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(神経内科外来を受診した地域在住高齢者における身体虚弱が最長発声持続時間に及ぼす影響)

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Short running title: Effects of physical frailty on MPT

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Abstract

Background: Maximum phonation time (MPT) is used to assess speech and other oral rehabilitation-related issues. Various factors contribute to MPT decline in older individuals. Although the impact of physical frailty on MPT has been suggested, this has not been conclusively determined.

Objective: To examine the relationship between MPT and physical frailty in community-dwelling individuals aged ≥60 years who were independently mobile. MPT-associated factors were investigated.

Methods: This cross-sectional study analyzed the clinical data of 122 patients (age [interquartile range]: 80.0 [74.0–83.0] years) without dementia who visited a neurology department between February 1, 2021, and January 31, 2023. Investigated factors included age, sex, weight, height, body mass index, smoking history, grip strength, functional independence measure, vital capacity, oral diadochokinesis, MPT, and Japanese Cardiovascular Health Study score. Physical frailty was assessed based on the total score from five items (weight loss, weakness, exhaustion, slowness, and low physical activity). The relationship between MPT and physical frailty was examined using Spearman's rank correlation coefficient and hierarchical multiple regression analysis.

Results: The MPT was negatively correlated with age ($r=-0.347$, $p<0.01$) and physical frailty ($r=-0.681$, $p<0.01$) and positively correlated with vital capacity ($r=0.474$, $p<0.01$) and height ($r=0.248$, $p<0.01$). The hierarchical multiple regression analysis, conducted with MPT as the dependent variable, demonstrated that physical frailty ($\beta=-0.59$, 95% confidence interval: −0.74 to 0.43, $p<0.001$) had a strong influence on MPT.

Conclusion: In older individuals, MPT is associated with physical frailty. When assessing MPT in clinical settings, it is advisable to perform a concurrent assessment of physical frailty.

Keywords: vocal speech, maximum phonation time, physical frailty, community-dwelling older adults, lung function, negative correlation

1. Background

Maximum phonation time (MPT) is a comprehensive evaluation of vocal speech.[1,-3] The MPT is a task of uttering /a/ as long as possible at a normal volume of voice; this method can be easily performed anywhere using a device that can measure time.[3] The reliability of this measurement method has been verified.[4] It has been used to measure the MPT for all age groups, from the younger to the older population, with accumulating standardized data.[5-9] MPT is an important assessment tool that has been applied in a variety of areas related to oral rehabilitation, including swallowing screening[10] and voluntary cough force screening,[11] as well as speech.

Although MPT has gained attention as a useful assessment tool as it does not require the use of special equipment and can be easily applied in clinical practice, the factors associated with MPT vary among studies. Age,[6-8] sex,[7,8,12] height,[7] body mass index (BMI),[13,14] and lung function[15,16] can affect the MPT of individuals without vocal speech problems. However, different studies have reported varying effects of age, sex, and lung function in individuals aged ≥60 years. The causes of decreased MPT have not yet been determined owing to the variations in the factors measured in different studies. Recently, an association between dysphonia and frailty in older adults has been reported,[17,18] and physical frailty may affect MPT in older adults.

Frailty[19] refers to the decrease in the physical, mental, and social reserves due to aging, making individuals vulnerable to various health disorders. Physical frailty, which is a component of frailty, indicates a state of increased physical and mental fatigue due to aging.[19] It is more common in women than in men and is also observed in many older individuals. It is usually characterized by decreased muscle strength, lung function, and physical function.[19] Therefore, physical frailty may have an effect on MPT; however, thus far, no study has evaluated this subject. Understanding the factors associated with MPT will be useful for oral rehabilitation assessment using MPT.

Therefore, this study measured the MPT in community-dwelling Japanese individuals aged ≧60 years. The relationship between MPT and physical frailty and the factors associated with MPT in older individuals were also investigated. We hypothesized that physical frailty contributes to changes in respiratory function and shortens MPT.

