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Original article

The association between masticatory ability and lower Timed Up & Go Test performance among community-dwelling Japanese aging men and women: The Toon Health Study

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A B S T R A C T

Objectives: Few studies examined the association between deterioration of masticatory ability assessed by objective marker and physical function. Therefore, we examined the association between salivary flow rate which is one of the objective and surrogate marker of masticatory ability and lower Timed Up & Go (TUG) performance which is one of major measurement of physical function among aging Japanese.
Methods: This cross-sectional study enrolled 464 Japanese aged 60–84 years old. Participants chewed tasteless and odorless gum for 5 min, calculated stimulated salivary flow rate (g/min) during all chews. The 3 m TUG was conducted, and 75th percentile value (6.8 s for men and 7.0 s for women) or higher was defined as lower TUG performance. Logistic regression analysis was used to examine the association between stimulated salivary flow rate and lower TUG performance.
Results: We found that the stimulated salivary flow rate tended to be negatively associated with the TUG time. We also observed significant negative association between stimulated salivary flow rate and lower TUG performance; the multivariable-adjusted OR (95% confidence interval, CIs) of lower TUG performance for the highest quartile of stimulated salivary flow rate compared with the lowest quartile was 0.34 (0.16–0.69, P for trend = 0.02). Further adjusting for BMI, the association was attenuated but remaind significant; the OR (95% CIs) in highest quartile was 0.37 (0.18–0.76, P for trend = 0.04).
Conclusions: Higher stimulated salivary flow, which means well masticatory ability, was inversely associated with lower TUG performance in the aging Japanese population.

1. Introduction

The number of aging people who need nursing care has been increased around the world, and was reached 6.41 million in 2018 [1]. Musculoskeletal conditions including fragility fractures, spinal cord disease and kneeosteoarthritis cause disability which need nursing care and have a significant impact on the quality of life (QOL) due to interference with daily life [2]. The number of patients with such musculoskeletal diseases has reached 1.71 billion worldwide [3], and they will be needed for nursing care.

Health disorders due to aging include not only musculoskeletal diseases but also decline of oral functions, ie, tooth loss and difficulty in chewing and swallowing. Decline of oral function cause a decrease in appetite and food intake, which are factors in the frailty cycle [4]. Although the several studies examined the association between oral and physical function in relation to frailty [5–8], those

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studies had limitations due to self-reported oral status, small sample size, and the limited populations, ie, aging people using day services.

Therefore, we thought it was necessary to conduct a study in large number of healthy community-dwelling and using a measurement that can objectively estimate their masticatory function. In this study, subjecting older Japanese people aged 60 years and over, the purpose was to examine the relationship the stimulated salivary flow rate, which is an alternative index of masticatory function [9] with Timed Up & Go (TUG) test [10], which is highly relevant to daily life functions, and is a useful test method to evaluate overall daily life activities, and physical functions of the elderly people [11]. In Japan, since most Japanese people change their lifestyles when they reach the age of 60 due to retirement, this study was conducted on elderly people aged 60 and over.

2. Methods

2.1. Participants and design

This study has a cross-sectional design and is part of the second survey of the Toon Health Study, an epidemiological study conducted in Toon City, Ehime Prefecture, Japan since 2009 [9].

Of the 811 participants in 2016 and 2017, those under the age of 60 (N = 342), those who did not perform the 3 m TUG due to physical health conditions (N = 4), those with incomplete lifestyle questionnaires (N = 1) were excluded, finally, 464 individuals (185 men and 279 women) were included in the present analysis.

The Institutional Review Board of Ehime University Hospital approved the study protocol (#170511), and informed consent was obtained from each study participant.

2.2. Timed Up & Go (TUG) test

TUG evaluates walking speed, standing up from a chair, and changing direction, and is highly related to daily life functions, including lower limb muscle strength, balancing when in a standing position, walking ability, and the risk of falling [11]. In this study, participants were observed and timed while rising from a chair, walked 3 m, turned, walked back, and sat down again. TUG was performed twice, and the average value was used for the analysis. The 75th percentile value (6.8 s for men and 7.0 s for women) or higher was defined as lower TUG performance in this study.

2.3. Measurement of stimulated salivary flow rate

All participants were required to fast for at least 10 h before blood examinations. To measure the stimulated salivary flow rate, the participants chewed tasteless and odorless gum (1 g) for 5 min. All saliva produced during that time was collected in a plastic tube. The collected saliva was weighted (g) and divided by the chewing time (5 min) to calculate the amount of saliva secreted per minute, which was used as the amount of saliva secreted during stimulation (g/minute) [9]. Since previous study has shown that high salivary secretion is associated with a high masticatory function [12], salivary secretion during mastication can be considered a surrogate index of masticatory function.

