Hapner; Analysis and interpretation of data: Ziegler, Hapner; Drafting of the manuscript: Ziegler; Critical revision of the manuscript for important intellectual content: Ziegler, Hapner.

## CONFLICT OF INTEREST

The authors declare that they have no financial conflicts of interest to disclose. The authors declare they are co-developers of PhoRTE, an evidence-based voice therapy program that addresses the voice needs of patients with presbyphonia.

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## SUPPLEMENTARY DATA

Supplementary data related to this article can be found online, at doi:10.1016/j.jvoice.2018.09.005.

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