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Maximum Phonation Time in Healthy Older Adults

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Introduction

Clinicians have many tools at their disposal to assess vocal function. Because of its simplicity and ease of use, maximum phonation time (MPT) is a frequently used clinical tool for assessing phonatory mechanics. MPT is the longest period during which a patient can sustain phonation of a vowel sound, typically /a/. A timer and audio recorder are the only equipment typically used to measure MPT. Many previous studies have used MPT to measure laryngeal function indirectly in different pathological circumstances, including patients with paralytic dysphonia [1,2] and those with weak or breathy voices [3]. In patients with dysphonia, it has been used to objectively assess severity as well as to assess improvement after voice therapy [4]. MPT has also been used to compare laryngeal function in healthy subjects and those with Parkinson's disease (5). Because it is frequently used across various clinical contexts, it is important to have sufficient normative data on MPT for all age groups.

While there are plenty of normative data on MPT in diverse subject populations, only a few studies have specifically examined MPT in older populations (65 and over). It is a commonly held assumption, however, that MPT varies with participant age [6,7]. Children tend to have shorter MPTs, require more trials to learn how to maximally phonate [8,9], and show more variation than young adults [6]. Young adults have less variation in MPT as a group and can phonate for a comparatively longer time than either children or older adults [6]. The few research studies on MPT done in older adults have demonstrated a decrease in average MPT compared with younger adults (see Table 1 for a selected summary). As in children, MPT in young adults may improve with increasing numbers of trials [10], although there is evidence that three trials can elicit a reliable MPT if patients receive proper instructions and practice [11]. The impact of increasing numbers of trials to elicit MPT has not been assessed specifically in older adults.

The purpose of this investigation was to measure MPT in healthy adult men and women age 65 and older, and to determine if MPT varies by specific age group, gender, or the number of trials. Reliable normative data for healthy older adults can help guide clinical decisions when using MPT to assess laryngeal function in elderly patients with presumed laryngeal pathology.

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Materials and Methods

Participants

Sixty-nine adult volunteers participated in this study (i.e., $n = 15$ age 65-70, $n = 26$ age 71-80, and $n = 28$ age 81-90). There were 34 men and 35 women. Participants reported no history of swallowing, speech, or voice problems. All participants were in reported good health and denied any known neurologic or otolaryngologic disorders via written medical questionnaire. Volunteers were not screened for singing status or prior vocal training. The participant pool reflected a convenience sample of healthy older adults in Forsyth County, NC. Participants were recruited by bulletins approved by the Wake Forest University Health Sciences Institutional Review Board. Informed consent was obtained.

Procedure

All subjects underwent fiberoptic endoscopic evaluation of swallowing (FEES) examinations during their clinical evaluation. The FEES examinations were reviewed by an otolaryngologist to rule-out laryngeal pathology, including but not limited to vocal fold immobility or lesions. Stroboscopy was not performed. Subjects were excluded if they reported any voice disturbance.

Participants underwent the MPT task while sitting upright. They repeated a maximum phonation time of /a/ three times with a one-minute rest period between each trial. Participants were instructed to hold the vowel /a/ as long as they possibly could, at their normal speaking volume, after taking a maximal inhalation. They were further instructed to hold the /a/ even if their voice started sounding strained and effortful, and to continue holding it until they could hold it no longer. The examiner showed participants how to perform the task with an abbreviated model of MPD. She modeled the beginning of the task by holding /a/ for a number of seconds with her own voice. She then demonstrated how long they should continue saying /a/ by imitating the end of the MPD. Participants were further coached, if needed, until each could perform the task as instructed. No instrumentation was used to record the pitch of participants; however, the examiner instructed participants to perform the task with their normal speaking voices. In addition, further feedback was provided for participants to continue in a higher or lower pitch, when necessary.

Statistical Analysis

Means and standard deviations (SDs) were calculated for maximum phonation duration by age group, gender and trial. Repeated measures analysis of variance (ANOVA) was performed to investigate maximum phonation duration as a function of age group, gender, and trial. Compound symmetry covariance structure was applied to take into account the correlation among trials within the same subject. Adjusted means of maximum phonation duration were estimated from the same model. Effects of age group, gender and trial were tested. Three-way and two-way interactions were examined and would not be included in the final model if not significant. Finally, repeated measures analysis of covariance (ANCOVA) was performed to include either height or body mass index (BMI) as an additional covariate. Significance level for each test was set at 0.05 for all analyses.