2. Materials and methods

2.1 *Participants*

This cross-sectional study included older adults who visited the neurology outpatient clinic at Mie Central Medical Center and requested an evaluation by a speech-language pathologist between February 1, 2021, and January 31, 2023. The data were obtained from the patients' medical records. The Mie Central Medical Center provides acute care in the region. Japanese-speaking community-dwelling individuals aged ≥60 years, those who were not diagnosed with dementia or neurodegenerative diseases, and those with a functional independence measure (FIM) walking score of 6 or more were included in this study. The exclusion criteria were: patients aged <60 years; patients receiving treatment for dysphagia, dysphonia, dementia, neurodegenerative diseases, and respiratory diseases; and patients who refused to undergo examination. This study was approved by the Ethics Committee of the Mie Central Medical Center (approval number: 202230) and conducted in accordance with the principles of the Declaration of Helsinki. Evaluations were performed by speech-language-hearing therapists after the attending physician had obtained verbal consent from the participants or their families.

2.2 *Outcome measures*

Data on age, sex, weight, height, BMI, smoking history, grip strength, FIM walking score, vital capacity, smoking history, MPT, oral diadochokinesis (ODK) diagnosis, and Japanese version of the Cardiovascular Health Study (J-CHS) score were obtained from the medical records.

2.3 *Maximum phonation time*

MPT was measured by a speech-language-hearing therapist. The participants were instructed to sit upright without leaning against the backrest and produce the /a/ sound for as long as possible at their normal volume of voice and pitch.[7,8] The MPT was measured using a stopwatch. The measurement was repeated thrice, and the maximum value was used for analysis.

2.4 *Oral diadochokinesis*

ODK was assessed by a speech-language-hearing therapist by asking the participants to produce the /pa/, /ta/, /ka/, and /pataka/ sounds.[20] All sounds were measured for 5 s using a stopwatch, with instructions to alternate repetitions at maximum speed. A counter was used to measure the number of repetitions, and the value measured within 5 s was used for analysis.

2.5 *Evaluation of physical frailty*

A version of Fried's frailty evaluation modified for the Japanese population (J-CHS) was used to evaluate the participants.[21] Five items were assessed (weight loss, weakness, exhaustion, slowness, and low physical activity), and the results were categorized as healthy for no applicable items, pre-frail for 1–2 applicable items, and frail for 3 or more applicable items. In this study, the total score of the applicable items was utilized. For weight loss, the participant was assessed for an occurrence of unintentional weight loss of 2 kg or more during the 6-month period; a score of 1 point was assigned for a "yes" response.[21] Weakness was measured using a grip strength meter, with 1 point awarded to men weighing less than 28 kg and women weighing less than 18 kg.[21] For low physical activity, a score of 1 point was awarded if the participant reported not exercising once a week.[21] For slowness, a score of 1 point was awarded if the participant had a walking speed of <1.0 m/s.[21] For exhaustion, a score of 1 point was awarded if the participant experienced unexplained tiredness within a 2-week period.[21]

2.6 *Vital capacity*

Vital capacity measurements were performed by a qualified laboratory technician according to the standard protocols for pulmonary function testing in the laboratory. A pulmonary function testing device (CHEST, CHESTAC-8900α) was used to obtain the measurements. For this test, the nose was occluded using a nose clip, and a mouthpiece was inserted. The participant took several breaths as usual to determine the resting breathing rate. Next, the participant was asked to exhale to the maximal expiratory position at the same rate as the resting breath. The participant was then asked to inhale to the maximal inspiratory position and exhale again to the maximal expiratory position. The vital capacity was measured as the volume change between full inspiration and complete expiration.

2.7 *Statistical analysis*

Statistical analyses were performed using EZR version 1.61 (Saitama Medical Center, Jichi Medical University, Japan). A p value of <0.05 was considered significant. Categorical variables are expressed as frequencies and percentages (%), whereas continuous variables are expressed as medians with interquartile ranges (IQRs).

