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Original Article

Five-year change in maximum tongue pressure and physical function in community-dwelling elderly adults

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Abstract *Background/purpose:* To identify age-related changes in maximum tongue pressure (MTP), it is necessary to determine individual biological age. The fitness age score (FAS) is used to calculate the biological age, based on the one-leg standing time with eyes open, vertical jump height, grip strength, functional reach, and 10-m walk time.
Materials and methods: The study included 112 community-dwelling elderly adults (42 males and 70 females). We investigated MTP, FAS, and body mass index (BMI) at baseline and 5 years later. MTP was determined with a pressure measurement device.
Results: A significant reduction in MTP, FAS, and BMI in both male and female subjects was observed at 5 years. A negative correlation between change in MTP and baseline MTP was observed, but there was no correlation between MTP change and baseline FAS, BMI, and change in FAS and BMI.
Conclusion: Age-related decline in MTP might be associated with high MTP, reflecting decreased reserve. Additionally, age-related decline in tongue function might be different from that of physical function.

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Introduction

The tongue plays a critical part in the process of digestion, including chewing, food transport, and bolus formation.[1] Functional deterioration of the tongue might lead to an adverse event such as aspiration.[2,3] Understanding of these changes is relevant to determination of life prognosis. Maximum tongue pressure (MTP) is widely used to evaluate tongue function, and can be measured with a specialized device.[4] MTP decreased with aging in many cross-sectional studies,[5–8] and this decline indicated decreased reserve capacity. However, this decline has not been demonstrated in longitudinal research.

Humans demonstrate individual differences in the aging process.[9] Therefore, biomarkers are needed to estimate individual biological age and determine aging speed. Previous studies have shown that physical function is related to mortality.[10–12] Kimura et al. developed an index to define physical fitness age (fitness age score, FAS), calculated from 5 fitness markers (one-leg standing time with eyes open, vertical jump height, grip strength, functional reach, and 10-m walk time).[13]

The relationships between oral function and physical function have been reported.[14–16] We hypothesized that good physical function is related to good tongue function in older individuals. Therefore, to identify aging tongue changes, it is necessary to consider individual aging speed calculated from physical fitness parameters. This study used FAS as an index of biological aging and investigated MTP changes over a period of 5 years.

Materials and methods

This longitudinal study included 112 elderly local residents (42 males, mean age: 72.4 ± 4.7 years, 70 females, mean age: 69.0 ± 4.5 years) who underwent physical fitness tests in 2008 and 2013 at the gymnasium of Kyoto Prefecture University of Medicine. All subjects were living independently and reported on their own. Subject characteristics, including past medical history and occlusal condition were collected using a questionnaire and oral examination. Those with neuromuscular diseases, such as Parkinson's disease, or brain and cardiovascular disease were excluded from the study. Other exclusion criteria were (1) dysphagia symptoms, (2) oral and maxillofacial pain, and (3) loss of occlusal support including prosthetic devices. This study was approved by the Kyoto Prefectural University of Medicine Research Ethics Committee (No. E-382). Written informed consent was obtained from all subjects.

MTP was determined with a tongue pressure measurement device (JMS, Hiroshima, Japan). Measurement of MTP was performed according to the method of Hayashi et al.[4] While in a sitting position, subjects placed the device between the tongue and anterior palate with the lips closed. They were then instructed to raise the tongue and compress a balloon against the palate for approximately 7 s using maximum voluntary effort. The average value of 3 measurements was defined as the MTP.

FAS was calculated based on combined values for the 10-m walk time, functional reach, one-leg standing time with eyes open, vertical jump height, and grip strength, using the following equation:

$$\text{Men: FAS} = -0.203\,X1 + 0.034\,X2 + 0.0064\,X3 + 0.044\,X4 + 0.046\,X5 - 3.05$$

$$\text{Women: FAS} = -0.263\,X1 + 0.033\,X2 + 0.0074\,X3 + 0.048\,X4 + 0.079\,X5 - 2.52$$

$$\left[\begin{array}{l} X1 = 10-\text{m walk time(s)},\ X2 = \text{Functional reach(cm)}, \\ X3 = \text{One}-\text{leg standing time with eyes open(s)},\ X4 = \text{Vertical jump height} \\ \text{(cm)},\ X5 = \text{Grip strength(kg)} \end{array}\right]$$

Grip strength was measured with a Smedley hand dynamometer (Takei Scientific Instruments Co., Ltd., Niigata, Japan). Grip strength in the dominant hand was measured twice and the maximum value was used for analysis. Vertical jump height was measured with a digital meter (Takei Scientific Instruments Co., Ltd., Niigata, Japan). The height of a vertical jump using both legs from an upright position without a running start was measured twice and the maximum value was used for analysis. The duration of standing on the dominant foot with eyes open was measured, with up to 120 s as the maximum. Walk time was defined as the time to walk 10 m at regular speed. The maximum distance from starting position to the stretched position was measured twice to determine functional reach, and the value was used for analysis.