Results

Unadjusted means of MPT by age group, gender, and trial are presented in Table 2. Adults in the 7th, 8th, and 9th decades of life had mean MPTs of 22.27 (SE = 1.56), 22.97 (SE = 1.11), and 21.14 (SE = 0.97) seconds, respectively. Females and males had mean MPTs of 20.96 (SE = 0.92) and 23.23 (SE = 0.96) seconds, respectively. Finally, MPTs for trials 1, 2, and 3 were 21.77 (SE = 1.09), 21.67 (SE = 1.12), and 22.80 (SE = 1.27), respectively.

The repeated measures ANOVA model indicates that neither age group, gender, trial, nor their interactions were statistically significant ($p > 0.05$). The p-values were 0.89 for the three way interaction, i.e., age group $\times$ gender $\times$ trial, 0.88 for age group $\times$ trial, 0.55 for gender $\times$ trial and 0.46 for age group $\times$ gender, respectively. The final model used to estimate adjusted means for age group, gender and trial was without interactions. The p-values were 0.80 for age group, 0.34 for gender and 0.13 for trial. Adjusted means of MPT were shown in Table 3. Adjusting for height ($p = 0.58$) or BMI ($p = 0.87$) does not change the general results.

Discussion

Compared with previous results [5,12-13], we found that MPTs were substantially longer than previously described for patients age 65 and older. Our study population was ambulatory and in good health, without any history of swallowing, speech, or voice problems, and no neurologic deficits. While even healthy older adults should undergo natural decrements in physiological function due to weakening of the laryngeal and respiratory musculature, our results demonstrate that in healthy older adults without debilitating comorbidities, the MPT can approach the durations seen in young adults.

It is not clear to what extent MPT is affected by natural aging-associated changes. MPT depends on many variables, including phonation volume (which varies with age, sex, and stature), mean airflow rate, comprehension of the task, and maximal effort [6]. Older adults have a statistically significant difference in their total pitch ranges, vital capacity, and maximum intraoral pressure compared with younger adults [11,14]. This may stem from a decrease in the power of respiratory muscles, less pulmonary elasticity, and/or sarcopenia in laryngeal muscles, even though laryngoscopic examinations do not routinely reveal changes in laryngeal mechanisms in older adults [12].

Across all age groups, men can sustain a longer MPT on average than women, presumably due to increased vital capacity. Nevertheless, aging affects laryngeal anatomy and physiology differently depending on one's gender. Vocal fold atrophy increases overall incidence of glottal gaps more in elderly men than in women [7]. Stroboscopic studies of vocal fold movement in elderly women indicate greater aperiodicity, reductions in mucosal wave, and reduced amplitude of vibration, compared with men [7]. Ultimately, it is not clear to what extent these factors diminish MPT to cause differential outcomes in men and women, or how global changes in anatomy and physiology affect young versus older adults. While there was a difference in MPT between men and women in our study (23.23 sec vs 20.96 sec), it was not statistically significant. It is possible that with a larger study size, this difference might become more robust and consistent with previous studies that have shown a gender gap. However, it is also possible that the gap between genders is less evident in healthy older adults.

Some researchers have argued that the number of trials required to elicit a truly maximal duration of phonation is at least five and as high as fifteen; others have stated that three trials is sufficient if the instructions for patients are clear (6). Our results demonstrated stable MPTs across trials, without any statistically significant variance or increase in performance by the third trial that might have necessitated additional trials. While there were no written instructions or videos for the participants to observe prior to phonation, the examiner modeled the MPT behavior so the participants could observe what was required. Furthermore, the examiner provided further instruction in the task, if needed, until the instructed behavior was acquired. However, generally, no more than one modeling of the expected behavior was required. The stability of our results indicates that three trials were sufficient to elicit reliable MPTs given this level of instruction and demonstration.

There may be a number of reasons why the MPTs in our study were substantially longer than those seen in other studies in older adults. One possibility is that our cohort was healthier than the other study populations because we employed more stringent inclusion/exclusion criteria. It is also possible that our protocol differed slightly from previous studies. The participants in our study were instructed to continue to phonate until they could hold it no longer, even if their voice sounded strained towards the end of phonation. The other studies in the elderly did not specify this, and it may have accounted for slight variations in the effort expended by participants during phonation. There is also the possibility that the vocal straining at the end of the MPT exercise could have led to vocal fry in some of our participants. If so, this would likely increase the MPT, as the rate of airflow in vocal fry is roughly three times lower than that in modal register (15) and this would allow a greater reserve of airflow. Furthermore, it is possible that, especially in the case of female participants, they may have mimicked the pitch employed by the study instructor, who was female.