The average (SD), median (IQR), and range (min–max) of the MPT were calculated and compared with the findings of previous studies[5,7,8] according to age, height, and physical frailty by sex. The relationships between MPT and age, sex, height, weight, BMI, vital capacity, physical frailty, and ODK were evaluated using Spearman's rank correlation coefficient. The relationship between the MPT and physical frailty was evaluated using hierarchical multiple regression analysis. The MPT was transformed into a common logarithm to ensure the normality of the distribution of regression residuals. The normality of their distribution was confirmed prior to regression analysis. Model 1 included age, sex, height, BMI, smoking history, and vital capacity as the independent variables. Model 2 added physical frailty to Model 1. These independent variables were preselected based on the clinical significance and impact of physical frailty. Multicollinearity was assessed using the variance inflation factor. The evaluation indicators were the standardized partial regression coefficient (β) and the 95% confidence interval (95% CI). The contribution rate of the regression equation was expressed as the adjusted R-squared (R^2) values.

2.8 *Sample size calculation*

The sample size was estimated using hierarchical multiple regression, with MPT as the objective variable. Six independent variables in Model 1 and seven in Model 2 were considered covariates. The number of cases required for the regression analysis was estimated as at least 105, allowing for 15 samples per independent variable. It was estimated that at least 50% of the participants met the exclusion criteria, including the presence of dementia, and 20% dropped out owing to deficits or other reasons. Thus, the number of participants needed for this study was set at 280. To evaluate whether the sample size for the hierarchical multiple regression analysis had sufficient statistical power, a post hoc analysis was conducted using G*Power version 3.1.9.6. The effect size was calculated based on the R^2 values obtained from the hierarchical multiple regression analysis, with the alpha error rate set at 0.05.

3. Results

We enrolled 261 (114 men and 147 women) participants in this study. After excluding 139 participants who met the exclusion criteria, 122 (53 men and 69 women) participants were included in the study (Figure 1). The participants' characteristics are presented in Table 1. The median age of the participants was 80 years, and their median height was 1.56 m. The median physical frailty score was 1 point, and the median MPT was 16.7 s.

Table 2 presents the results of the MPT analysis according to age. MPT tended to decline with age, for both men and women. Table 3 lists the results of the MPT analysis according to height. Both men and women exhibited higher MPT values as height increased. Table 4 presents the results of the physical frailty analyses. The MPT scores tended to decrease with increasing frailty scores.

Spearman's rank correlation analysis showed positive correlations between MPT and height ($r=0.248$, $p<0.01$), vital capacity ($r=0.474$, $p<0.01$), and ODK with /pa/ ($r=0.203$, $p=0.03$), /ta/ ($r=0.274$, $p<0.01$), /ka/ ($r=0.24$, $p<0.01$), and /pataka/ ($r=0.285$, $p<0.01$). Age ($r=-0.347$, $p<0.01$) and physical frailty scores ($r=-0.681$, $p<0.01$) were negatively correlated with MPT.

Table 5 shows the results of the hierarchical multiple regression analysis. Model 1 showed a significant effect of vital capacity on MPT, with an adjusted R^2 of 0.25. Model 2 was analyzed by adding the physical frailty score to Model 1; results showed that the vital capacity and physical frailty scores significantly affected MPT, with an adjusted R^2 of 0.50.

The post hoc power analysis was conducted with a sample size of 122, an alpha error rate of 0.05, seven predictors, and an effect size (f2) of 1.0, which was calculated using the R^2 value of 0.5. As a result, a power of 1.0 was obtained.

4. Discussion

This study examined the relationship between MPT and physical frailty in community-dwelling older individuals. The results revealed that MPT was inversely correlated with physical frailty. Compared with other related factors, including lung function, physical frailty significantly influenced the MPT. The determination coefficient was 0.50, indicating high goodness of fit. Therefore, physical frailty should be assessed simultaneously when evaluating the MPT in older patients without voice disorders. To the best of our knowledge, no previous study has investigated this subject.