2.4. Assessment of the other measurements

Body mass index (BMI) was calculated as measured weight (kg)/ measured height $(m)^2$.

Waist and hip measurements were taken. The waist should be around the navel, and the hip should be the upper border of the pubic symphysis. The measure was placed horizontally with the ground, and the values were measured in 5 mm increments. When the position of the navel was lowered due to excessive obesity, the measurement was made at the midpoint between the lower border of the ribs and the anterior superior iliac spine. Skinfold thickness was measured using a caliper. Measurement sites were the upper arm, the back under the scapula, and the abdomen, all of which were measured on the right side. Each time before starting the caliper measurement, it was calibrated using the attached weight. Triceps skinfold thickness was measured by pinching the midpoint between the acromion process and the olecranon parallel to the direction of the arm. Shoulder blade skinfold thickness was measured by pinching just below the lower end of the scapula in a 45° upward direction toward the spine. Abdomen skinfold thickness was measured by pinching the side of the navel vertically. Physicians asked the participants' medical history. The participants underwent a 75-g oral glucose tolerance test (OGTT). Fasting and postprandial serum glucose levels at 2 h after OGTT were measured. Diabetes mellitus (DM) was defined as fasting serum glucose $\geq$ 7.0 mmol/L (126 mg/dL) and/or as $\geq$ 11.1 mmol/L (200 mg/dL) at 2 h after OGTT and/or taking hypoglycemic agents or insulin injection. Hypertension was defined as a systolic blood pressure $\geq$ 140 mmHg and/or a diastolic blood pressure of $\geq$ 90 mmHg and/or current treatment with antihypertensive agents. Smoking habits (current/past/non-smoker), drinking habits (current/past/non-drinker) and number of teeth were determined by self-administered questionnaires. The presence or absence of denture was confirmed in an interview. To evaluate physical activity, the metabolic equivalents of task (MET) metric was assessed by the Japan Arteriosclerosis Longitudinal Study Physical Activity Questionnaire (JALSPAQ), the moderate validity was verified using the doubly labeled water method [13].

2.5. Statistical analysis

The participants were divided into quartiles according to the sex-specific stimulated salivary flow rate. The age- and sex-adjusted means and proportions of the characteristics of the participants were estimated according to sex-specific quartiles of stimulated salivary flow rate by the analysis of covariance, and tested the linear trend by regression analysis using median value of each quartile. The multivariable-adjusted odds ratios (OR) and 95% confidence intervals (CIs) of lower TUG performance according to the quartiles of the stimulated salivary flow rate were calculated by logistic regression analysis after adjusting for sex, age, current drinking and smoking statuses, physical activity, DM, the number of remaining teeth and denture, and tested the linear trend by using median value of each quartiles. We further adjusted for BMI because overweight was associated with both muscle dysfunction [14–16] and stimulated salivary flow rate [8]. SAS 9.4 (SAS Institute Inc, Cary, NC, USA) was used for statistical analysis, and the significance level was set at less than 5% by a two-tailed test.

3. Results

3.1. Subject characteristics

Table 1 shows the characteristics of the participants according to quartiles of stimulated salivary flow rate. Participants with higher stimulated saliva flow was younger, and had a lower means of BMI, waist and hip circumferences, waist-hip ratio, triceps and shoulder blade skinfold thicknesses, abdomen skinfold thickness, and higher mean number of remaining teeth ($P < 0.05$).

Table 1
Characteristics of participants according to sex-specific quartiles of stimulated salivary flow rate.