Another possible reason the MPTs in this study were so long, though perhaps a less likely one, relates to the fact that American adults are taller on average than they were when the previous studies on MPT in older adults were conducted (1966, 1972, and 1982, respectively). Because thoracic volume is related to height, at least in children and young adults (16), maximum phonation time could be longer in our cohort due to their increased vital capacities. However, the average height of American adults (age 20 – 74) only increased by about one inch from 1960 to 2002 (17), which might not be enough to account for such a dramatic increase in vital capacity. Also, while we collected participants' height in our study, this metric was not provided in the other studies in the elderly, so a direct comparison of participant heights could not be made. Perhaps a more relevant change in American body composition is average weight, which increased 24 lbs from 1960 – 2002 in the 20 – 74 age group (17). However, increased weight tends to impair respiratory function (18), not increase it; thus, an increased average weight should decrease MPT, which would not be consistent with our results. The height and weight of participants in this study did not have a significant impact on their measured MPTs, but this is an area that has not been previously studied and could bear clinically significant results with future research and a larger sample size. As this was the first study on MPT in the elderly since 1982, it remains unclear whether our results reflect the changing American body habitus, or whether the spectrum of normative data previously described was simply incomplete.

Perhaps the most important element that could have accounted for the MPT variability between our study and others was the usage of instrumentation to control pitch and intensity of phonation. A review of multiple previous papers (8-9, 12-13, 19-22) has demonstrated that there is no standardized method to acquire MPT in terms of instrumentation. Some researchers have measured pitch and ensured that patients remained within a certain frequency during MPT trials, while multiple others have measured MPT without any instrumentation, and have simply relied on either written instructions or demonstration of the task by an instructor. Indeed, this discrepancy in techniques has been reviewed by Shanks and Mast (19), who suggested that drastic differences in published MPT results in the 1960s and 1970s might have been due to different techniques employed to acquire it. Hirano et al (22) employed a method that took into account mean flow rate and air consumption, but did not control for pitch and loudness, and found average MPTs of 34.6 sec for males and 25.7 for females (in all ages). Ptacek and Sander (21), on the other hand, controlled for pitch and loudness and found a range of 17.7 sec – 25.7 sec for males and 11.5 sec – 24.1 sec for females, across all pitch and loudness levels. Isshiki and Von Leden (20) argued that while normal subjects had different flow rates depending on the pitch and intensity during phonation, most of the patients in their study with voice disorders were unable to control pitch and intensity as requested. Because of this, they had their subjects

participate “during comfortable easy phonation, without precise control of pitch and intensity.” This was the approach employed by Isshiki, Hirano, and Von Leden in many of their early papers on MPT. (These researchers did, however, use a pneumotachograph to measure air flow rates in subjects.) In terms of the methods used by researchers to measure MPT in older adults, a review of the techniques employed in the three previously published papers on MPT in this population can be found in Table 4.

While we recognize that inconsistency in pitch and intensity could potentially affect MPT, we support the conception of maximum phonation time's utility as an in-office exam articulated by Shanks and Mast (1977):

Information-yielding and practical vocal tasks which do not require elaborate instrumentation are still sought by clinical speech pathologists for diagnostic and evaluative purposes. Also, for speech pathologists who travel extensively or who have a limited equipment budget, portability and economy are desirable features of vocal assessment techniques...Maximum duration of phonation is an information-yielding vocal task which utilizes portable materials, a stop watch and a tape recorder. It is economical in terms of administration time and could produce objective data describing vocalization.

Standardization of pitch and intensity might provide more reliable results for MPT, but an approach that is reliant on minimal instrumentation that measures MPT in a subject's normal speaking voice will be the most useful for practicing clinicians who may not have the full range of instrumentation required to incorporate these controls. Therefore, it was our approach to adopt the conception of MPT that was reliant on nothing more than a stopwatch and a recorder.

Future studies should standardize an MPD approach (with or without frequency and sound pressure level monitoring), so that normative data will be based on an identical technique.

Conclusions

Given the limited amount of normative data on MPT in older adults, our results widen the spectrum of what should be considered a normal MPT in older adults without significant health problems or underlying laryngeal pathology. In this cohort of healthy older adults, many could phonate for at least 20 seconds in the absence of pathology. Three trials were sufficient for accurate MPT measures, and in this study population the difference between genders was less evident compared to prior studies that have been done in younger individuals. Future studies should emphasize the importance of standardized procedural techniques to diminish the possibility of confounders on the measurement of MPT.