This study included community-dwelling older adults who visited a neurologist; adults diagnosed with dementia were excluded. Adults with dementia may not have been able to understand the instructions, and the data may not have been obtained appropriately. Many studies use Mini-Mental State Examination scores for determining the cognitive status of patients, but this does not reliably exclude those with dementia and may result in the inclusion of persons with dementia. This study appropriately investigated the MPT in community-dwelling older adults aged 60 years or older as it was able to exclude those with dementia diagnosed by a specialist.

The results of the MPT analysis according to age, height, and sex are similar to the findings of some previous studies.[5,7,8] The MPT was prolonged as the height increased, as reported in our previous study.[7] This is because vital capacity also increases with height, which may explain the prolongation of the

MPT. Similar to the findings of a previous study,[8] our current study showed that the MPT decreased with age. Lung function declines with age and is unable to generate the aerodynamic resistance necessary for vocalization. Additionally, the present study included community-dwelling older patients who visited an outpatient neurology clinic, and patients diagnosed with neurodegenerative diseases and dementia were excluded. Thus, the group included in this study was appropriate for investigating the MPT in older adults aged ≥60 years.

The results of the hierarchical multiple regression analysis suggest that physical frailty significantly influenced the MPT. Its effects on MPT could potentially be due to decreased lung function,[22] diaphragmatic atrophy, and decreased muscle strength in these individuals.[23] A previous study from the United States[24] reported that individuals with physical frailty demonstrated decreased lung function and increased airway limitation. Physical frailty is associated with decreased respiratory muscle strength. Atrophy of the diaphragm is also observed with age.[24] MPT requires voluntarily controlled long exhalation. Hence, total body mobility and control of exhalation by the diaphragm are necessary for prolonging the MPT. In this study, we observed that the J-CHS score increased as lung function decreased. This could be because it can be difficult to control exhalation and voice voluntarily for a long duration due to physical frailty. Consequently, MPT is strongly influenced by both lung function and physical frailty.

The present study also examined the relationship between ODK and MPT and found positive correlations among /pa/, /ta/, /ka/, and /pataka/. Watanabe et al.[25] reported that the ODK values were lower in frail individuals than in healthy individuals. This finding is similar to the results of MPT and ODK reported in the present study, and MPT may be closely related to oral function. However, as oral function was not assessed in this study and posture[26] and other factors were not limited, further research is needed.

Our findings suggest that individuals aged ≥60 years with decreased MPT may be physically frail. Furthermore, lower MPT was associated with lower ODK, suggesting that physical frailty may contribute to the decline in MPT and overall oral motor function.

This study has several limitations. First, this was a single facility that only included Japanese individuals. The measured range of physical characteristics evaluated in this study, such as height and BMI, was relatively small; therefore, caution is required when generalizing the results of the present study. Second, we could not measure the respiratory muscle strength and muscle mass. Furthermore, sarcopenia may also affect the MPT. Third, oral and laryngeal functions were not assessed. ODK was measured as an oral movement using a counter, but this measurement was not recorded. Thus, the counts may not have been measured accurately. In addition, other oral problems, such as the recently emerged concept of oral frailty, may have influenced the results.

5. Conclusions

This study examined the association between MPT and physical frailty in community-dwelling individuals aged ≥60 years. To the best of our knowledge, this study is the first to report that physical frailty, in addition to vital function, significantly influences the MPT. As physical frailty likely shortened the MPT, physical frailty should also be assessed and appropriately addressed when MPT is used as an assessment tool in patients aged ≥60 years without speech impairment. This study's findings may influence future assessment protocols and rehabilitation programs, leading to more effective and holistic approaches to managing oral motor function and physical frailty in individuals aged ≥60 years.

Author contributions

KU developed the study design, collected the data, and drafted the manuscript. AI and AY designed the study. TK and KY conducted the study protocols and collected the data. All the authors reviewed and approved the final manuscript.

Data availability statement

All data supporting the findings of this study are available from the corresponding author upon reasonable request.

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TABLE 1 Participants' clinical characteristics.