	Stimulated salivary flow rate				P-value
	Q1 (low)	Q2	Q3	Q4 (high)	
N	115	117	116	116	
Men, %	46 (40.0)	46 (39.3)	47 (40.5)	46(39.7)	–
Age, yr	69.3	69.5	69.3	67.9	0.04
Stimulated salivary flow rate, g/min	0.60	1.09	1.51	2.23	< 0.01
Number of remaining teeth	18.1	22.1	22.6	21.7	0.02
BMI, kg/m^2	24.3	23.5	23.0	22.9	<0.01
Waist circumference, cm	87.1	85.5	83.9	83.6	< 0.01
Hip circumference, cm	93.7	92.4	92.1	91.8	0.04
Waist-Hip ratio	0.9	0.9	0.9	0.9	< 0.01
Triceps skinfold thickness, mm	17.8	16.7	16.1	14.3	< 0.01
Shoulder blade skinfold thickness, mm	20.6	19.2	17.5	16.1	< 0.01
Abdomen skinfold thickness, mm	34.6	33.3	29.0	29.2	< 0.01
Denture use, %	37.6	37.4	29.5	31.1	0.15
Current drinker, %	54.1	45.3	54.3	58.1	0.31
Current smoker, %	7.5	6.7	7.4	9.5	0.53
Hypertension, %	56.0	49.7	49.5	42.1	0.09
Diabetes mellitus, %	21.5	22.7	19.7	14.5	0.09
Physical activity (Mets • h/day)	34.3	34.9	34.8	35.2	0.08

Age- and sex-adjusted means and proportions.
Men: Q1: ≤ 1.03; Q2: 1.05–1.60; Q3: 1.62–2.03; and Q4:2.03+ (g/minute).
Women: Q1: ≤ 0.70; Q2:0.70-1.02; Q3:1.03-1.45; and Q4:1.46+ (g/minute).

3.2. Association between stimulated salivary flow rate and TUG time

Table 2 shows the TUG time according to the quartile of the stimulated salivary flow rate. We found that the stimulated salivary flow rate was negatively associated with age- and sex-adjusted the TUG time; the time for highest quartile (5.96 s) was significantly lower than that for the lowest quartile (6.52 s), (P = 0.04).

However, after adjustment for smoking status, drinking habits, physical activity, DM, the number of remaining teeth and denture, the association weakened and became bordeline-significant. The respective times for the highest and lowest quartile was 6.00 s and 6.48 s (P = 0.11). When we further adjusted for BMI, the association was not reached significant (P = 0.28).

3.3. Association between stimulated salivary flow rate and lower TUG performance

Table 3 shows the ORs (95% CIs) of lower TUG performance according to the quartiles of the stimulated salivary flow rate. The age- and sex-adjusted OR of lower TUG performance in the highest quartile (Q4) was significantly lower than that of the lowest quartile (Q1); the OR (95% CI, was 0.31 (0.15–0.63, P = 0.01)). After adjustment for confounding factors, the association weakened but remained significant; the multivariable-adjusted OR (95% CI) in the highest quartile (Q4) was 0.34 (0.16–0.69, P = 0.02). When we further adjusted for BMI, the association was slightly attenuated but the remained significant association; the multivariable-adjusted OR (95% CI) in the highest quartile (Q4) was 0.37 (0.18–0.76, P = 0.04).

4. Discussion

In this study, a higher masticatory function assessed by the stimulated salivary flow rate was inversely associated with lower TUG performance for Japanese men and women aged 60 years or older even after adjustment for BMI.

This is the first study which examined the association between masticatory function assessed by objective measurement and lower TUG performance. In previous study in older adults showed that lower occlusal force was associated with a slower walking speed [17–19]. Therefore, our findings may support this previous finding.

One of the mechanisms for our findings is that a high masticatory function is associated with a low risk of overweight [9] which may cause muscle dysfunction [14–16]. However, we found the slight attenuation of the association after adjustment for BMI, thus other mechanisms may be underlie the association. The other potential reasons of the association between higher masticatory function assessed by stimulated salivary flow rate was inversely associated with lower muscle function were as follows. The association between the masticatory function and overweight is thought to be related to the secretion of leptin, a hormone produced in adipose tissue and involved in appetite suppression. Mastication stimulates the satiety center and suppresses appetite, which has been shown to be useful in diet and obesity control. In other words, chewing well for a long time activates the brain and increases the amount of histamine, which in turn stimulates the satiety center and the sympathetic nervous system, which in turn stimulates the secretion of leptin secreted by fat cells, leading to appetite suppression, peripheral lipolysis, and increased energy

Table 2
Association between stimulated salivary flow rate and TUG time according to sex-specific quartile of stimulated salivary flow rate.

	Stimulated salivary flow rate				P-value
	Q1 (low)	Q2	Q3	Q4 (high)	
N	115	117	116	116	
Age-and sex-adjusted time, sec	6.52	6.15	6.60	5.96	0.04
Multivariable adjusted time, sec[a]	6.48	6.13	6.62	6.00	0.11
Multivariable adjusted time, sec[b]	6.40	6.11	6.64	6.03	0.28

[a] Adjusted for age, sex, current drinking and smoking statuses, physical activity, DM, number of remaining teeth and denture.
[b] Further adjusted for BMI.