Body mass index (BMI) was calculated as weight (kg) divided by height in meters squared (m^2).

Changes in MTP, FAS, and BMI were calculated from the differences between between baseline and 5-year follow-up values. The data were analyzed using Stat Flex version 6 (Artech Co., Ltd., Osaka, Japan). A paired-t test was used to investigate changes over a period of 5 years. The correlations between the measured items were evaluated using Pearson's coefficient. The required sample size was 85 when the correlation coefficient was 0.3, the significance level was 5%, and the power was 80%.

Results

MTP, FAS, and BMI were significantly decreased in both male and female subjects at 5-year follow-up (Table 1). The mean change in MTP calculated from the differences between baseline and follow-up values was −4.6 ± 7.9 kPa in males and −3.2 ± 7.5 kPa in females. The mean change in FAS was −1.70 ± 1.93 in males and −1.67 ± 2.21 in females.

Table 1 MTP, FAS, and BMI at baseline and 5-year follow-up.

Males	Baseline		Follow-up		*P*-value
	Mean	SD	Mean	SD	
MTP (kPa)	36.8	8.9	32.3	7.2	<0.01
FAS	1.453	2.415	−0.252	0.873	<0.01
10-m walk time (s)	7.1	1.6	6.8	0.9	0.13
Functional reach (cm)	38.3	6.4	35.0	6.4	<0.01
One-leg standing time with eyes open (s)	63.4	45.6	36.1	41.5	<0.01
Vertical jump height (cm)	30.5	7.4	27.7	7.2	<0.01
Grip strength (kg)	35.3	7.2	33.3	6.9	<0.01
BMI	22.8	2.3	22.3	2.4	<0.01
Females					
MTP (kPa)	34.6	8.4	31.4	6.4	<0.01
FAS	1.992	2.239	0.323	2.018	<0.01
10-m walk time (s)	6.7	0.9	6.8	1.0	0.64
Functional reach (cm)	34.4	7.1	32.2	5.8	<0.01
One-leg standing time with eyes open (s)	66.1	42.0	35.4	37.7	<0.01
Vertical jump height (cm)	23.5	4.9	21.6	5.3	<0.01
Grip strength (kg)	22.7	4.1	21.5	3.9	<0.01
BMI	22.0	2.2	21.6	2.2	<0.01

MTP, tongue pressure. FAS, fitness age score. BMI, body mass index. Paired-t test was used to compare baseline to follow-up.

Table 2 Correlations between MTP changes and baseline characteristics.

Males	Correlation coefficient	*P*-value
Age	−0.206	0.19
MTP (kPa)	−0.634	<0.01
FAS	0.200	0.20
10-m walk time (s)	−0.299	0.05
Functional reach (cm)	0.286	0.07
One-leg standing time with eyes open (s)	0.179	0.26
Vertical jump height (cm)	0.306	<0.05
Grip strength (kg)	0.038	0.81
BMI	0.004	0.98
Females	Correlation coefficient correlation	*P*-value
Age	0.044	0.72
MTP (kPa)	−0.680	<0.01
FAS	0.097	0.42
10-m walk time (s)	−0.086	0.48
Functional reach (cm)	−0.072	0.55
One-leg standing time with eyes open (s)	0.104	0.39
Vertical jump height (cm)	−0.051	0.67
Grip strength (kg)	0.027	0.83
BMI	−0.052	0.67

MTP, tongue pressure. FAS, fitness age score. BMI, body mass index. Pearson's correlation coefficient was used for analysis.

Mean change in BMI was -0.5 ± 0.9 in males and -0.4 ± 1.2 in females. There was a significant correlation between MTP change from baseline and baseline vertical jump height in males ($r = -0.634$, $P < 0.01$, $r = 0.306$, $P < 0.01$), and between MTP change from baseline and baseline MTP in females ($r = -0.680$, $P < 0.01$) (Table 2). A weakly positive correlation was seen between MTP change and the change in 10-m walk time in males ($r = 0.343$, $P < 0.05$). However, there was no correlation between MTP change and change in other measurements in females (Table 3).