	Total (n=122)
Age (years)	80.0 [74.0–83.0]
Sex, male (%)	53.0 (43.4%)
Height (m)	1.56 [1.50–1.63]
Weight (kg)	54.0 [48.0–60.7]
BMI (kg/m^2)	22.2 [19.8–24.2]
J-CHS (point)	1 [0–2]
MPT (s)	16.7 [11.5–21.2]
ODK	
/pa/	33.0 [31.0–34.0]
/ta/	32.0 [31.0–33.0)
/ka/	31.0 [30.0–32.0]
/pataka/	11.0 [10.0–12.0]
VC(ℓ)	2.36 [1.99–2.86]
FIM total	126.0 [116.3–126.0]

Note: Data are expressed as the median [interquartile range] or count (%).

Abbreviations: BMI, body mass index; FIM, functional independence measure; J-CHS, Japanese version of the Cardiovascular Health Study; MPT, maximum phonation time; ODK, oral diadochokinesis; VC, vital capacity

TABLE 2 MPT analysis according to age.

Age group (years)	n	Mean (SD)	Median [IQR]	Range (min–max)
Men				
60–69	4	25.3 (6.2)	22.6 [22.0–26.0]	21.5–34.6
70–79	21	20.5 (7.7)	20.0 [14.4–27.2]	8.9–32.9
80–89	25	17.4 (7.0)	17.3 [11.9–20.2]	9.2–40.7
90–100	3	11.5 (3.6)	10.5 [9.5–13.0]	8.4–15.5
Total	53	18.9 (7.6)	18.2 [12.7–22.3]	8.4–40.7
Women				
60–69	4	16.4 (2.6)	17.3 [16.0–17.6]	12.6–18.4
70–79	28	18.8 (7.5)	17.1 [13.7–22.5]	8.9–38.6
80–89	29	15.5 (6.9)	15.6 [10.4–19.0]	5.5–40.2
90–100	8	12.3 (5.0)	11.7 [8.2–15.6]	6.8–20.3
Total	69	16.5 (7.0)	15.7 [11.0–20.3]	5.5–40.2
Both				
60–69	8	20.9 (6.5)	19.9 [17.2–22.4]	12.6–34.6
70–79	49	19.5 (7.6)	19.2 [13.8–24.3]	8.9–38.6
80–89	54	16.3 (7.0)	15.7 [11.3–19.3]	5.5–40.7
90–100	11	12.1 (4.5)	10.6 [8.5–15.4]	6.8–20.3
Total	122	17.5 (7.3)	16.7 [11.5–21.1]	5.5–40.7

Note: The unit for all values is “seconds.”

Abbreviations: IQR, interquartile range; MPT, maximum phonation time; SD, standard deviation

TABLE 3 MPT analysis according to height.

Body height group (m)	n	Mean (SD)	Median [IQR]	Range (min–max)
Men				
<1.50	0			
1.50–1.59	15	18.9 (9.1)	17.3 [11.9–23.8]	8.4–40.7
1.60–1.69	33	17.8 (6.5)	17.6 [12.1–20.3]	8.9–34.6
1.70–1.79	5	25.9 (5.9)	22.3 [21.5–32.8]	21.3–32.9
Total	53	18.9 (7.6)	18.2 [12.7–22.3]	8.4–40.7
Women				
<1.50	29	16.2 (6.5)	15.7 [10.8–20.3]	6.8–32.3
1.50–1.59	33	15.9 (7.6)	14.7 [10.4–18.5]	5.5–40.2
1.60–1.69	7	20.2 (6.2)	20.6 [16.5–22.9]	11.3–30.3
1.70–1.79	0			
Total	69	16.5 (7.0)	15.7 [11.0–20.3]	5.5–40.2
Both				
<1.50	29	16.2 (6.5)	15.7 [10.8–20.3]	6.8–32.2
1.50–1.59	48	16.8 (8.1)	15.2 [10.9–19.5]	5.5–40.7
1.60–1.69	40	18.2 (6.59	17.9 [12.8–21.2]	8.9–34.6
1.70–1.79	5	25.9 (5.9)	22.2 [21.5–31.8]	21.3–32.9
Total	122	17.5 (7.3)	16.7 [11.5–21.1]	5.5–40.7

Note: The unit for all values is “seconds.”