Table 3
The multivariable odds ratios (OR) and 95% confidence intervals (95%CIs) of lower TUG performance according to sex-specific quartile of stimulated salivary flow rate.

	Stimulated salivary flow rate				P-value
	Q1 (low)	Q2	Q3	Q4 (high)	
N	115	117	116	116	
Lower TUG performance	38	26	39	14	
Age-and sex-adjusted OR (95%CI)	1.00	0.52(0.28–0.97)	1.04(0.58–1.85)	0.31(0.15–0.63)	0.01
Multivariable OR (95% CI)[a]	1.00	0.54(0.29–1.02)	1.09(0.60–1.98)	0.34(0.16–0.69)	0.02
Multivariable OR (95% CI)[b]	1.00	0.57(0.30–1.09)	1.20(0.66–2.21)	0.37(0.18–0.76)	0.04

[a] Adjusted for age, sex, current drinking and smoking statuses, physical activity, DM, number of remaining teeth and denture.
[b] Further adjusted for BMI.

expenditure, thereby suppressing the accumulation of body fat [20–22].

Mastication is also important to maintain the masticatory function for proper nutrition intake. It is thought that the decline of oral function in the frailty cycle [4] affects each element of mastication and lower muscle function. It has been reported that elderly people with decline of masticatory function have decreased intake of foods such as vegetables, fruits, meat, seafood, and beans, as well as nutrients such as protein, calcium, iron, niacin, and vitamin C [23–25]. Decline of masticatory function cause weight loss and decline of nutritional balance in relation to lower muscle function, sarcopenia, decreased vitality, muscle weakness, and physical function [4]. On the contrary, it has been reported that when oral function improves, appetite and energy, protein, dietary fiber and vitamin C intakes, and food intake diversity improves [26], and those improvemnts may cause muscle function maintained.

One of the features of this study is that it evaluates masticatory function as objective measurement of saliva secretion using gum, whereas in the previous study [5] the state of oral function was self-reported and was a subjective index. In this regard, previous cross-sectional study in Japanese elderly people showed higher stimulated salivary flow rates for 2 minutes were associated with good masticatory function as evaluated by gummy jelly chewing [27], therefore this study is justified in choosing stimulated salivary flow rate as a valid metric that reflects masticatory function.

In addition, it is a further feature that the study was conducted with healthy participants and with sufficient participants ($N = 464$ men and women), previous studies that limited the target population to females [6], frail elderly [7], or with a small number of participants [8].

On the other hand, since this study is a cross-sectional study, it is not possible to mention the causal relationship. However, according to a intervention study [26] which examined the effect of teaching mastication, nutrition, and exercise by health classes for the elderly reported that masticatory function, grip strength, and upper arm circumference were significantly increased after participating in the classes. In other words, since it has been reported that masticatory function is related to the improvement of muscle function, it can be assumed that masticatory function has an effect on muscle function in this study as well. Furthermore, we did not use the clinical definition of musculoskeletal ambulation disability symptom complex (MADS) [28] because few participants ($N = 7$) were met the criteria (≥ 11 s). Therefore, our findings could not support the association between higher masticatory function and MADS [22]. Third, we did not consider medication or polypharmacy in this study. In a previous cross-sectional study, we had adjusted for considerations for participants taking medications that affect salivation, but after adjustment, the association remained statistically significant [29], and we therefore considered the effect of medication in this study to be negligible. Fourth, we did not measure ultrasound, shealography, and MRI to assess the state of salivary gland. These points are also the limitations of this study.

In conclusion, higher stimulated salivary flow, which is a surrogate marker of masticatory function, was inversely associated with the lower TUG performance in the aging Japanese population.

CRediT author statement

Saori Miyazaki: Conceptualization, Formal analysis, Investigation, Writing – original draft, Visualization. **Koutatsu Maruyama:** Conceptualization, Investigation, Writing – review & editing, Supervision. **Kiyohide Tomooka:** Writing – review & editing. **Shinji Nishioka:** Investigation. **Noriko Miyoshi:** Investigation. **Ryoichi Kawamura:** Writing – review & editing. **Yasunori Takata:** Writing – review & editing. **Haruhiko Osawa:** Writing – review & editing. **Takeshi Tanigawa:** Conceptualization, Investigation, Writing – review & editing. **Isao Saito:** Conceptualization, Investigation, Writing – review & editing.

Conflicts of interest

The authors declare no competing interests.

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