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Table 1
[†] **Selected Studies of MPT in Healthy Females and Males and Young and Older Adults**

Age Group	Sex	M	SD	Range
Older Adults [5]	M (65-75 yrs)	14.6	5.9	-
	F (66-93 yrs)	14.6	5.8	-
Older Adults [12]	M (68-89 yrs)	18.1	6.6	10.0-37.2
	F (66-93 yrs)	14.2	5.6	7.0-24.8
Older Adults [13]	M (85-92 yrs)	13.0	-	7.0-12.0
	F (85-96 yrs)	10.0	-	6.0-18.0
Young Adults [5]	M & F	18.2	4.3	-
Young Adults [20]	M	22.6	8.1	9.3-43.3
	F	15.2	5.0	6.2-28.4
Young Adults [21]	M	34.6	-	15.0-62.3*
	F	25.7	-	14.3-40.4*

* The ranges in this study are only from the "Critical Region," that is, only the values that fell within the normal population defined by the authors (at a 5% level of significance).

[†] This table presents selected studies of MPT previously characterized by Kent et al (6) in a review article.

Table 2
Unadjusted Means of Maximum Phonation Time(s) as a Function of Age, Gender, and Trial

	Age Group	Trial 1	Trial 2	Trial 3	Mean	Std. Error of the Mean	Range
Males	61-70	26.00	26.14	26.57	26.24	1.22	16-35
	71-80	23.21	22.57	23.57	23.12	1.71	7-58
	81-90	21.77	21.23	22.15	21.72	1.53	10-50
	Total	23.24	22.79	23.65	23.23	0.96	7-58
Females	61-70	17.25	18.12	21.00	18.80	2.55	8-60
	71-80	22.83	22.50	23.08	22.81	1.37	12-45
	81-90	20.00	20.33	21.60	20.64	1.25	5-41
	Total	20.34	20.57	21.97	20.96	0.92	5-60
Both	61-70	21.33	21.87	23.60	22.27	1.56	8-60
	71-80	23.04	22.54	23.35	22.97	1.11	7-58
	81-90	20.82	20.75	21.86	21.14	0.97	5-50
	Total	21.77	21.67	22.80	22.08	0.67	5-60
By Trials	Mean	21.77	21.67	22.80	22.08		
	Std. Error	1.09	1.12	1.27	0.67		

Table 3
Adjusted Means of Maximum Phonation Time as a Function of Age, Gender and Trial

	Age Group	Trial 1	Trial 2	Trial 3	Mean	Standard Error	95% CI
Males	61-70	23.12	23.02	24.15	23.43	2.68	18.13-28.72
	71-80	23.67	23.57	24.70	23.98	2.09	19.84-28.12
	81-90	22.00	21.90	23.03	22.31	2.13	18.10-26.51
	Total	22.93	22.83	23.96	23.24	1.63	20.01-26.46
Females	61-70	20.94	20.84	21.97	21.25	2.62	16.08-26.42
	71-80	21.49	21.39	22.52	21.80	2.18	17.48-26.12
	81-90	19.82	19.72	20.85	20.13	2.04	16.10-24.17
	Total	20.75	20.65	21.78	21.06	1.60	17.90-24.22
Both	61-70	22.03	21.93	23.06	22.34	2.40	17.60-27.08
	71-80	22.58	22.48	23.61	22.89	1.82	19.29-26.49
	81-90	20.91	20.81	21.94	21.22	1.76	17.75-24.69
	Total	21.84	21.74	22.87	22.15	1.16	19.85-24.45

Table 4
Procedural Differences in the Measurement of Maximum Phonation Time in the Elderly

Study	Procedure employed	Pitch and/or Intensity Measured?
Kreul EJ (5)	Each vowel sound was demonstrated to the subjects, and they were urged, through standardized instructions and example, to sustain each vowel sound just as long as possible. All vowel productions were monitored for correctness and all efforts were recorded to the nearest half second.	No
Ptacek and Sander (12)	Pitches were specified for participants as follows: 130 Hz for males and 210 Hz for females. Whenever necessary, playback of the vowel /a/ sustained at the correct frequency was fed into the earphone worn by the subject to assist him in his frequency monitoring. Sound pressure level (re 0.0002 dyne/cm ²), monitored by a VU meter, was 82 dB (+/- 4 dB), with a mouth-to-microphone distance of two inches.	Yes
Mueller PB (13)	A microphone "VISI-PITCH 6087A" was used to ensure consistency of pitch and loudness levels in intrasubject trials. The author excluded participant data in which the variability between trials was greater than 10 Hz.	Yes