Abbreviations: IQR, interquartile range; MPT, maximum phonation time; SD, standard deviation

TABLE 4 MPT analysis according to J-CHS score.

J-CHS group (points)	n	Mean (SD)	Median [IQR]	Range (min–max)
Men				
0	26	21.9 (6.9)	21.8 [16.2–26.5]	10.6–34.6
1	9	21.6 (8.5)	18.7 [17.4–23.2]	13.0–40.7
2	10	14.9 (3.8)	14.6 [11.5–17.5]	10.6–21.3
3	7	11.0 (4.1)	9.2 [9.0–10.5]	8.4–20.2
4	1	11.1		11.1
5	0			
Total	53	18.9 (7.6)	18.2 [12.7–22.3]	8.4–40.7
Women				
0	24	21.8 (7.5)	20.7 [16.8–23.5]	10.3–40.2
1	12	17.6 (4.7)	16.4 [15.1–19.2]	10.4–28.2
2	15	15.6 (2.7)	15.6 [13.6–17.6]	11.3–20.6
3	16	9.3 (2.9)	8.9 [7.4–10.1]	5.5–17.2
4	1	11.0		11.0
5	1	8.6		8.6
Total	69	16.5 (7.0)	15.7 [11.0–20.3]	5.5–40.2
Both				
0	50	21.9 (7.1)	21.1 [16.5–24.6]	10.3–40.2
1	21	19.3 (6.7)	17.4 [15.2–19.7]	10.4–40.7
2	25	15.3 (3.1)	15.5 [12.6–17.6]	10.6–21.3
3	23	9.8 (3.3)	9.0 [8.0–10.5]	5.5–20.2
4	2	11.0 (0.1)	11.0 (11.0 11.0)	11.0–11.0
5	1	8.6		8.6
Total	122	17.5 (7.3)	16.7 [11.5–21.1]	5.5–40.7

Note: The unit for all values is "seconds."

Abbreviations: IQR, interquartile range; J-CHS, Japanese version of the Cardiovascular Health Study; MPT, maximum phonation time; SD, standard deviation

TABLE 5 Univariate and hierarchical multiple regression analysis of MPT.

	Univariate analysis		Hierarchical multiple regression analysis									
	Rank correlation		Model 1					Model 2				
	r	p value	β	95% CI	p value	VIF	R^2	β	95% CI	p value	VIF	R^2
Age (years)	−0.347	<0.01	−0.10	−0.29–0.09	0.291	1.50	0.25	−0.09	−0.24–0.07	0.270	1.50	0.50
Sex			0.11	−0.17–0.39	0.444	3.18		−0.07	−0.30–0.16	0.547	3.31	
Body height (m)	0.248	<0.01	−0.12	−0.39–0.14	0.361	2.83		−0.12	−0.33–0.10	0.284	2.83	
Smoking history			0.03	−0.20–0.27	0.765	2.16		−0.09	−0.28–0.11	0.376	2.22	
BMI (kg/m²)	0.137	0.132	0.11	−0.06–0.27	0.201	1.10		−0.02	−0.16–0.12	0.740	1.17	
VC	0.474	<0.01	0.56	0.31–0.81	<0.001	2.53		0.26	0.04–0.48	0.020	2.90	
J-CHS (point)	−0.681	<0.01						−0.59	−0.74–0.43	<0.001	1.42	

Note: Spearman's rank correlation analysis was used to assess the correlations. MPT was used as the dependent variable. The results of the analysis of variance of Model 1 and Model 2 showed a p value of <0.01. Normality tests for residuals were performed using the Shapiro–Wilk normality test: p=0.3356 for Model 1 and p=0.6 for Model 2.

Abbreviations: β, standardized partial regression coefficient; BMI, body mass index; CI, confidence interval; J-CHS, Japanese version of the Cardiovascular Health Study; MPT, maximum phonation time; VC, vital capacity; VIF, variance inflation factor

Figure legend

Figure 1. Flowchart for patient selection