Table 3 Correlations between change in MTP and change in FAS and BMI.

Males	Correlation coefficient	*P*-value
Δ FAS	−0.187	0.24
Δ 10-m walk time (s)	0.343	<0.05
Δ Functional reach (cm)	−0.102	0.52
Δ One-leg standing time with eyes open (s)	−0.045	0.78
Δ Vertical jump height (cm)	−0.209	0.18
Δ Grip strength (kg)	0.017	0.91
Δ BMI	0.22	0.16
Females		
Δ FAS	−0.009	0.94
Δ 10-m walk time (s)	0.025	0.84
Δ Functional reach (cm)	0.021	0.86
Δ One-leg standing time with eyes open (s)	−0.011	0.93
Δ Vertical jump height (cm)	0.074	0.55
Δ Grip strength (kg)	0.014	0.91
Δ BMI	0.072	0.56

Pearson's correlation coefficient was used for analysis. Δ indicates the change from baseline to follow-up. MTP: tongue pressure, FAS: fitness age score, BMI: body mass index.

Discussion

MTP was significantly decreased in both males and females at 5-year follow-up. These results correspond with those from prior cross-sectional studies.[17–19] It is thought that muscle weakness with aging is due to loss of mass caused by muscle fiber atrophy. Tamura et al. reported that aging strongly affected tongue thickness.[20] FAS and BMI also decreased in both males and females. Sarcopenia has been defined as age-related decline in skeletal muscle mass and function and is a risk factor for adverse outcomes such as physical disability, poor quality of life, and death.[21] Therefore, the decline of tongue muscle mass caused by aging and sarcopenia could lead to decreased MTP. This longitudinal study suggests that tongue muscle mass is even reduced in elderly adults living independently.

A negative correlation between MTP change and MTP at baseline was observed in both males and females. Previous

research has revealed that healthy older adults generate lower MTP than younger individuals.[22] While MTP has been shown to decrease with age, no significant age differences have been found for maximum swallow pressure.[23]

It may conclude that swallow pressure reserve is the difference between the MTP and the maximum swallow pressure, and a decreased swallow pressure reserve increases the risk of dysphagia by limiting the amount that MTP can decrease (due in part to sarcopenia) without affecting the MSP. Recently, four Japanese academic societies have published position papers on sarcopenia and dysphagia. Among them, they proposed that one of the diagnosis of sarcopenia due to sarcopenia is that MTP is less than 20 kPa.[24] In our subject, the MTP after 5 years did not fall below this value for both men and women and kept around 30kPa as in previous reports.[5,25] This may conclude that healthy elderly people could maintain this value.

No correlation was observed between change in MTP and FAS at baseline. Moreover, measurements at baseline were not associated with MTP changes, other than the weak correlation with vertical jump height in males. Additionally, there was no correlation between the change in MTP and the change in physical other measured items, other than the weak correlation with 10-m walk time in males. Although a correlation between tongue function and hand grip has been reported,[3,26] this seems unlikely because of the low correlation coefficient. In this study, no correlation was observed between MTP and hand grip. These results indicate that aging changes in tongue muscle are different from those in skeletal muscles that affect physical function.

Our hypothesis was that physical function may be linked to tongue function through malnutrition, as part of the frailty cycle.[27] However, the relationship could not be verified because MTP change was not affected by BMI in this study. Ogawa N et al. suggested that sarcopenia also affects tongue muscle.[28] A greater number of frail subjects are needed to determine the relationship between MTP changes and weight loss. In addition, it was assumed that a high FAS would have an effect on the maintenance of tongue muscle strength; however, a relationship was not confirmed in either males or females. The weak correlation between MTP and the measured items in males might indicate a sex difference in the relationship between physical function and tongue function. Although not evaluated in this study, this finding could be associated with sex differences in laryngeal structure and function[29] or social and cognitive activity. A limitation in this study was the small sample size, making it difficult to perform more detailed assessment of nutritional status and sex differences.

This study examined age-related changes in MTP according to individual biological age, defined as FAS calculated from physical function parameters. MTP was decreased at 5-year follow-up and high MTP was associated with a larger decrease in MTP in both males and females. However, no other factors showed a strong association with changes in MTP. Thus, the physiological aspects of age-related changes in MTP may be different from those associated with physical function.

Declaration of Competing Interest

The authors declare no conflict of interest.

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